Building Materials and Health

A study of perceptions of the healthiness of building and furnishing materials in homes

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Abstract

This thesis explores people's perceptions of building and furnishing materials in domestic interiors in relation to human health.

Although recently there has been an increase in discussion of the adverse impacts building and furnishing materials have on human health, it is also noted that change in removing 'risk' materials from the market is not happening fast enough. Rather than focusing on professional views or the regulative changes that have effected some improvements, this thesis focuses on popular views, as these are currently an under-researched but significant factor for change. Popular perception of the healthiness of materials directly relates to everyday choices which might influence indoor air quality in people's homes. Hence understanding these perceptions is an important element in improving this situation.

The primary question of this thesis is how informed, or knowledgeable, the general population is about risks to human health associated with building and furnishing materials, and secondarily, whether any predictors of people's views can be observed. Because of the limited availability of similar studies this thesis is exploratory. It consists of two main studies:

- The core survey of 247 participants from three countries (61 NZ general, 65 NZ architects, 60 US, and 61 UK) explores what people think about the healthiness of common materials and evaluates this data for any demographic or psychological predictors of knowledge; and
- The follow-up trial evaluates the effectiveness of an educational intervention and provides more detailed mixed-method data on the views of 12 participants.

The studies use quantitative approaches that are commonly used in psychological research.

The thesis shows that there are significant limitations in the existing knowledge of risks associated with building and furnishing materials especially amongst the general population, which poorly differentiates between the health impact of similar looking materials such as vinyl and linoleum, and particleboard and MDF with and without formaldehyde. This leads to the conclusion there is need for improvement in the general level of knowledge about the healthiness of materials.

In terms of predictors, gender is found to be the strongest predictor of recognition of risks with women tending to rate materials more accurately in terms of their risk to health, and males rating all materials higher. Similarly, women demonstrated greater change in their ratings and actions following the educational intervention. Experience with asthma and allergies was also a predictor of more accurate rating of materials but this trend was milder. When the five personality traits were evaluated, openness mildly but consistently correlated with more accurate health ratings of materials, while agreeableness correlated with tendency to give high ratings regardless of how healthy materials were. No clear patterns were found for extraversion, emotional stability and conscientiousness. No clear pattern for the environmental concerns was found in the core study, although these seemed to be predictors after the educational intervention.

These findings show that exploring people's views about architecture using psychological instruments has produced useful results. This thesis observed a number of possible predictors of people's architectural views and choices, suggesting a possible new research field to confirm these.

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(Thompson 2004, 255)

Chapter 1

Introduction

A frog jumps into a pot of water which is gradually being heated. As the water gets warmer, the frog adjusts its body temperature and continues to adjust to the increasing water temperature until, ultimately, the frog gets boiled alive. (Saunders, 2002: 5)

Every so often human society receives news that a particular human activity or behaviour is not beneficial long term and adjustments have to be made. This thesis deals with one small niche where such change is needed, and possibly has already started. Since World War Two, the total production of synthetic chemicals, made artificially by chemical reaction, has increased from less than 10 million tons in 1945 to over 110 million tons by the early 2000s (Baker-Laporte, 2008: 272). This trend has impacted many aspects of human life and the natural environment, one strand of which is chemicals used in building and furnishing materials, where synthetic chemicals can be used on their own or in various mixtures with other components that could be more natural in origin.

This thesis focuses on the role that the perception of building and furnishing materials as being healthy, or not, has on the choices people make and the healthiness of domestic environments.

The majority of products that present risk to human health have been developed relatively recently, particularly since the second half of the nineteenth century, and with great diversification since World War Two. Some 15 years ago it was estimated there were more than four million registered man-made chemicals in the world with 60-80,000 in common use, and 1,000 being added every year (Pearson 1998, 61; Saunders 2002, 9; Thompson 2004, 14-5). It is estimated that fewer than 2% of these synthetic chemicals have been tested for their effects on human health and more than 70% have not been tested at all (Snyder in Saunders 2002, 9). It is also suggested insufficient information exists for health assessments of 95% of chemicals used in construction products (Pacheco-Torgal, Jalali, and Fucic 2012, xv). However, development of synthetic chemicals is still accelerating, with the suggestion that 'more new materials have been developed in the last 20 years than in the rest of history combined,' with these making up about half of the materials in current use (Schörpfer 2011b, 19; Brownell 2006, 6). In addition, there is a lack of information and research on the additive and synergistic effects of combinations of chemicals (Armstrong 2007, 61).

As a result, many new chemicals appeared in buildings after World War Two and, together with tightening the building envelope in response to energy conservation needs, poorer health outcomes and indoor air quality problems were soon observed (Andersen and Gyntelberg 2011; IBN 2011). In the early 1980s, this culminated with the recognition of sick building syndrome (Andersen and Gyntelberg 2011; Rostron 1997). Although building and furnishing materials are not unique in their negative contribution to indoor air quality and health, they are recognised as important contributors in this area (Andersen and Gyntelberg 2011; Clausen et al. 2011). Since the 1970s, the increasing air-tightness of buildings, leading to insufficient air exchange, has led to the build-up of indoor toxicants (see Chapter 3; Clausen et al. 2011, 221; Sundell 2011). Consequently, research on indoor air quality and the impact of building and furnishing materials on human health has developed steadily since World War Two, being especially proactive in the last 20-30 years (Clausen et al. 2011). Unfortunately, research is not considered to be keeping up with the need for new knowledge in this area (Clausen et al. 2011, 225-226), with concerns that control of conditions in domestic spaces is even harder to achieve (Howden-Chapman and Carroll 2004).

In 1986 and 2002 two different editions of *Hazardous Building Materials* were published (Curwell and March 1986; Curwell et al. 2002). Although the two editions differed significantly, reflecting the changes in both regulations and materials production over the period, they jointly asserted that '[e]pidemiological research must of necessity lag behind material developments which inevitably means that the population's health may be at risk in the intervening period' (Burgess, Curwell and March in Curwell and March 1986, 3; Curwell and March 2002, 1). This lag is a perpetual feature of developments in the construction industry, and the two editions of *Hazardous Building Materials* clearly captured the accelerated recognition of the issues associated with lead and asbestos. The 1986 edition operates within the regulatory framework of limited use of asbestos in construction and lead in paint, focussing significant effort on education about these and the need to seek for alternatives, while in the 2002 edition these concerns are only dealt with in terms of past alterations to older houses. Nevertheless, the new edition remarked 'we have moved only a short distance since 1985' (Bradman in Curwell and March 2002, ix). This perception of the slow accumulation of

knowledge in this area seems reflective of the time lag between early indications of the risks and regulatory elimination of a product.

This time lag between research and regulation is problematic, given that globally societies, including New Zealand, are witnessing an increase in the prevalence of modern diseases such as cancer, multiple allergy syndrome, allergies, asthma, autism, and attention deficit disorder (Thompson 2004, 6). Some of the worst prognoses expect that in 50 years everybody will have some form of cancer (Pielou in Saunders 2002, 9), despite more than 90% of cancers probably being avoidable (Bradman 2002). People are repeatedly informed of the wisdom of changing different facets of modern lifestyles to improve the chances of a healthy life, and some consider these educational efforts understate the role of the indoor environment (Armstrong 2007). Additionally, the health impact related to indoor air pollution costs an estimated US\$400 billion per year in the US (Birkeland 2008, 105).

Increase in allergic diseases is especially clear worldwide, with estimates that by 1990 20% of the population suffered from an allergic disease (Spengler and Chen 2000; 570). Interestingly, the first documented case of hay fever was recorded mid 19th century by a British physician who had to collect data for another 10 years before he found 7 additional cases (Spengler and Chen 2000; 570). Thus, hay fever was first recognised as a health condition around the time of industrialisation in the country where this process was most accelerated. In 2004, Sundell reported on multidisciplinary reviews of all scientific literature conducted in the Nordic countries and Europe, which established that the increasing incidence of asthma and allergy throughout the developed world in the past thirty years was probably due to environmental changes, as the period was not long enough for change through genetic evolution (Sundell 2004). Sundell also pointed out that the then available scientific means could still not provide sufficient explanation for this change, which they interpreted as a general decrease in health (Sundell 2004). Considered and dismissed were theories that the cause was concentration of a single VOC chemical or the total mass of VOCs (TVOCs) (Sundell 2004). Research available since, points to an increase in recognition of indoor chemical reactions and more sophisticated understanding of within body reactions to air pollutants, but it is still insufficient for conclusive proof. Chapter 3 discusses different stages of this process, and explains why delays between recognition and action occur.

Taking an alternative position, a proportion of authors suggest 'prudent avoidance' or the precautionary principle (Pearson, 1998; Saunders, 2002; Thompson, 2004). The precautionary principle was established as Principle 15 of the 1992 Rio Declaration on Environment and Development and states 'where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation' (Philip, 2001). Applied to domestic indoor spaces, the precautionary principle implies avoidance of building and furnishing materials suspected to be harmful to human health without waiting for proof of their harmfulness (Pearson, 1998; Saunders, 2002; Thompson, 2004).

In a sense, the healthiest approach would be to use only substances that are proven to be harmless. This approach would echo well with the definition of health by the World Health Organisation (WHO) as the enjoyment of the highest attainable 'state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO 2014). A similar approach can be observed in some newer legislation which defines harmlessness as 'proven to be safe' rather than 'not proven to be harmful.' The New Zealand Psychoactive Substances Bill, which came into action in August 2013, stipulates that no substances are to be sold under this Bill until proven by the manufacturers to be safe (Radio New Zealand 2013).

Advancements in new, human made chemicals and materials are one outcome of the same processes that have produced better testing abilities, better understanding of possible risks, better medical ability to help people cope with and recover from different conditions, and generally much better regulatory controls, which at least theoretically aspire to protect society at large. As seen with the example of urbanisation, regulations often play a pivotal role in mediating needs and limitations, and do this by establishing safe benchmarks (Petrović 2003; Lees 1985; Olsen 1986; Sutcliffe 1981; Blau and Platzer 1999). The problem with contemporary regulations and legislation is that most are based on proof or solid scientific evidence, and until this exists it is often hard to make changes.

1.1 Perception of architecture and materials

The social and cultural perception of architecture is studied infrequently, although studies in this area all indicate that this is a potent field of investigation. Studies dealing with the social and cultural perception of urban forms form one cluster of such works, including Andrew Lees, *Cities Perceived* (1985), Robert Fishman, *Bourgeois Utopias* (1987), and David Hamer, *New Towns in the New World* (1990). Often operating on the crossover between social and urban history, these works have helped expand understanding of the mechanisms through which social perception influences the development of urban forms. A cluster of works taking a similar approach deals with the social perception of housing, including Sharon Marcus, *Apartment Stories* (1999), and David Jeremiah, *Architecture and Design for the Family in Britain, 1900-70* (2000). Jeremiah's work is particularly relevant given he discusses the evolution of housing forms in close relationship with the evolution of health concerns. Over the seventy year period he surveyed, Jeremiah demonstrated a succession of health related systems of ideas and their integration into public policies and housing. The author's own earlier work, *Your New House – or Would a Flat Suit You Better?* (2003) also operated in this area. Approaching from a similar perspective, it seems the social and cultural perception and understanding of materials could also reflect dominant ideas about health at a particular time, which in turn would relate to policies dealing with building materials and health.

However, the number of works that explicitly engage with evaluations of popular perception in relation to the core issues of this thesis is small, mostly recent, and come from the discipline of psychology. For example, Ben Rosenthal's PhD thesis (2011) evaluated information seeking behaviour in relation to indoor environment risks, personality and motivation (Rosenthal 2011). However, Rosenthal's study approached the problem from psychology as the core discipline and only considered the architectural aspects of the problem very generally, focussing on indoor air quality (as one group) and issues related to radon gas (Rosenthal 2011). In 2003, Lai and Tao evaluated the perception of environmental hazards in Hong Kong, and although primarily focused on natural environmental hazards, their work offered useful insights into the study of popular perception of risks (Lai and Tao 2003). Both studies, however, focused on the perception of risk, and did not provide much detail of the architectural issues, only discussing risks related to the built environment in a general manner.

There is also significant difference between these works in terms of methodology. Works on popular views of architecture are based on literature survey research of historical examples. They use a broad cross-comparison of very diverse historical sources (anything from built architectural forms to contemporary private letters) in an attempt to extract a multifaceted interpretation of the observed architectural phenomenon (Lees 1985; Fishman 1987; Hamer 1990; Marcus 1999; Jeremiah 2000). It is the repetition of similar indications from diverse sources that authorises the conclusions drawn. In terms of methodology, this is similar to much development in the history and theory of architecture since the 1980s (Frampton 1980; Frampton and Futagawa 1983; Kruft 1994; Colomina 1994; Wigley 1995; Heynen 1999; Curtis 1996; Riley 1996). The limitation of such a methodology is that it requires historical distance before sufficient 'facets' of the story can be accumulated for interpretation, and is therefore, inappropriate for study of current practices.

In contrast to this general approach, which can be seen as operating within the broad umbrella of humanities and which dominates study of the history and theory of architecture, in social sciences, such as psychology, much development has been undertaken to refine research methods capable of studying contemporary phenomena. One prominent philosophical approach to contemporary studies in psychology is critical realism, which has been developed since 1978 based upon Roy Bhaskar's work (Danermark 2002, 4). Reacting against the positivist approach which has dominated many of the social sciences since the 1930s, critical realism retains the positivist belief in generalist claims, but makes a shift from epistemology to ontology, and from study of events to study of mechanisms (Danermark 2002, 4-5). Critical realism proposes that scientists undertake an ongoing process of improving the concepts used to understand the studied mechanisms. Thus, conclusions can be extracted from what is observed, while acknowledging that there are limitations and relativities inherent in every step.

This thesis thus proposes a study of people's current views on building and furnishing materials drawing from philosophical frameworks and research methods common in contemporary psychology, but applied to a study of architecture.

1.2 Research questions

The research questions of this thesis are developed as a tripartite hierarchy, operating at different levels of detail.

The primary question is: ***How informed, or knowledgeable, is the general population about risks to human health associated with building and furnishing materials commonly used in domestic spaces? (Q1)***

However, in order to deepen the quality of understanding a secondary question is asked: ***Could any predictors be observed that relate to how informed participants are? (Q2)*** The aim is to see if there are any observable cultural, individual, or psychological characteristics that correlate with higher or lower levels of knowledge on the risks related to materials. If such patterns exist, they could provide useful insights to help target future actions towards increasing the level of knowledge in the general population.

This second question relates to the hypothesis of this thesis: ***There are observable predictors (demographic, individual, psychological, or cultural) of people's views of the health risks associated with building and furnishing materials.*** The fundamental assumption of any study of popular perception of architecture inherently acknowledges the probable existence of mechanisms in society and culture which influence the way people interpret architectural forms. For example, the author's Master's Thesis investigated the social and cultural reasons behind urban apartments and individual suburban houses being seen in different cultures as the most desirable housing form (Petrovic 2003). If architecture is understood solely as a utilitarian construct, the observed diversity in housing preferences would probably not exist. It is suggested here that similar cultural and other social constructs are implicated in the way people react to information that certain building materials are suspected of posing a health risk, and that this difference in reaction could influence their views and be translated into behaviours for change.

Finally, the third question is: ***Could education affect both knowledge and action in relation to the health risks associated with building and furnishing materials? (Q3)*** Logically, information that something could be harmful ought to translate directly into a behaviour change. However, in real life other mediators could influence such transition. Such mediators would be reflective of cultural or individual patterns similar to those raised by the second question, and thus Q3 can be seen as a special case of Q2. Furthermore, this question starts to look into how the results from the first two questions could affect behaviour change. Although this study records what people know about materials, it is doing so from an active position of searching for the most effective ways to support the outcome of a healthy home in terms of its building and furnishing materials.

1.3 Thesis structure

The thesis is organised in three parts, each with its own focus and discussion of appropriate research methods.

Part I	Evaluation of current patterns of what is known in terms of the impact that building and furnishing materials have on human health, based on a review of architecture related sources (Chapter 2), and medical sources (Chapter 3)	Literature review
Part II	Core study – How informed, or knowledgeable, is the general population about risks to human health associated with building and furnishing materials commonly used in domestic spaces and whether there are any observable predictors (Chapters 4-8)	Mainly quantitative methods
Part III	Follow-up trial intervention – can an educational intervention be used to bring about changes? (Chapter 9)	Mixed quantitative and qualitative methods

The structure of the thesis closely relates to the tripartite hierarchy of the research questions (Figure 1.1). All parts contribute to answering the primary research question (Q1) through use of three different research methods: part I uses a literature review, part II presents data collection and contains the analyses of the core survey data, while part 3 presents data collection and contains the analyses of the follow-up trial intervention. The question on predictors (Q2) is addressed through two studies discussed in parts 2 and 3, while only discussion of the follow-up trial in part III deals with the third question, evaluation of the effectiveness of education (Q3).

Figure 1.1: Thesis structure in relation to tripartite research questions. (Source: Author.)

1.4 Methodology

1.4.1 Limitations of existing work

As a foundation of the investigation, a literature review was undertaken to evaluate research methods in similar research. Early literature reviews, conducted in 2010 and 2011, failed to identify detailed surveys of people's views about building and furnishing materials. The sources identified generally included building materials within surveys which had their primary focus on other subjects, and these form two distinct groups.

The first group are studies dealing with the environmental appraisal inventory (EAI) which was developed by Schmidt and Gifford (1989), partly developed and tested by Fridgen (1994), and further developed and tested in a different cultural context by Walsh-Daneshmandi and MacLachlan (2000). This inventory asked participants to rate, on a seven-point Likert scale, each of 24 (later increased to 26) environmental risks based on three dimensions:

- 1) appraisal of threat to self;
- 2) appraisal of threat to the environment; and
- 3) appraisal of control, or the degree to which personal control was perceived in relation to a particular hazard (Schmidt and Gifford 1989).

In the environmental appraisal inventory, only two hazards could be seen as relevant to building materials: 'Fumes or fibres from synthetic materials – asbestos, carpets, plastics, etc.' and 'Radioactivity in building materials (e.g. radon gas)' (Schmidt and Gifford 1989; Fridgen, 1994; Walsh-Daneshmandi and MacLachlan 2000). Two studies reported means and in both samples the hazards related to building materials received mid-low level rating of importance to self: 'fumes or fibres from synthetic materials' were rated as 14th, while the 'radioactivity in building materials' was rated 16th and 13th both out of 24/26 respectively (Schmidt and Gifford 1989; Walsh-Daneshmandi and MacLachlan 2000). This suggests that compared to other environmental hazards, those related to building materials were not seen by the survey subjects as especially significant. Walsh-Daneshmandi and MacLachlan (2000) conducted factor analysis of this inventory and reported that when evaluated only for impact on self, the environmental hazards tended to group into techno-human hazards, natural hazards, and everyday life hazards. The building materials fell within techno-human hazards (Walsh-Daneshmandi and MacLachlan 2000).

The work of Lai and Tao (2003) can also be seen as part of this general group, although it used a different survey apparatus. It included 25 environmental hazards, with only 'Indoor air quality' and 'Radioactivity in building materials' related to this study (Lai and Tao 2003). However, it was identified too late to influence design decisions for the core survey.

This investigation of only one item for building materials was also found in the second group of studies focused on building user surveys. The Probe series of investigations attempt to improve existing post-occupancy building evaluations (Cohen et al. 2001; Bordass, Leaman and Ruyssevelt 2001), and the same scales were used in subsequent building evaluations (Baird 2010). However, materials were not explicitly mentioned in this questionnaire, with questions typically taking the form 'Do you feel less or more healthy when you are in the building?' (Probe Investigation questionnaire, 2010). Similarly, Probe investigation reports fail to mention building materials, only noting that there has been a noticeable decrease in complaints in this area since the 1980s and the appearance of the sick building syndrome (Leaman and Bordass 2001). Rather than considering detailed user views of materials, the Probe questionnaire focused on quality of indoor air environment in terms of air exchange, comfort temperature, and level of user control over the indoor air environment (Baird 2010). This can be seen as reflective of the general emphasis on ventilation, as discussed in section 3.3.

This early literature review only identified work that included questions about large numbers of materials in a small number of questions, while most did not deal specifically with building and furnishing materials. This indicated that views on different materials have not yet received much research attention. Therefore, this research was approached from the perspective of needing to develop new research tools. For this purpose a combination of qualitative and quantitative research tools were reviewed.

1.4.2 Grounded theory and other qualitative research methods

Grounded theory research methods are one of the most comprehensive approaches for development of a new theory in an area that has not previously been studied. Grounded theory methods consist of systematic inductive collection and analysis of data with the objective of building middle-range theoretical frameworks that explain the collected data (Charmaz 2003: 249). Through this process, analytic interpretations of data are developed, which helps inform further data collection and its refinement by repeating the process (Charmaz 2003: 250). Therefore, grounded theory methods focus on systematic discovery of theory from data, and help generate theory (Glaser and Strauss 2009: 1-2). The grounded theory methods can be seen as able to extract objectively the key features of the data out of data itself and can be useful when developing new research categories without much prior work in the area. However, this assumed objectivity of the grounded theory methods was criticised, especially during the 1990s, as potentially reflective of positivism in the traditional sense, which assumes an objective, external reality and a neutral observer (Charmaz 2003: 250). Nevertheless, this remains a reputable process for development of new study areas.

Together with grounded theory, other qualitative research methods were considered, especially discourse analysis, narrative analysis, and case studies. With the increase in research interest in qualitative research methods in the last two decades, all these qualitative research methods have seen a general increase in use, becoming mainstream (Willing and Stainton-Rogers 2008: 1-2). Qualitative research methods can be based on a series of similar types of data. For example interviews could be used for any of the methods listed above, but their use would vary depending on the method. Discourse analysis would focus on written texts, group talk and interviews; narrative analysis on interviews, autobiography and similar personal accounts; grounded theory on in-depth interviews; while a case study could take a wide variety of forms (Willing and Stainton-Rogers 2008: 542). For the purpose of this study, discourse and narrative analysis were considered as less advantageous than grounded theory and case studies, because the objective was to identify research methods to enable the extraction of theory from data as directly as possible.

However, when evaluating the relevance of grounded theory for this study, two limitations were identified:

- 1) If the assumption that the general population does not know much about building and furnishing materials was correct, then the same population could easily provide a distorted account of the materials, possibly even failing to identify some commonly used. This could lead to development of a theory that is partial. (This type of distortion was observed in received responses to open entry questions and is discussed in Chapter 8).
- 2) Properly executed grounded theory could take significant time and effort and thus would need to become the primary focus of this study. Although in itself valid, this would limit the opportunities to provide a more objective measure of people's knowledge about materials and evaluate the effect of educational intervention.

Therefore, it was decided not to adopt grounded theory or other qualitative research approaches as the main methods. Given the gap in knowledge in this area, it was considered that a more diverse approach would start to identify relevant findings and the most successful methods of data collection, thereby making a more significant contribution to existing knowledge. Therefore, rather than 'grounding' all of the survey tools, a mixed approach was adopted with a predominant use of quantitative measures and an inclusion of a small number of open-ended questions which asked the participants to report or qualify their views. The grouping and analysing of the responses to open-ended questions provide mini qualitative explorations (Chapter 8), which are reflective of some of the grounded practices.

Because so little work was found in this area, it was determined that an exploratory study was most appropriate. For this reason, a strategic decision was made for a reasonably wide investigation of this relatively unknown territory, rather than more grounded and detailed investigations of a smaller number of important points. In addition, the use of the framework of critical realism provided opportunities to study societal mechanisms even within a context of heightened relativity. These decisions have impacted on the work on many levels.

1.5 Objectives and specific methodologies used

Part I: Evaluation of current patterns of what is known in terms of the impact that building and furnishing materials have on human health

Although it seems possible to assume that there is confirmed knowledge about which building and furnishing materials are healthy or unhealthy, the early literature review identified that this is a much contested area. The purpose of this thesis was not resolve these conflicts, but rather to study how the general population engages with building and furnishing materials in the midst of this contested process. Therefore, chapters 2 and 3 do not establish which materials are healthy or unhealthy, but rather provide an overview of key characteristics and patterns that influence the process of expert negotiations toward actual knowledge. Because this thesis accepts this relativity, subsequent observations and conclusions are based on the results of the surveys. In terms of methodology, part I provides a review of the existing literature.

Part II: Core survey

The most significant data collection method in this study is the self-administered survey questionnaires of the core survey. Since the mid 20th century psychology has extensively used survey-based research methods to quantify societal patterns (Willing and Stainton-Rogers 2008). Although, survey-based research has been criticised on the grounds that the very action of asking a question starts to influence the answers (Beam 2012), it is currently a reputable research practice in social sciences.

For the purpose of this study, survey-based research offered two significant advantages:

1. It enabled fairly quick and direct study of the contemporary context; and
2. The use of self-administered questionnaires helped reduce the bias in responses.

Others have observed that self-administered questionnaires are related to a lesser social desirability response bias and higher concurrent validity, than structured interviews (Chang and Krosnick 2010). Given that it was possible participants would not even know what some of the building and furnishing materials that they were asked to rate were, any data collection strategies that could include provision of help, such as structured interviews, would have also reduced the accuracy of collected data, since identification of materials was seen to be part of how people perceived them. Therefore, self-administered paper or online questionnaires were used as the only data collection approach for the core survey.

Because this thesis does not establish which building and furnishing materials are healthy or unhealthy, the survey samples were used to provide their own benchmarks of participants' views on the healthiness of materials. The sample of NZ architectural academics and practitioners, who because of their education might be expected to know more about materials, was used to provide additional definition of this.

The exploratory nature of this thesis and the absence of comparable research, have rendered it impossible to target specific potential predictors of the level of knowledge participants might have. Therefore, rather than targeting such predictors from the outset, as would normally be the case in psychology research of this type, this study cast a wide net in the hope that some relevant observations could be extracted. At this level, the thesis aspired to ground some of the parameters that are indicated to be likely predictors, so that future research can specifically target these and make more concrete conclusions.

Part III: Follow-up trial intervention

The main objective of the follow-up trial intervention was to evaluate the effectiveness of an educational intervention, thus addressing the third research question of this thesis. In the early stages of this research, much consideration was given to whether the main focus should be on measuring how much people know about the risks associated with building and furnishing materials, or undertaking research on how to increase the level of knowledge, assuming that it would be reasonably low. At the time, it was concluded that accurate measurement of the situation would serve as a better basis for future research and therefore the core survey became the main focus. However, the follow-up trial intervention begins the next step, by measuring the success of one educational intervention. Because it was not the primary focus of this study, the follow-up trial intervention should be seen as an early experiment into how an educational intervention could be

positioned. In general terms, the follow-up trial is a mixed method study and details of its methodology are discussed in chapter 9.

Finally, because there are significant differences in the objectives and research methods of different parts of this thesis, any additional details are specifically introduced in each part. Similarly, although part I contains much of the literature review, this thesis uses a 'running literature review' approach and elements of literature review are introduced where relevant, such as in the beginnings of parts II and III, which review literature specific to those parts. Further discussion of the works of others occurs where the results obtained from the thesis studies are compared with the broader context.

Part I: Evaluation of current patterns of available knowledge about the health impact of building and furnishing materials

Chapter 2

Review of architectural sources

This chapter provides a review of architecture related sources on building and furnishing materials in relation to human health. The core question of this chapter is whether the architecture related sources adequately deal with this issue. Because the early investigations did show that there are quite significant limitations in available information on healthiness of building and furnishing materials in architecture related sources, for the purpose of this thesis much greater emphasis was placed on the review of medical and other primary sources, which is discussed in the next chapter. Therefore, this chapter reads more as a very general review of why architecture related sources are unable to deal in great detail with the issues related to adverse impact that building and furnishing materials can have on human health.

When reviewing the architectural literature that deals with building and furnishing materials in relation to health three distinct bodies of knowledge were observed:

1. Construction and building science sources;
2. Tectonics and experimentation with materials; and
3. Sustainability sources.

1.1 Construction and building science sources

The construction and building science literature seems best suited to deal with all aspects of building and furnishing materials, including their impact on human health. However, there are great differences within this body of literature, and generally it is possible to observe two broad categories of writing:

- Knowledge-developing sources which report results of empirical work (primary sources); and
- Knowledge-summarising sources which provide handbooks and guides (secondary sources).

Overall, this area of study has been experiencing growth for many years in both types of sources, but the growth in knowledge-developing sources is very impressive. In the 1950s and 1960s, knowledge-developing sources operated as a new field in many countries and often faced not only limitations in existing knowledge, but also technical limitations, such as multiple regression analysis not being available for large data sets due to computational limitations, and no clear publishing opportunities (Andersen and Gyntelberg 2011). With the establishment of the *Indoor Air* journal in 1991, a focal point for these efforts was established and in the first 20 years of its existence the journal published 843 original or review articles (Nazaroff 2011). These works are generally multidisciplinary and scientific in nature, and often face the challenge of providing a sufficiently scientific exploration of relatively uncharted material. For example, earlier this year (2013), the *Indoor Air* journal published in the same issue two articles which disprove each other: Carlstedt, Jönsson, and Bornehag (2013) asserted that the use of soft PVC as flooring material may increase the human uptake of phthalates in infants, while Blakey et al. (2013) (all authors are employed in the vinyl industry) have challenged the result based on small number of procedural imperfections. Because any early work is likely to suffer from procedural imperfections, this type of literature has been going through the many challenges of developing a new body of knowledge. Nevertheless, some specific sub-disciplines have been successfully articulated as important areas of study. For example, studies of indoor air chemistry have experienced growth at an exponential rate between 1991 and 2007, as can be seen by the number of published papers in this area (Figure 2.1), leading to the conclusion that it can be seen as a sub-discipline in its own right (Weschler 2011).

Figure 2.1: Papers related to 'indoor chemistry' published in *Indoor Air* since its inception. (Source: Weschler 2011.)

In contrast to knowledge-developing sources, which generally operate through journal articles, and conference papers, knowledge-summarising sources often take the form of books, and attempt to summarise available knowledge into a format that is easy to use for architecture and building professionals. Good examples of such literature published in the last several years are Fernando Pacheco-Torgal, Said Jalali, and Aleksandra Fucic (eds.), *Toxicity of building materials* (2012), Osman Attmann, *Green architecture: advanced technologies and materials* (2010), and John Fernandez,

Material architecture: emergent materials for innovative buildings and ecological construction (2006). Such works are generally based on the knowledge-developing sources, but are also reflective of the legislative recommendations at the time of writing. While this can be seen as unavoidable, it tends to lead to relatively conservative representation of the problem: only issues that are almost impossible to disprove are discussed. The key problem here is that the subject matter is evolving fairly rapidly, making it hard for sources of this kind to keep up. Unfortunately, the architectural or building professions generally rely on these knowledge-summarising sources when making decisions about material specifications, and consequently they could find it difficult to learn about health suspicions not yet proven. This problem becomes even more significant when paired with subsequent regulative changes that are never retrospective and the frequent changes manufacturers make to individual products.

Because of these characteristics, for the purpose of this thesis, many of the knowledge-developing sources are considered in chapter 3, complementing primary sources from medical disciplines, while only a small number of titles from the knowledge-summarising group were sufficiently up to date at the time of writing this thesis to be included there. It should be noted here that the construction and building science literature has also engaged with the need for more sustainable consideration of materials and this is discussed later in this chapter.

1.2 Experimentation with tectonics and materials

A group of architectural sources reflects interest in the visual and tectonic properties of materials and in the last ten years there has been an increase in publications dealing with materials and materiality (Kottas 2011; Schörpfer 2011a; Brownell 2008; Riera Ojeda 2003; Pasnik 2003). Many of these develop from an interest in construction materials, however it is interesting to observe that most fail to discuss to any extent physical materiality and the impact these materials could have on human health (Kottas [2011]; Riera Ojeda 2003). Two possible interpretations for these shortcomings seem reasonable. Many of these works refer to the seminal work of Kenneth Frampton (1995) on tectonics, and work of architects who strongly rely on the expressive properties of materials such as Carlo Scarpa or Peter Zumthor (Frampton 1995; Pasnik 2003). Generally, this body of work can be seen as a reaction against the postmodernist approach to architecture as representation of ideas, with its interest in architecture as a physical manifestation. However, this approach has been criticised for its emphasis on the haptic and visual aspects of materials, without sufficient acknowledgement of materials science and engineering (Fernandez 2006, 10-1). Fernandez argues that there is a strong divide between architectural design and more scientific knowledge about materials (Fernandez 2006, 16-7). Research undertaken for this thesis concurs with such observations. For example, the Avery Index to Architectural Periodicals defines itself as ‘a comprehensive listing of journal articles on architecture since 1934’ (ProQuest 2013), with over 700,000 records listed (Avery Index 2013). However, indoor air issues are not significantly covered. For example, the *Indoor Air* journal is not referenced (Avery Index 2013), and search on ‘formaldehyde’ provides only six results (searched August 2013). Interestingly, between 1997 and

2013, 282 articles which mention formaldehyde were published in *Indoor Air* journal (Wiley Online Library search, 2014).

Figure 2.2: Grijs Baker, Teapot 'high-tech accent,' Droog Design for Rosenthal, 1997. Porcelain with alumina-boria-silica fibres. (Source: Ramakers and Bakker 1998, 136.)

Figure 2.3: Tejo Remy, 'You can lay down your dreams,' 1991. Discarded drawers are reused, but all wood casings are made new. (Source: Ramakers and Bakker 1998, 38.)

A distinctly different stream of developments based on materials comes from product and furniture design focused on playful subversions of the conventional, with the work of the Droog Design group from the 1990s being seen as a good example of this (Droog Design 2013; Ramakers and Bakker 1998). Some of their projects explicitly focused on creative subversions of material properties, such as the 1997 'Droog Design for Rosenthal' collection (Figure 2.2; Ramakers and Bakker 1998). The playful subversion of norms which underpin such work makes it hard to see these as an expression of theoretical concepts similar to tectonics. Rather, Ramakers has observed that they build upon the work of the Italian post-modern design groups of Memphis and Alchemia, but with new elements (Ramakers and Bakker 1998, 30). Some of these new influences mentioned by Ramakers were the new government policies which appeared in the late 1980s and which emphasised the importance of environmental design. This influenced experimentation such as Tejo Remy's 1991 graduation work (Figure 2.3; Ramakers and Bakker 1998, 37, 40). Although it is now hard to see such design as environmental, given the high level of new materials used in their production, design pieces such as

these inspired other projects that have looked more explicitly into environmental impact (Alesina and Lupton 2010).

The design approach that explicitly uses materials as the core of design intention, either in terms of tectonics through texture and detail, or through materials experimentation, has since been echoed in many other architectural and design works and has been integrated into design education (Figure 2.4; Alesina and Lupton 2010; Brownell 2008). Unfortunately, the health impact of materials and environmental concerns has not been systematically considered or reported in the architectural and design literature, and many of these sources only promote design experimentation with any type of material, regardless of whether such materials have already been noted as possibly unhealthy.

Figure 2.4: Fragment of cover page of *Transmaterial*. (Source: Brownell 2006, cover page.)

1.3 Sustainability related sources

In contrast to literature on architectural construction and building science, and that on tectonics and experimentation with materials, literature on sustainability provides a body of work that is often primarily based on a platform of principles, and such an approach could play an important role in improving awareness of health risks associated with building and furnishing materials.

In recent years, sustainability has become a significant theme within architecture. Much of this development has been centred around recognition that architecture has significant impact on the environment through the construction and operation of buildings and infrastructure (Roodman and Lenssen 1995). In 1995, buildings were estimated to account for one-sixth of the world's fresh water withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows (Roodman and Lenssen 1995, 5). As the literature in this area has expanded, building and furnishing materials have been considered in relation to a variety of issues such as embodied energy (Vale and Vale 1991, 31-2, 41-2), waste (Birkeland 2008), and ventilation (Daniels 1997). The works on sustainability however, vary greatly in the extent to which they include issues related to building materials and health. Many of these sources briefly explain indoor air quality issues and at least

provide some examples of problem substances and available alternatives (Vale and Vale 1991, 32, 114; Birkeland 2008, 28-9, 105-6, 313-4; Daniels 1997). However, this is not the rule and some sources not only fail to mention health issues but even recommend applications that could be seen as unhealthy. For example, in 2000 Daniel Chiras emphasised the importance of reusing and recycling materials, focusing very strongly on the impact on the natural environment, rather than acknowledging that some recycled materials pose risks for indoor air environments, such as recycled tyre walls (Chiras 2000). Therefore, although the impact of building and furnishing materials on health is discussed in some sustainability literature, this is not always the case.

However, in sustainability literature it is possible to identify two useful principles. One of these principles suggests that in addition to impact on the natural environment impact on users' health should be considered, including consideration of the workers involved in the construction (Vale and Vale 1991, 128). The other idea promotes the use of natural, generally more traditional materials, over the newer, generally more synthetic materials (Vale and Vale 1991; Baggs and Baggs 1996; Pearson 1998; Pearson 2005; Vale 2008). The reasons for recommending natural over artificial materials is that they have been tested over many generations (Pearson 1998; Pearson 2005), they can often be used close to their natural state, thus having lower embodied energy (Vale 2008, 55), and their impact on the natural environment when disposed of is more favourable than that of more synthetic materials (Birkeland 2008).

Recent sources that directly discuss building or furnishing materials in relation to sustainability vary greatly in their treatment of the impact materials have on human health (Gesimondo and Postell 2011; Schörpfer 2011a; Attmann 2010; Fernandez 2006). Some provide chapters or sections dealing with health and listing many of the possible concerns (Gesimondo and Postell 2011), some record current legislative practices but go no further (Attmann 2010), while some still imply a celebration of artificial materials, with minimal acknowledgement of the potential health risks (Fernandez 2006). Especially telling is the treatment of nanotechnology, which is generally discussed in such literature positively (Yeadon 2011; Attmann 2010), with rare reference to existing knowledge of the adverse health effects these materials can cause (Gesimondo and Postell 2011, 19). Therefore, for the purpose of this thesis direct search of the primary, knowledge development sources was considered to be essential (see Chapter 2).

1.4 Other sources

In addition to these sources, which are all part of what architecture as a discipline engages with, there is a series of other sources which are generally more available to the public. One such type are the numerous internet-based sources which have appeared in recent years and which deal with building and furnishing materials, and include references to ecological or sustainability issues. Although some websites are clearly associated with relatively authoritative organisations, such as the Green Building Council (2013) or Environmental Choice New Zealand (2013), and are thus part of the apparatus used by the architects and building scientists, the overall increase in the total number

of websites makes it hard for the general population to adequately evaluate between them (one search revealed more than 30 websites in this area). Furthermore, there are no clear standards in what different websites cover and in many cases health concerns associated with materials are not included. For example on one website a piece of hard maple was described as ‘beautiful, natural hardwood,’ while MDF was described as ‘a versatile material’, with no more detailed information about the type of glue used (www.inventables.com, accessed August 2013). In addition, many manufacturers have a direct interest in how they are presented in internet sources, and many businesses are already moving ahead of regulations, because they see direct market advantages from being seen by consumers as environmentally desirable (Cotter 2008, 149). Much of this is driven by consumer awareness and this position is seen as giving ‘an unprecedented opportunity to harness innovation for the sake of environmental responsibility’ (Brownell 2010, 6). Unfortunately, the level of difficulty observed in this review to extract clarity on the subject of the impact of building materials on human health could prove to be one of the challenges the general population would have to navigate if using these sources.

Probably the most passionate recognition of the health risks in contemporary housing and promotion of the need for improvement comes from non-academic or marginally academic sources, and due to their tone, these works are likely to be very approachable for the general population. Some of the most passionate books in this area are written by people who have personally suffered a great deal from sensitivities to their immediate environment. *The Sick House Survival Guide* by Angela Hobbs (2003) and John Bower’s two books on healthy house building (1989; 2000) are good examples of accounts of this nature. A similar group of sources in this category are sources related to the Building Biology or *Baubiologie* (*Baubiologie* was developed in Germany based upon studies of unhealthy housing built in the early years after World War Two (IBN 2011; HBELC 2011)). These sources are again more based on experience than scientific proof and include books such as Athena Thompson’s *Homes that Heal: and those that don’t* (2004) and Paula Baker-Laporte, Erica Elliott and John Banta, *Prescriptions for A Healthy House: a practical guide for architects, builders and homeowners* (2008). The strength of these books is that they generally provide excellent accounts of many suspected unhealthy materials and unequivocal evidence that the problem with indoor environment is real, at least for some individuals. Although they generally attempt to reference the information that they present, many of their references refer to opinion-based articles, experiential accounts, and similar non-scientific sources. These sources are often passionate and written in a tone that can provoke intense reactions, and from that perceptive they might inspire the general population to make changes. However, their existence does not mean that much of the general population is aware of such texts.

1.5 Chapter conclusion

Based on this review of architecture related literature, it is possible to conclude that recent discussion of materials has increased in more than one field of architectural study. However these discussions jointly fail to provide a comprehensive body of knowledge on the impact building and furnishing materials can have on human health. Therefore, a review of more primary sources from

the medical and related disciplines is needed to evaluate the actual level of current knowledge in this area.

Nevertheless, the multifaceted nature of the increase potentially indicates that it is possible to observe early signs of a paradigm shift in the way values are positioned within architecture and design, giving materiality of artefacts greater importance than in the previous fifty years. On a very general level, it seems possible that the essence of these changes has been inspired by the increasing general awareness of sustainability issues, and that therefore the new developments are seeking ways of using materials more wisely. However, at this point in time, it is hard to see that significant reflection of factual materiality is integral to these developments, especially, as the impact on indoor air quality does not seem to play a significant role in these discussions. Successive regulatory changes in recent years have produced some changes in the literature, and perhaps a new type of literature will develop, given that sources published since the 2010-11 US ban on formaldehyde already indicate greater awareness of health issues (Gesimondo and Postell 2011; Schörpfer 2011a). Unfortunately, because this change only took place a couple of years ago, it is hard to be certain about these trends.

Chapter 3

Review of medical and other scientific sources

3.1 Introduction

From the part of the literature reviewed in the previous chapter, it can be seen that architecture related sources generally struggle with limitations in knowledge about the proven health risks associated with building and furnishing materials, and this is often aligned with the professional responsibility to reflect the current regulations. Due to these limitations, the literature reviewed varied greatly in its coverage of health issues. Therefore, for this study, it was important that a review be undertaken of medical and other scientific, primary sources. Although the primary focus is the impact of building and furnishing materials on human health, in many cases it was important to look into specific substances of concern that are commonly found in these materials. This chapter provides a summary of these findings.

The core research question of this chapter is whether any clear patterns can be observed in the way knowledge about risk substances is integrated into social practices. Of special interest is whether there are any significant improvements over time, and if so, what form these take.

Rather than providing a detailed overview of all existing knowledge (which would be a thesis in its own right), this chapter uses the four phases of progression in the recognition of risks posed by certain substances, devised in this research to organise available information into a clear system for its interpretation, and to illustrate key patterns in the development and assimilation of new scientific knowledge. Figure 3.1 summarises the key features of each phase. The first phase records the early recognition of risks associated with a certain substance, the second begins to regulate its use, the

third leads to a progressive decrease in allowed levels, and finally the fourth phase records the complete ban of the substance. Although for specific substances some of these phases could overlap and progress at different speeds, these phases help organise knowledge about the harmful effects of substances commonly found in building and furnishing materials, and illustrate the issues around integrating knowledge about risk substances into everyday life.

This chapter is organised by the four phases, but in a reverse order, starting with the most recognised health hazards in building and furnishing materials. The fourth phase substances, being clearly recognised as health hazards, are especially relevant for this discussion, because only they can help in evaluating the effectiveness of their elimination and how long the whole process took. Therefore, this chapter starts with the recognised health hazards of lead and asbestos as examples of substances in the fourth phase. Second and third phase substances provide good examples of the contradictions and difficulties associated with the process of starting to eliminate substances recognised as harmful. One feature of these phases is that the differentiation between them could easily be blurred if developments are more accelerated, although there is a significant qualitative difference between them in terms of the allowable thresholds for exposure to a substance. This blurring is the reason they are discussed here as one heterogeneous group. Formaldehyde and phthalate plasticisers are used as examples of this process, but to provide background they are discussed within the context of other VOCs and general issues associated with indoor air quality. Finally, a brief overview of the first phase substances helps evaluate the processes which surround the decisions around introducing or diversifying of use of substances that are only suspected of causing harmful effects.

The PubMed database was recognised as a suitable source when searching for an effective method of acquiring information on the established medical understanding of the health risks associated with substances used in building and furnishing materials. It is hosted by the US National Library of Medicine and comprises more than 23 million citations for biomedical literature from MDLINE, life science journals, and online books (PubMed 2013). Other journal articles have used PubMed as their main search tool for systematic review of literature on medical subjects. For example, Checkoway et al. (2012) searched the PubMed database of publications between 1966-2012 to review the association between formaldehyde exposure and lymphohematopoietic malignancies (Checkoway et al. 2012). In addition to the PubMed data base, complementary information was sourced from websites of official organisations or regulating bodies, such as the World Health Organisation (WHO) and the (US) Environmental Protection Agency (EPA), and some published detailed overviews, such as *Toxicity of Building Materials*, edited by Pacheco-Torgal, Jalali, and Fucic (2012).

There is much debate on how to define what is unhealthy for humans. Richard Philp in his book *Ecosystems and Human Health: toxicology and environmental hazards* (2001) explains that toxicological studies have developed research methods to establish thresholds for acute toxicity of

Figure 3.1: The four phases of recognition of health risks and summary of their key features. (Source: Author.)

many substances. However, it is much harder to evaluate the impact from low level exposure, especially if these are chronic exposures or have a cumulative effect. Additionally, there is much development in understanding reproductive and geno-toxicity, when a substance is more damaging to reproductive organs or alters the genetic makeup of an unborn child. One of the factors that complicates many studies in this area is the fact that the human body has the ability to self-heal and contemporary medicine is still unable to explain why in some people or situations these self-healing mechanisms seem to be active or inactive (Philp 2001, n.p.). The discussion in this chapter should be considered against this backdrop.

3.2 Fourth phase: lead and asbestos

This section takes a detailed look at lead and asbestos, two examples of substances in Phase 4: they are well known, have been known about for a long time, and have even been legislated against for a reasonably long time. In fact, when the health risks associated with building materials are mentioned many people immediately think of these two, well known hazardous materials. Both lead and asbestos have been known about and used since prehistoric times. The adverse health effect of lead was clearly observed during the time of the Ancient Greeks, while for asbestos the effects were only noted in the late 19th century. Thus, both lead and asbestos were already in the first phase of the early recognition of risks before the start of the 20th century. Yet, despite this, both materials have seen prolific use during the 20th century. This historical reality, or paradox, of a high increase in the use of materials which were already in part recognised as health hazards is very important. It clearly establishes the idea that during much of the 20th century human health was not valued as much as the physical properties both materials offered. As this section shows, the evolution of the increased recognition of the risks they posed and gradual regulation against them also tells an important story of repeatedly slow reactions, tendencies to dismiss strong indications of a health problem as being based on insufficient evidence, and general continuation of favouring the physical properties of the material and economic efficiency over human health. This is a good example of a disregard for the precautionary principle.

3.2.1 Lead (Pb): general overview

Lead has been used by human society for at least 4-5,000 years (Brown and Margolis 2012, 1). Lead (Pb) is a naturally occurring metal which, historically, has been used in architecture for its pliability in forming the glazing beads (comes) in lead windows, lead roofs, flashings and plumbing. During the 20th century it was mainly used in architecture as a stabiliser for lead-based paints.

As early as 370 BC, Hippocrates made some of the earliest recorded observations of health issues related to lead and other heavy metals (Philp 2001, ch.6, unpaginated). Some sources have proposed that lead poisoning influenced the fall of the Roman Empire (Hayes 2012, 283). Better understanding of the risks eventually led to the passing of the first Food and Drugs Act by the British

Parliament in 1875, but despite this cast lead solders and other lead toys were fairly common until the late 1940s and early 1950s (Philp 2001, ch.6, unpaginated). Therefore, it is possible to observe that lead was already in the first phase of recognition of health risks before the start of the 20th century, but that the second phase did not start until mid century.

Lead can negatively affect almost every organ, system and process in the human body, including the cardiovascular, gastrointestinal, hemolymphatic, urinary, immune, nervous, and reproductive systems, and can cause tumours in laboratory animals (Carlisle, 2009). Of all the systems listed, the main target for lead toxicity is the central nervous system (Sanders et al. 2009). For painters with high lead exposure peripheral neuropathy and cognitive impairment were recorded, starting with problems with the upper limbs (Krishnan et al. 2012, 957). However, lower levels of on-going exposure can lead to inhibition of several enzymes involved in heme synthesis, influencing functions of the peripheral and central nervous system and increasing blood pressure (Jakubowski 2011, 1).

Young and unborn children are more at risk from lead than adults because their brain and nervous systems are developing, and because their bodies absorb much higher proportions of ingested lead than adult bodies (Sanders et al. 2009). The blood-brain-barrier recognises one common form of lead in the body as calcium thus allowing its entry into the brain, where lead can take over the functional role of calcium, altering neurochemistry and behaviour, especially in the immature brain (Sanders et al. 2009). Acute lead poisoning in children starts with vertigo and irritability, progressing to delirium, vomiting and convulsions (Philp 2001, ch.6, unpaginated). Studies have shown that lead exposure in children persists into adulthood, and has been associated with brain damage, mental retardation, behavioural problems, developmental delays, violence, and death at high levels of exposure (Sanders et al. 2009).

The half-life for lead in blood is generally 30-35 days, while in bones it is 25 years; bones, hair and teeth are where most of the free blood lead deposits (Philp 2001, ch.6, unpaginated; Carlisle, 2009). Lead in the bones may be remobilized back into circulation at times of stress and tension, such as pregnancy, illness, traumatic life events, and aging (Zahran 2009; Machida 2009). Although the human body can eliminate lead, most of it stays in the body for a long time contributing to the total body load. Lead can come in different forms. The International Agency for Research on Cancer (IARC) recognises different forms of lead as varying in their carcinogenicity: they classify inorganic lead compounds in Group 2A (probably carcinogenic to humans), elemental lead in Group 2B (possibly carcinogenic to humans), while organic lead compounds are classified as Group 3 (not classified for carcinogenicity to humans) (IARC 2013). Carcinogenicity of substances differs from their toxicity, but lead is recognised as a risk in both areas.

3.2.2 Regulations against lead

During the 1970s, systematic actions against lead exposure started in many parts of the world. In this period the main focus was leaded petrol and lead-based paints. Recognitions of the health risks associated with lead in petrol increased during the 1970s leading to removal of leaded petrol in many countries during the 1980s and 1990s (O'Grady and Perron 2011). In the US, the Lead Paint Poison Prevention Program was introduced in 1970 (Philp 2001, ch.6, unpaginated). This was followed with the 1977/8 US ban of lead-based paint (Roberts et al. 2012). The level of restriction varied in different countries at different times, for example the 1976 Canadian limit for lead in interior paints was set eight times higher than the US restrictions two years later (O'Grady and Perron 2011). In France, the sale of lead carbonate, which was used in paint, was officially only banned in 1993 (Lucas et al. 2012). In New Zealand, this process started during the late 1960s, when Resene removed lead from its decorative paints ahead of other manufacturers (*North & South* 2011). Therefore, for many developed countries during the 1970s lead has gone through the second and third phase of recognition of risk, leading to bans from the late 1970s.

Unfortunately, these trends are not shared by all countries. In the last ten years, high levels of lead in new paints have been found in twenty countries from five continents (Ewers et al. 2011). Most are developing countries where legislation limiting lead content either does not exist or is ineffectively enforced, but some are more developed countries such as India and Taiwan (Khan et al 2010; Ewers et al. 2011). For example, the study of Ewers et al. (2011) tested newly purchased paints in Taiwan and found that the median lead concentration was more than 30 times the current US standard and less than half of the paint samples had lead content within the current US standard (Ewers et al. 2011). They observed that when samples from China were tested these had lower levels of lead.

3.2.3 Impact of low levels of lead on human health

Since the introduction of more strict regulations against lead, new studies have measured the impact of low levels of lead on human health. Evaluation of such low levels is generally not possible before regulative action. Therefore this section shows the importance of action to limit exposure before a more sophisticated understanding of the issues is made possible.

Current research indicates that even very low levels of blood lead in children can cause a measurable negative impact on their development. Levels of safe exposure have changed in the later decades of the 20th century. In 1991, the US Centers for Disease Control and Prevention decreased earlier action blood lead levels to 10µg/dL (this equates to 100µg/L, with measures in both µg/dL and µg/L found in the literature) for children under the age of six (Roberts et al. 2012, 1), and the same measure was established in many other countries soon after (Oulhote et al. 2011). Good indicative examples of earlier action blood lead levels of concern include the 1960 US level of 60µg/dL (Jakubowski 2011, 3) and the 1987 Canadian level of 25µg/dL (O'Grady and Perron 2011, 178), clearly indicating a general trend to lower acceptable levels.

The action blood lead level of $10\mu\text{g}/\text{dL}$ for children reflected the knowledge available at that time, which demonstrated a decline in IQ points with every incremental elevation of blood lead levels greater than $10\mu\text{g}/\text{dL}$ (Roberts et al. 2012, 1). In 1978, the US national blood lead level in children aged 1-5 years was over $10\mu\text{g}/\text{dL}$ for 13.5 million children or almost 90% of American children (Brown and Margolis 2012, 3). Extracting figures from a graph, by the early 1990s that figure had dropped to about 10% and continued dropping to approximately 1.5% of all American children by 2007-2008 (Figure 3.2; Brown and Margolis 2012, 3). Similarly, in the late 1970s, the geometric mean blood lead level for all American children was $15\mu\text{g}/\text{dL}$, and in 2012 it was under $2\mu\text{g}/\text{dL}$ (Brown and Margolis 2012, 3). This significant decrease in blood lead has enabled more subtle studies, and also indicates that in some countries, even after the official bans on use of lead as a sign of the fourth phase of recognition, some of the features of the third phase continued, creating a need to decrease regulated levels to help children specifically at risk.

Figure 3.2: Timeline of lead poisoning prevention policies and blood lead levels in children aged 1-5, by year, from National Health and Nutrition Examination Survey, United States, 1971-2008. Abbreviations: BLL = blood lead level; GM = geometric mean. Source: Brown and Margolis 2012, 3.

Research since the 1970s has demonstrated that the greatest rate of decline in IQ occurs in blood lead levels of between 3 and $8\mu\text{g}/\text{dL}$ (Roberts et al. 2012, 1). Therefore in 2000 the World Health Organisation Regional Office for Europe recommended efforts be made to ensure that at least 98% of an exposed population of all ages has blood lead levels under $10\mu\text{g}/\text{dL}$, which implies the current median blood lead level is under $5.4\mu\text{g}/\text{dL}$ (Jakubowski 2011, 3). A very similar level and rationale

were set in 2012 by the US Centers for Disease Control (Roberts et al. 2012, 1). A French survey from 2007 involved 3,800 children and estimated a geometric mean for blood lead level of $1.5\mu\text{g/dL}$, with 0.11% of children having a higher blood lead level of above $10\mu\text{g/dL}$ (Oulhote et al. 2011, 2). A study from 2007-2008 compared blood lead levels for children in six European cities (mainly central European) and three non-European cities. It showed that blood lead levels in children varied very little between European countries but was noticeably higher in the non-European cities they studied, these being in China, Ecuador and Morocco (Hrubá et al. 2012). This implies that many parts of developed world have lead exposure under reasonable control, but that this is not a trend shared world-wide.

Earlier studies such as one from 1995 suggested a mean decrease in full-scale IQ of the order of 2 IQ points for a change in mean blood lead level from $10\mu\text{g/dL}$ to $20\mu\text{g/dL}$ (Jakubowski 2011, 4). Subsequent studies have established that in fact much of the decrease of IQ occurs for exposures under $10\mu\text{g/dL}$: for a change of exposure from $2.4\mu\text{g/dL}$ to $10\mu\text{g/dL}$, IQ tends to change by 3.9 points, while for a change of exposure from $20\mu\text{g/dL}$ to $30\mu\text{g/dL}$, IQ changes by 1.1 points (Jakubowski 2011, 4). Similarly, in the 1990s, research established strong links between IQ and blood lead levels in children of two years of age, while subsequent research, even of the same cohort, suggests that exposures of school age children to lead may be more strongly related to performance in cognitive testing (Mazumdar 2011). Several studies have found that poorer performance in these types of test correlate to higher levels of lead, even for levels as low as $2\mu\text{g/dL}$ (Jakubowski 2011; Zahran et al. 2009; Amato et al. 2012).

The current low and moderate blood lead levels in many parts of the western population have also been shown to have a significant impact on other aspects of children's development. Moderate blood lead levels are correlated to lower growth rate, lower height and lower weight for age (Yang et al. 2012). Levels of lead from $5\mu\text{g/dL}$ have been found to alter reproductive hormones in young girls (Gollenberg 2010). Lead has contributed to attention-deficit hyperactivity disorder (ADHD), and this was even a trend with children who are asymptomatic for ADHD (Winneke 2011). It has been suggested that lead and other heavy metal prenatal exposure impairs the development of visual processing (Ethier et al. 2012). Further, blood lead level has been found to be correlated to increased stress responses at currently 'normal' levels under $10\mu\text{g/dL}$ (Gump et al. 2009). Concerns have been raised that lead poisoning can cause nerve damage to the sense organs and nerves controlling the body, increasing the chance of neurodegenerative diseases like Alzheimer's and Parkinson's disease later in life (Sanders et al. 2009; Li et al. 2010).

While the negative impact of lead on memory, learning and IQ has often been studied, there is also evidence that lead influences other behaviours such as mood (depression), anxiety, schizophrenia and violence/aggression (Sanders et al. 2009). It has been noted that lead-exposed four to five year old children exhibit an increase in aggression, and from there lead exposure has been associated with juvenile delinquency and criminal behaviour (Sanders et al. 2009, Narag, Pizarro and Gibbs 2009). Between 1979 and 1984, a Cincinnati-based study recruited pregnant women living in

impoverished neighbourhoods with a high concentration of older, lead contaminated housing (Wright 2009). It measured prenatal and early childhood exposure to lead, and subsequently compared that data with the local criminal justice records on arrests of the same children by 2005, then 19-24 years of age. Increased blood lead levels before birth and during early childhood were associated with higher rates of arrests than the control group. Also, average childhood blood lead was significantly associated with higher risk of arrest involving violent crime (Wright 2009). In a similar New Zealand study, 1265 Christchurch children were studied from birth (in 1977) to age 21 (Fergusson, Boden and Horwood 2008). Their dental lead levels at ages 6-9 were significantly associated with both officially recorded violence/property convictions and self-reported violence/property offending.

More recent research on lead has attempted to identify more subtle ways in which lead is harmful for human bodies. For example, lead has also been researched in relation to body processes such as oxidative stress, cell membrane biophysics and signalling and neurotransmission (Verstraeten, Aimo and Oteiza 2008). Another study has established that the presence of lead in cells can trigger the sequence of pre-programmed bodily processes called apoptosis, which leads to the elimination of cells without releasing harmful substances into the surrounding area (Yedjou et al. 2010). While this is a healthy process that protects the body from unhealthy cells or substances, Yedjou et al. noted that the mechanisms by which lead induces this elimination remain unclear. However, their study has demonstrated how the presence of lead nitrate can trigger cellular processes that lead to the formation of human leukemia (HL-60) cells (Yedjou et al. 2010). A 2011 study established that there are genetic biomarkers of increased neurotoxic risk, indicating that boys with a particular genetic expression are most likely to be effected (Sobin 2011). Research of this nature could lead to development of targeted prevention programmes particularly for those who are more at risk.

More recent studies have also made much progress with identifying both possible sources of high exposure, such as certain food plants that tend to absorb and carry higher concentrations of lead (for mushroom varieties particularly prone to absorbing lead see Petkovšek and Pokorny 2013) or foods, such as brown rice, that might be able to help reduce mammal lead-induced toxicity (Zhang et al. 2010). Furthermore, it has been observed that blood lead levels seem to fluctuate in relation to the seasons, without a proper understanding yet of what influences these fluctuations (Havlena, Kanarek and Coons 2009).

The results of these studies of more recent, post-regulation issues associated with lead clearly indicate that when the general level of exposure is very high, it is very hard for the research community to evaluate the important thresholds for adverse effects on human health accurately.

3.2.4 Issues facing recovery from lead contamination

Some significant sources of lead have continued even after its official bans. The US Centre for Disease Control and Prevention lists these as: lead-contaminated soil, food, tap water, lead-paint, folk remedies, pottery, and dust (Brown and Margolis 2012). During the late 1970s and early 1980s, when recognition of the risks associated with lead exposure culminated in various bans, all of these sources were likely to contain lead. Since then, there has been much improvement: lead in tinned food and lead in new paint have been eliminated in developed countries, and much work has been done to reduce the prevalence of lead pipes in public water supplies (Brown and Margolis 2012). However, the historical use of lead has left a legacy of contamination in the natural environment, since elemental lead does not degrade (Carlisle et al. 2009). Furthermore, lead continues to be newly harvested, and is often used in electronic items, which creates new potential lead pollution at recycling points for electrical waste (Yang et al. 2012). In addition, due to poorer regulations in less developed countries, imported items manufactured in such countries can introduce new lead contamination (Guney and Zagury 2012). Unfortunately, even in very recent years hidden lead has been found in internationally available toys and low-cost jewellery (Guney and Zagury 2012).

Nevertheless, the most significant concern associated with lead in developed countries is lead in paint in older housing. In the US this is increasingly recognised as a problem that comes together with poverty, because the US children from low-income families are about three times more likely to have high blood lead levels than children from middle and high-income families; and similarly, children from the inner city, with concentrations of older housing, are four times more likely to have elevated blood lead levels than children in other areas (Sanders et al. 2009). One comprehensive US intervention specifically targeted windows because they have the highest likelihood of containing lead paint and the highest amounts of lead dust (Dixon et al. 2012). Surveying 189 homes from four cities, they had a group where all windows were replaced, a group where some were replaced, and a group with no replacement windows. All windows that were not replaced were repaired and maintained. Their results show that 12 years after the intervention homes with all windows replaced had interior floor dust lead and window sill dust lead levels almost half those in non-replacement homes, even when controlling for other factors (Dixon et al. 2012). The homes where some windows were replaced also exhibited a decrease, which was about half the decrease from complete replacement (Dixon et al. 2012). Furthermore, one study found a child with a blood lead level of $23\mu\text{g}/\text{dL}$ who lived in a house with lead containing paint which was observed to have excessive dust on the windowsills, dirt on the carpet, and a dirt-covered yard but no evidence of peeling paint (Roberts et al. 2012, 3), indicating that overall cleaning in older houses can contribute to the problem. While window replacement is a fairly expensive strategy and can often be impracticable, improvements in management of household cleaning can come at no or very low cost, and many studies have evaluated the effectiveness of different educational initiatives on lead risks and strategies to reduce exposure, including effective and safe cleaning in housing with lead paint (Section 9.2).

This general pattern also applies to New Zealand, where much housing, especially if built before World War Two could have lead containing paint. Much effort has been made to inform people

involved with the maintenance and repainting of lead containing paint to support good practices. For example Resene paint shops provide free tests of chips of paint for the presence of lead and provide free printed and verbal instructions on how to work with lead containing paint. Despite this, between 2011 and 2013 during the writing of this thesis three individual houses in the same suburb were observed to have all their external paint removed before repainting (Figure 3.3). All appeared built before the 1960s, and so could have lead in their paint. For the two older houses workers were observed wearing protective gear. In one case the paint removal was by sanding during the dry summer months, no clear effort was being made towards protecting the surroundings, and often big clouds of dust hovered or blew around the neighbourhood. In the other case, no such dust was observed, which could be either because of good practices or at least in part due to very wet weather at the time.

Subsequently, phone calls were made to Wellington City Council and the Department of Labour about the current legal position of such activities. The City Council referred to the Department of Labour who explained that if there is a contractor doing the work, the site falls under the category of a workplace and they can insist on adequate protective measures. However, if no contractors are involved, and a DIY enthusiast is undertaking the work on their own property, this is not covered by the same regulations, and therefore probably no action could be taken. This gap in regulation indicates that for similar work, there are currently no established practices protecting the interests of the individual and the whole community.

Figure 3.3: A Wellington suburban house sanded before painting.
(Source: Author.)

3.2.5 Lead: summary

This overview shows that early regulations against lead exposure were delayed after the articulated recognition of the risks. Although it is hard to give a clear date when the first phase of recognition started for lead, because it probably dates to prehistoric times, it is easy to assert that lead was established in the first phase of recognition before the start of the 20th century. Yet, no significant efforts towards regulation can be observed in the first half of the century. During the 1970s many

Western countries experienced the greatest change in treatment of lead through the proposed elimination of leaded petrol and leaded paints, and this decade can be seen as an accelerated second and third phase of recognition of risk. The fourth phase then emerged by the end of the 1970s with the ban on leaded paint, which was followed during the 1980s-90s with the ban on leaded petrol. Despite these bans in Western countries, many less developed countries are still in the very early phases of risk recognition.

Furthermore, for lead, research and subsequent decreasing 'action levels,' generally characteristic of the third phase, are still on-going, long after the bans. Now it is known that the average blood lead levels common in US children of the 1970s have probably negatively impacted many aspects of their development, which was impossible to observe while the overall level of lead pollution was much higher. Similarly, the main current source of contamination is old housing with lead paint, which in the past was a relatively minor risk, compared to new application of such paints, lead water pipes and the pollution from leaded petrol. Furthermore, the total impact is still unknown, because the release of blood lead stores in the later stages of life has generally not yet happened for the children of the 1970s. More sophisticated understanding of the adverse effect lead has on the human body will continue to be produced in years to come. For instance, a recent cost-benefit analysis suggests that for every dollar spent to reduce lead hazards \$17-\$220 is saved, which compares well to immunisation costs (Brown and Margolis 2012). Therefore, lead still does not appear to be a cold case.

3.2.6 Asbestos: general overview

Asbestos use began 4500 years ago, but significantly increased during the 20th century, and peaked during the mid 1970s (Park et al. 2012). Asbestos is the general commercial name for a group of naturally occurring mineral silicate fibres of the serpentine and amphibole series (Figure 3.4; Park et al. 2012). Asbestos minerals are crystalline with weaknesses in the crystal structure which causes long thin fibres to be released along fracture planes and become airborne when the rock is stressed (Donaldson and Poland 2012). Normally, asbestos is defined as a mineral fibre with lengths of 5-10µm, proportionally small fibre diameters of usually under 1µm, and with an aspect ratio >3:1 (Park et al. 2012). While its mineral chemical composition gives asbestos its recognised properties against fire, in the building industry it was also often used to reinforce a surrounding material, such as cement, due to the properties of these mineral fibres. In New Zealand, asbestos containing products were widely used in construction between the 1920s and mid 1980s, in products such as roof tiles, wall claddings, vinyl flooring, sprayed fire protection, decorative ceilings, roofing membranes, adhesives and paints (Level 2013).

Figure 3.4: Asbestos fibre types. Amphiboles (e.g., crocidolite, amosite, anthrocityte, and others not shown) are straight, rod-like fibres, whereas serpentines (e.g., chrysotile) are curvilinear fibres. (Source: Liu, Cheresh and Kamp 2013.)

Unfortunately, the same feature that gave asbestos fibre good applicability in the construction industry is the foundation of the health problems it causes, and in contrast to lead, this somewhat narrows down the range of impacts asbestos has on human body. Although much research has been undertaken over the last decades, the precise molecular mechanisms involved with asbestos are not yet fully understood (Liu, Cheresh and Kamp 2013). However, it is well known that asbestos exposure can lead to a series of different lung diseases such as pulmonary fibrosis (asbestosis), pleural abnormalities (effusion and plaques) and malignancies (bronchogenic carcinoma and mesothelioma) (Liu, Cheresh and Kamp 2013). Further, due to their small diameter, proportionally long length and biopersistence, these fibres are easy to inhale, and once in the body they can cause a number of processes in the lung that could lead to carcinogenesis (Donaldson and Poland 2012). Long biopersistent fibres can generate free radicals chronically that directly damage DNA, leading to long accumulation of dose and interaction with cells of the immune system. In addition, the long fibres create a series of processes that inhibit positive cell functioning and trigger the defensive mechanism, which become chronic due to cellular inability to expel pollution of the size and proportion of asbestos fibres (Donaldson and Poland 2012).

One of the challenges with research on asbestos is the long latency period between exposure to asbestos and presentation of health concerns, ranging from 15 to 40 years (Liu, Cheresh and Kamp 2013). This is related to the damage which asbestos fibres create due to the body's inability to eliminate them effectively, which keeps certain protective and eliminative processes in a state of chronic overuse, thus gradually creating health problems (Sanchez et al. 2009; Donaldson and Poland 2012). Delays like this have historically made conclusive research more difficult and contributed to blurring of the recognition of the problem.

The evaluation of the health impact of asbestos is further complicated by its natural variability which at least, on a theoretical level, justifies the assumption that its impact could vary to reflect this. Generally, chrysotile asbestos has been seen as potentially less harmful due to various estimates that once in the body it disintegrates, which makes it less pathogenic than the amphiboles (Donaldson and Poland 2012). This could potentially be very significant, given that chrysotile asbestos represented as much as 95% of the asbestos used worldwide since 1900 (Park et al. 2012). Unfortunately, recent reviews strongly assert this is a misconception (Kanarek 2011), and concur with the International Agency for Research on Cancer (IARC), that all forms of asbestos are recognized human carcinogens and should be banned (Paglietti et al. 2012). Furthermore, in 2009, having asserted the need for a complete ban on all asbestos use, the IARC concluded that several non-pulmonary forms of cancer can be caused by exposure to asbestos, and that asbestos has been associated with risk of systematic autoimmune disease (Park et al. 2012).

There is also recognition that occupational exposure to asbestos means the substance has often made its way into workers' homes through the dust brought home on clothing, which then exposes families to risk (Peretz et al. 2008). More recently, cases of long latent asbestos related health problems are becoming apparent in adults who were exposed to asbestos as children through their parents' work (Reid et al. 2013; Peretz et al. 2008). Similarly, longitudinal studies of people who were exposed to asbestos outdoors as children in the 1970s because of local mining are now giving conclusive results that childhood exposure to asbestos increases cancer incidence rates, mainly but not exclusively due to an increase in rates of mesothelioma (Reid et al. 2013). The number of individual cases of this nature is likely to continue increasing because of the long latency period.

In contrast to lead where evaluations of bodily exposures are possible (as seen through measured blood lead level and bone lead level), none of the articles found during this review reported such measures for asbestos. Rather, many research articles used questionnaires and interviews to obtain descriptive accounts of possible asbestos exposure (Peretz et al. 2008; Olsen et al. 2011), or in comparison with the measured prevalence of asbestos in air (Reid et al. 2013). This, together with the long latency period, makes accurate studies very difficult, and this is especially the case for lower levels of exposure. Recent research has, through studies of the children of asbestos workers or children who lived in affected neighbourhoods, established that their exposure, which was probably much lower than that of the asbestos workers themselves, has also led to adverse health effects (Reid et al. 2013; Peretz et al. 2008). Thus, it seems that for asbestos indirect indications will be needed to evaluate the extent of adverse effects from lower levels of exposure. Studies of removal work carried out now could become especially useful in showing the impact even lower levels of exposure has on human health, but these are likely to mean waiting for 40-50 years before enough evidence accrues given the long latency period.

3.2.7 Regulations against asbestos

Around 1977, when the demand for asbestos peaked internationally, some 25 countries produced a total of 4.8 million metric tonnes per year, to be used in 85 countries (Park et al. 2012). Although the use of asbestos has since been banned in many industrialised countries, early in the 21st century, global use was still 2.1 million metric tonnes per year, primarily in Asian and less developed countries, where most of it is used to manufacture asbestos cement building materials (Park et al. 2012). In New Zealand, asbestos use peaked in 1975 with the import of 12,500 tonnes (Department of Labour 2005: 35-6). By 1983, one year before phasing out of asbestos started in New Zealand, this was reduced to 3,000 tonnes/year (Department of Labour 2005: 35-6).

This prolific industrial use of asbestos during the 20th century should be seen in contrast with early recognitions of its negative health impact. In 1898, early in the period of the industrialised use of asbestos, Adelaide Anderson, Principal Lady Inspector of Factories in the Home Office, accurately noted that '[t]he sharp jagged edge of the insoluble mineral dust had undoubtedly occasioned much illness and death from respiratory disease' (Department of Labour 2005: 38). Early in the 20th century, the relationship between asbestos dust exposure and fibrosis of the lungs and asbestosis was already recognised, and by the 1950s and early 1960s the relationship between lung cancer and mesothelioma and asbestos exposure was confirmed (Department of Labour 2005: 38). Yet, the production was at that time still internationally increasing. This makes asbestos a good example of a material that has been used for a long time since first being recognised as a hazard, thus since the first phase of recognition of risk.

Although early regulations that deal with asbestos date back to 1931 with the formation of the British Asbestos Industry Regulations (Department of Labour 2005: 38), it was in the 1980s that much change took place and many countries started to ban use of blue and brown asbestos (Department of Labour 2005: 35-6). However, the complete ban of asbestos generally took place later: Italy in 1992 (Paglietti et al. 2012); New Zealand in 2002 (Waikato District Health Board 2012); Australia in 2003 (Olsen et al. 2011); and Japan in 2005 (Park et al. 2012). By 2012, 52 countries have completely banned use of any form of asbestos (Paglietti et al. 2012). Therefore, for asbestos the start of the fourth phase generally came in two stages. For many countries there were about 20 years between the start of banning and complete bans, which often occurred at the start of the 21st century, more than one hundred years since articulation of the first phase of recognition of risk.

3.2.8 Issues facing recovery from asbestos contamination

Although still in use in many less developed countries, it is now possible to start assessing the legacy of asbestos since its official ban in many developed countries. Unfortunately this reveals new types of concern. Olsen et al. (2011) discuss the impact of asbestos in three waves: first the workers mining and milling raw asbestos and manufacturing asbestos products; second the workers who used asbestos products in industry, such as the building industry; and finally the third wave consisting of people diagnosed with asbestos related diseases after a short term and/or low level

exposure in the home or workplace, often due to activities related to home maintenance or renovation involving asbestos containing building products. The amounts of asbestos used varied greatly between products. For example, sprayed asbestos varied between 5% and 95% asbestos content (Dumortier and De Vuyst 2012). Similarly, the prevalence of asbestos containing products in different countries more or less reflected the ease of its availability. For example, in Australia, where naturally occurring asbestos was mined until the 1960s, 25% of all new homes were clad in asbestos cement (Olsen et al. 2011). Generally, asbestos containing materials that are in good condition and are not the subject of everyday wear and tear, pose little risk. In other cases the risk can be very high. For example, asbestos-vinyl flooring tiles have been shown to suffer the on-going release of asbestos fibres in normal use of the space (Sebastien, Bignon and Martin 1982). Thus, they are a health hazard both while installed and if removed. These great differences make it hard to make any general estimates on possible exposure levels.

The problem is that even after the new use of asbestos was banned, much of it remained in existing structures, often as asbestos cement materials used in cladding, roofing or piping (Olsen et al. 2011), but also in vinyl and linoleum floors and as a sprayed compound (Level 2013). Thus, not surprisingly, the clearance of installed asbestos from buildings is now recognised as a major construction business in developed countries (Dumortier and De Vuyst 2012). The New Zealand Department of Labour recognises floor sanders, asbestos removal workers, brake lining repair workers, building maintenance workers and demolition workers as being most at risk from asbestos in the years to come (2005: 25-6). One of the problems they observe is that much of that removal work is carried out by low-skilled casual labour (Department of Labour 2005: 25-6). In 1992, an audit of floor sanders in Christchurch revealed work practices which included a failure to prevent spread of dust to other rooms, poor respiratory protection for sanders, sanders transferring asbestos dust to their vehicle and home on their work clothes and tools, lack of a thorough 'clean up' after sanding, and even the careless disposal of sanding dust (Department of Labour 2005: 25). Similar problems with poor compliance with established and regulated procedures for the safe removal of asbestos have been noted in other countries (Dumortier and De Vuyst 2012).

Unskilled DIY removal of asbestos can be a particular problem because it is very hard to regulate and monitor. During the work on this thesis, through personal communication it was learned a mother removed kitchen vinyl and some 'dusty stuff' from underneath it. She was part way through the removal before it was suggested that, based on the age of the house, the 'dusty stuff' could contain asbestos and that expert asbestos removal advice should be sought. Based on a subsequent conversation, this did not happen and the DIY practice continued until all of the material was removed. More importantly, it appeared no measures were taken to remove food preparation activities from the kitchen area where this removal was undertaken. A case such as this of unskilled, DIY work in the privacy of the home completely falls outside any monitoring and regulating procedures. Although information and education were available, it had to be actively sought by the person undertaking the DIY work. For them, it was easier not to seek information, given that the 'dusty stuff' was very easy to scrape off. The ease of removal made additional information about perceived risks less important. Current educational and regulatory programmes are focussed on

tradespeople who are most likely to be exposed to risks involved with the removal of asbestos, and are not actively targeting the general population. Potentially this is a way of preventing similar experiences to that described above.

3.2.9 Other asbestos related risks

Current knowledge focuses on risks associated with inhalation of asbestos. Ingestion and dermal exposure have so far received very limited research attention. One area of concern is asbestos in drinking water (Kjærheim et al. 2005; Koumantakis et al. 2009; Wei et al. 2013). Consideration of the presence of asbestos in water is especially important because between the 1920s and the 1980s, asbestos cement was commonly used in mains water supply systems in many countries, including New Zealand (Browne et al. 2005; Department of Labour 2005: 36). To remediate problems with taste, asbestos-cement pipes were sometimes lined with vinyl-based coatings (Spence et al. 2008). As these networks age they become prone to frequent pipe bursts. Additionally, asbestos can enter water systems from mines or natural occlusion making its way into the rivers, lakes and water table reserves in measurable quantities (Koumantakis et al. 2009; Wei et al. 2013). However, studies to date generally do not provide strong evidence of an association between exposure to asbestos in drinking water and the presence of gastrointestinal or respiratory cancers (Kjærheim et al. 2005; Browne et al. 2005; Koumantakis et al. 2009), but the cases that have been found indicate a 20 year or longer delay between exposure and development of cancer (Kjærheim et al. 2005). Additional problems have also emerged: asbestos in river water has been associated with a negative impact on the behaviour of fish and other water life; and results indicate that homes supplied with asbestos contaminated water are associated with an increase of airborne asbestos (Koumantakis et al. 2009). Therefore, it is possible to anticipate that studies of total risks from asbestos could enter a new phase with a heightened recognition of these other risks.

Replacements for asbestos are generally called man made mineral fibres (MMMFs) and often take a similar form of being long, thin fibres. Although generally these are considered to break transversely, rather than longitudinally like asbestos, concerns have been raised that a similar pathology could be observed with these materials. Carbonari et al. (2011) studied the in vitro impact of glass fibres, ceramic fibres, and Wollastonite fibres (form of asbestos), and found that naturally occurring Wollastonite fibres induced blood vessel formation in a similar fashion to that observed for other asbestos while the glass and ceramic fibres did not exhibit such similarities. They concluded that the size and shape of the fibres and their chemical composition and bio-persistence are important factors influencing the development of adverse health effects and that very thin, persistent fibres are the most harmful (Carbonari et al. 2011). When evaluating the impact of dermal exposure to ceramic fibres introduced as an asbestos replacement, a high level of dermal irritation was observed (KeiĆ-Świerczyńska and Wojtczak 2000).

3.2.10 Asbestos: summary

The limitations in the available knowledge about risks associated with asbestos indicate that it is still a less recognised and understood health risk than lead. Understanding of the important mechanisms of response to asbestos within the human body is still missing. Once these are more understood, this new knowledge could change the way asbestos is considered. This situation reinforces the reality that many discoveries associated with the third phase of risk recognition continue into the fourth phase, but also that it is essential to take actions to reduce exposure to hazards based on early knowledge, rather than waiting for the full picture to emerge.

3.2.11 Fourth phase conclusion

The examples of lead and asbestos show that many issues are still unresolved more than three decades since serious legislative efforts have attempted to control their use in Western countries. As discussed, scientific research is still revealing the exact mechanisms of the adverse health impacts these substances have. Some of the longer term and across generation observations are only now becoming available for exposure to the substances in the 1970s. In both cases newer research shows that much lower levels and shorter exposures than assumed in the 1970s or 1980s also have strong adverse health effects. The levels that were used and built-in during the 20th century now seem both high and hazardous.

Therefore, when reflecting on the core research question related to this chapter, it is clear that the most significant pattern that was observed is delays in responding to recognition of significant indications of high health risks. As Olsen et al. (2011) explained many Western countries are now facing the 'third wave' of adverse health impacts from both lead and asbestos, through the removal, maintenance, or poor use of already built-in materials. Although these do not impact on everybody in contemporary society, as suggested for lead, at times the broader community could be at risk from one person's unskilled work. Poor legislative control of DIY activities and a high presence of built-in hazards regularly contribute to the creation of new, although completely preventable, diseases through exposure to these well-known hazards. Current legislation is powerless here.

Further successful removal of health hazards from already built-in materials that contain lead and asbestos is unlikely to be achieved through the use of legislation. Legislative changes have been excellent in removing hazards from new building, but existing built-in hazards also have to be addressed. It is irresponsible to allow continued unregulated, unpredictable exposures from well-known hazards through unskilled activities. To make improvements in this area broad scale education is more likely to be effective in changing the attitudes people have towards the materials in their homes. This approach is evaluated in more detail in Chapter 9.

Furthermore, the way 20th century society has approached the use and regulation of lead and asbestos shows serious problems with the paradigm of waiting for a scientific proof, and only then legislating. Solid indications existed long before complete evidence, and in the case of lead and asbestos these indications were clear even before the start of the 20th century. The time lapse, of about a century, between solid indications and action, enabled prolific increased use over a very long period, thus unjustifiably increasing the levels of exposure of many people. For the health of the general population a more precautionary principle has to be adopted. It is essential to develop a way of recognising the risks as being potentially serious much sooner. This thesis proposes the examples of lead and asbestos are evidence for advocating for a paradigm shift, towards adopting more of a precautionary principle attitude.

Finally, the examples of lead and asbestos are in many ways easy to discuss. They are well known as harmful for the human body in almost any form of exposure. They are also very persistent, both having a very long half-life, and are very hard to eliminate from the environment properly. While these characteristics make them highly undesirable, they also make that undesirability very obvious. Therefore, the only partial elimination of the health hazards associated with lead and asbestos is very disappointing, and sets a grim agenda for some of the other substances considered here. The next section deals with the less obvious hazards of formaldehyde, plasticisers and other VOCs. These chemicals are more reactive and much faster to change their form, making it hard to collect permanent data on them. These features make obtaining accepted scientific knowledge even more difficult.

3.3 Second and third phases: VOCs, formaldehyde, vinyl and plasticisers

Compared to fourth phase substances, there is much less clarity about substances in all other phases, and exact delineation between the phases is often hard to establish. In this section the broad group of volatile organic compounds (VOCs) is used to show the complexities inherent with the presence of organic chemicals in indoor air. VOCs, including SVOCs, formaldehyde and some phthalate plasticisers, are also considered a good example of the complexities that surround substances in the third and second phases (and sometimes in the first phase). The focal question is whether the process of recognising health risks has accelerated since the very slow responses to the hazards of lead and asbestos. The main objective is to illustrate some of the challenges in progressing from a suspicion the chemicals are harmful to their more complete understanding and elimination.

3.3.1 Overview of VOCs

There is no agreed definition of VOCs, with definitions and lists of substances somewhat varying between key international organisations monitoring their possible impact on human health (Guieysse et al. 2008). The United States Environmental Protection Agency (EPA) defines VOCs as any compound of carbon, but they also exclude compounds such as carbon monoxide, carbon

dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate (EPA 2012). Generally, VOCs are based on carbon chains or rings (Guieysse et al. 2008). They are organic chemical compounds whose composition means they can evaporate under normal indoor air temperature and pressure, and often the boiling point is used to differentiate between different VOCs (EPA 2012). Depending on boiling point and volatility, the World Health Organisation (WHO) categorises indoor organic pollutants as very volatile, volatile, and semi-volatile (Table 3.1), while the EPA acknowledges this classification as somewhat arbitrary because all of these volatile compounds fall within the broad definition of the VOCs (EPA 2012). In this chapter they are, therefore, considered as one complex group. Already the official definitions of VOCs indicate some of the inconsistencies in the study of these chemicals, closely followed by inconsistent use of names of the same chemical (ATSDR 2013).

Table 3.1: Classification of volatile organic pollutants. (Source: EPA 2012).

Description	Abbreviation	Boiling Point Range (°C)	Example Compounds
Very volatile (gaseous) organic compounds	VVOC	<0 to 50-100	Propane, butane, methyl chloride
Volatile organic compounds	VOC	50-100 to 240-260	Formaldehyde, d-Limonene, toluene, acetone, ethanol (ethyl alcohol) 2-propanol (isopropyl alcohol), hexanal
Semi volatile organic compounds	SVOC	240-260 to 380-400	Pesticides (DDT, chlordane, plasticizers (phthalates), fire retardants (PCBs, PBB)

Taking the broadest definition, VOCs provide a good basis for an evaluation of the impact of the numerous chemicals developed since World War Two. The US Agency for Toxic Substances and Disease Registry (ATSDR) lists 43 chemicals as VOCs with reasonably well established adverse health effects (ATSDR 2013). Almost a half are specifically acknowledged as synthetic in origin; of the remainder, some come from crude oil or petrol processing, others are synthetic copies of chemicals that naturally appear in very small amounts in the oceans or volcanic eruptions, with only one quarter being natural in origin (ATSDR 2013).

VOCs can cause various health effects like eye, nose and throat irritation, headaches, loss of coordination, nausea, and damage to liver, kidneys and the central nervous system (Katsoyiannis, Leva, and Kotzias 2008; EPA 2013). Some of these chemicals 'can cause cancer in animals; some are suspected or known to cause cancer in humans' (EPA 2013), with others have toxic effect (ATSDR 2013). VOCs can enter homes through the use of paints, varnishes, solvents, and building and furnishing materials, as well as many hobby, home office and art and craft materials, combustion, and cleaning products (EPA 2013). Thus, one part of VOC exposure in homes is related to building and furnishing materials, while the other is related to everyday activities in the space. The focus of this discussion is the former.

The most recognised hazardous VOCs for human health include formaldehyde and the aromatic compounds of benzene, toluene, ethylbenzene, xylenes, and styrene (later Table 3.4). Benzene, and more recently formaldehyde, are recognised by official organisations as high risk both for toxicity and carcinogenesis and are given highest priority on both scales (ECHA 2013; IARC 2013; IRIS 2013; PubChem Compound; ATSDR 2013). Toluene, styrene and xylenes still engender much discussion on their exact level of toxicity and carcinogenesis, which has influenced their current lower level of recognition as risks (ECHA 2013; IARC 2013; IRIS 2013; PubChem Compound; ATSDR 2013). From this it is possible to consider benzene and formaldehyde as currently in phase 3 of recognition, while toluene, styrene and xylenes are probably in phase 2, given that official organisations are acknowledging a growing body of knowledge on their harmful effects (CalEPA 2013; IRIS 2013; PubChem Compound; ATSDR 2013).

Currently there is no method capable of measuring all VOCs present in a space, rather different measuring approaches are used for different VOCs. For example, benzene and toluene are measured using a different method than for formaldehyde and other similar compounds (EPA 2012). This means different researchers tend to focus on a selection of VOCs when assessing indoor air, making the results less comparable. For example two studies evaluating VOCs from carpets used different sampling techniques and only one VOC was tested in both studies, making comparisons difficult (Wilke, Jann and Brödner 2004; Katsoyiannis et al. 2008). Measurements of SVOCs are even more complex and take longer because of the sorption of the measuring instruments (Xu et al. 2012; Wilke, Jann and Brödner 2004).

There are other difficulties with assessing levels of VOCs in indoor air, as their concentrations depend on the indoor air conditions. For example, Pegas et al. (2011) have demonstrated that in schools VOC emissions increase for most groups of substances during the winter, which they propose could be attributed to a decrease in ventilation during colder periods (Pegas et al. 2011). However, there are important exceptions to this general rule, as formaldehyde emissions are highest in warmer periods (Pegas et al. 2011). Room temperature, relative humidity and ventilation rate all directly influence the emission of VOCs.

With the absence of firm definitions of VOCs, various measuring methods, and many factors influencing fluctuations in VOCs levels indoors, it is not surprising that research papers often provide results that are only partially comparable. This lack of consistency indicates the relative infancy of research into VOCs, and is a significant feature of any discussion in this area.

3.3.2 Indoor air quality

In contrast to lead and asbestos which once built-in get released only if mechanically disturbed, there are many chemicals in domestic environments that readily get released under normal air conditions. Therefore, any discussion of VOCs is inseparably related with indoor air quality.

Since the 1980s' recognition of sick building syndrome, indoor air quality has received increasing attention. One reason was the recognition that most people spend between 80-93% of their time indoors (Liu and Little 2012a; Guieysse et al. 2008; Sexton and Dyer 1996). Recently, Delgado-Saborit et al. (2011) studied the time 100 British subjects spent in different environments and confirmed that 87-91% was indoors (Delgado-Saborit et al. 2011). Another study claims nearly 25% of US residents are affected by poor indoor air quality either at work or home (Guieysse et al. 2008). This differentiation between workplace and home is significant, because Delgado-Saborit et al. found on average for their participants 62% of their time indoors was at home, 16% at work, 12% in other indoor environments, and 5-7% commuting, with the average time outdoors ranging between 2-5% (Delgado-Saborit et al. 2011). These figures translate to an average of 14-15 hours/day at home and only 30-75 minutes/day outdoors. These proportions signal that indoor air quality at home could be an important factor in people's health.

Some works have focussed on indoor air in relation to children's health (Phipps 2008; Howden-Chapman et al. 2008; Thompson 2004). Toxicology studies recognise that generally the body's ability to biotransform and excrete toxins is less efficient at the extremes of life, as for young children such processes are not fully developed until 6-12 months of age, and sometimes as late as 6 years of age (Philp 2001, chapter 1, unpaginated). Children also have higher metabolic rates, which increases their exposure (Philp 2001, chapter 1, unpaginated), making them more vulnerable than adults. Furthermore, many VOCs linger close to the floor, because of their weight compared to air, which can increase concentration of indoor air pollution at the inhalation levels of children. In addition, children, especially the very young, spend larger proportions of their time at home indoors (Phipps 2008; Thompson 2004), increasing the relevance of indoor air quality in homes.

Another significant development since the recognition of sick building syndrome have been investigations of ventilation rates, which have established a need for an increase first to 10l/s per person and subsequently to a recommended 20l/s per person (Wargocki et al. 2002). In 2002, a multidisciplinary overview of the literature established that outdoor air supply rates lower than 25l/s per person in commercial and institutional buildings correlated with an increased risk of sick building syndrome and more short-term sick leave and reduced productivity (Wargocki et al 2002; Sundell 2004). It has also been suggested that improving the indoor environmental quality in all US office buildings could prevent sick building syndrome and absence for millions of US office workers, while also improving work performance, with a potential annual economic benefit of \$17-26 billion dollars (Fisk, Black, and Brunner 2011). As result, there has been much development in ventilation systems and better understanding of indoor air quality needs.

When considering reducing indoor contamination from VOCs, the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) proposes three options: source elimination; dilution with ventilation air; and air filtration (ASHRAE 2009, 10.10). As an organisation they have focussed on the two latter. In addition to increasing ventilation rates, there has been experimentation in new ways of removing VOCs from indoor air using filtering and purification systems. Unfortunately, literature in this area indicates available products can successfully remove particular matter but still struggle to remove gaseous chemicals from air effectively (Schmid, Jecklin and Zenobi 2011; Hart et al. 2011; Guieysse et al. 2008). Furthermore, some could be producing even more harmful chemicals (Schmid, Jecklin and Zenobi 2011; Hubbard et al. 2005). It is claimed some textiles can remove VOCs from indoor space (www.drapalux.com) but no independent confirmation of such results is available. The most noticeable measured VOC removal has so far been observed with pot plants (Pegas et al. 2012; Daniels 1997, 194), but studies generally record high variability in level of decrease and fall short of making explicit recommendations. Some of the more recent experimental work includes use of genetically modified plants capable of absorbing high levels of formaldehyde from surrounding air (Nian et al. 2013). However, perhaps a more traditional approach that places greater emphasis on elimination of hazards would be a more reliable course of action than any of these experiments.

As suggested, the workplace has been the primary focus of developments in ventilation and occupational health (ASHRAE handbook 2009). However, more recent studies are indicating indoor air quality in homes is generally poorer than in offices and other public buildings (Nielsen, Larsen and Wolkoff 2013; Wolkoff and Nielsen 2010). The focus on improving ventilation and air filtration systems still relies on removing the indoor air pollution once it happens, rather than removing the pollution sources. Spaces with poorer ventilation protocols, like dwellings, have not been addressed to the same level, despite the fact as stated above that people spend most of their time at home. Potentially, high reliance on mechanical ventilation is not a good approach for domestic environments, as it is impossible to regulate and insist on regular use of such systems. For many dwellings installation of such systems could be either technically difficult or financially impossible. Therefore, elimination or encapsulation of the source could prove a more effective strategy in domestic spaces.

Another expectation is that gradual removal from the market of products containing harmful substances through regulation will filter down to all situations. The experiences with lead and asbestos indicate that such an approach deals poorly with existing or built-in materials.

3.3.3 Formaldehyde

One VOC that has received much research attention in recent years is formaldehyde. Formaldehyde (HCHO) is a naturally occurring organic chemical; it is a product of one-carbon metabolism and is a toxic compound because it can combine with proteins, nucleic acids, and lipids (Nian et al. 2013). In contrast to lead and asbestos, which are naturally occurring substances unrelated to the natural

processes of living organisms, formaldehyde is part of the natural chemistry and metabolism of many living organisms and therefore, as discussed below, it is much harder to talk about complete elimination of formaldehyde. Its reactivity and quick absorption in humans makes it additionally difficult to evaluate. Formaldehyde is found in most human and other living cells in varying concentrations as a normal product of the metabolism of serine, glycine, methionine, and chlorine (Checoway et al. 2012). Formaldehyde is a gas at room temperature (WHO 2010; Salthammer, Mentese and Marutzky 2010). In ambient air, the half-life of formaldehyde is about one hour, because it is either transformed into carbon dioxide through the process of photo-oxidation or reacts with hydroxyl radicals to give formic acid (WHO 2010).

Scientifically, formaldehyde was first described in 1855, and by 1867 a German chemist achieved its synthesis through dehydration of methanol (Salthammer, Mentese and Marutzky 2010). The early 20th century saw much development in applications of formaldehyde. In 1907, the combination of phenol and formaldehyde became available to industry under the name 'bakelite' (Salthammer 2013). In 1931, the first glue based on the combination of urea and formaldehyde entered the market, and the first commercial particle board was produced during World War II in Bremen, Germany and since 1950 has become a common alternative to solid wood (Salthammer, Mentese and Marutzky 2010).

The recognition of health concerns related to formaldehyde soon followed its more popular use. In 1962, indoor air pollution from release of formaldehyde from installed particle board was first observed (Salthammer 2013; Mentese and Marutzky 2010). During the 1960s and 1970s, some very high indoor concentrations of formaldehyde were caused by the hydrolysis of urea-formaldehyde resins, and since then great efforts have been made to reduce the release of formaldehyde into indoor air (Salthammer 2013). In 1977 in Germany an early guideline on formaldehyde specified a value of 0.1 ppm for human exposure in dwellings (Salthammer, Mentese and Marutzky 2010). By 1981, early regulations of formaldehyde emissions from wood-based materials were established in Germany and Denmark, followed by the United States in the mid 1980s (Salthammer, Mentese and Marutzky 2010). Since 1981 the IARC has evaluated formaldehyde every few years, and in 2004, reclassified it from group 2B 'possibly carcinogenic to humans' to group 1 'carcinogenic to humans' (IARC Monograph 88 2006), with additional adjustments to this classification in 2012 (IARC Monograph 100F 2012). Nevertheless, to date there is no universally agreed standard regarding acceptable exposure to formaldehyde.

Formaldehyde can enter the human body through inhalation, ingestion or dermal absorption (Kim, Jahan and Lee 2011). In addition to formaldehyde emissions in air, it has been used in many cleaning and cosmetic products and even as a food preservative for some Italian cheeses, dried foods and fish (Kim, Jahan and Lee 2011). Once absorbed, the high solubility of formaldehyde in water causes possible rapid absorption in almost every tissue in the body (Salthammer, Mentese and Marutzky 2010; Kim, Jahan and Lee 2011). The biological half-life of formaldehyde is extremely short at about 1 minute (Salthammer, Mentese and Marutzky 2010; Wolkoff and Nielsen 2010).

The World Health Organisation (WHO 2010) notes that large amounts of formaldehyde can be released into the natural environment through biomass combustion, such as forest or bush fires, or natural decomposition, or through anthropogenic activities, such as industrial emissions and fuel combustion from traffic, and other combustion processes (WHO 2010). When used as glue, as in composite wood, formaldehyde is generally in combination with another active chemical in the form of urea-formaldehyde, phenol-formaldehyde and melamine-formaldehyde (UF, PF and MF resins), and these accounted for 63% of global demand for formaldehyde in 2011 (IHS Chemical 2012). More recently, China has become the largest single market for formaldehyde, and in 2011 consumed 34% of world demand (IHS Chemical 2012). Between 2011-2016 world consumption of formaldehyde is forecast to grow at an average rate of almost 5%, with continuing rapid demand in China and Asia balancing out moderate growth in North America and Western Europe (IHS Chemical 2012; Kim, Jahan and Lee 2011). Therefore, even after the significant efforts to reduce exposure to formaldehyde in Western countries, its use is forecast to increase in non-Western countries, following similar trends to the examples of lead and asbestos.

Indoor air sources of formaldehyde include combustion processes such as smoking, heating, cooking, and candle or incense burning (WHO 2010), although formaldehyde levels from these will vary with life-style. Building materials and consumer products that emit formaldehyde are a major source of non-combustion indoor formaldehyde, especially in the first few months after installation (WHO 2010). The main sources are composite wood products such as medium density fibreboard (MDF), particleboard and plywood, due to use of urea-formaldehyde or phenol-formaldehyde glues, fibreglass insulation containing similar glues, and other products such as carpets and drapes where formaldehyde has been used as a biocide (Walkoff 2010). Two additional sources of indoor formaldehyde, which have received more research attention recently, are indoor chemical reactivity and outdoor formaldehyde. The WHO recognises that chemical reactions in air through the oxidation of volatile organic compounds (VOCs) and reactions between ozone and alkenes (especially terpenes) within indoor spaces contribute to secondary formation of formaldehyde (WHO 2010). They also note that these chemical processes and resulting indoor concentrations are still not fully quantified (WHO 2010). This is consistent with other sources which have observed that publication of research related to indoor air chemistry has greatly increased in the last 10-15 years, from a position of virtually nothing before the 1990s (Weschler 2011).

Although formaldehyde can now be seen as being in an early phase of complete elimination, more recent work often focusses on demonstrating that very low level exposures to it are harmless, arguing against further decreases in regulated levels. In 2010, Nielsen and Wolkoff, at the time on the World Health Organisation's team developing *WHO guidelines for indoor air quality: selected pollutants* (2010), concluded that there are levels of formaldehyde where no excess nasopharyngeal cancer is observed (Nielsen and Wolkoff 2010). Further, they argued for the 'no observed adverse effect level' (NOAEL) approach when regulating for exposure to formaldehyde (Nielsen and Wolkoff 2010). The same approach was adopted by the WHO (2010). Nielsen and Wolkoff argued that based on estimates the risk to the general population from 0.1 to 0.2ppm of formaldehyde is negligible, and further that the earlier (2000) guideline set by the WHO of 0.08ppm (0.1mg m^{-3}) introduces an

additional margin-of-exposure, and that there was no need to change these (Nielsen and Wolkoff 2010). (Nielsen, Larsen and Wolkoff (2013) recommend the conversion factor: $1\text{ppm} = 1.228\text{mh}/\text{m}^3$ at 25°C and 1atm .) This level was considered 'defendable for prevention of all types of cancer, including lymphohematopoietic malignancies' (Nielsen and Wolkoff 2010).

Significant reductions in indoor air formaldehyde levels have recently been achieved in many places, for example Rio de Janeiro (Figure 3.5; Salthammer 2013). Experts are now asking whether further reductions of indoor formaldehyde levels are possible due to outdoor formaldehyde levels (Salthammer 2013). For much of the history of formaldehyde investigations, indoor levels were higher than outdoor levels. With more recent reductions in the former, Salthammer (2013) suggests indoor concentrations of 0.008ppm (the lower end of WHO recommended levels) are often unachievable because outdoor concentrations are higher (Figure 3.6).

Figure 3.5. Formaldehyde concentrations (mean values, minima, maxima) in Rio de Janeiro. (Source: Salthammer 2013.)

Figure 3.6: Range of formaldehyde concentrations in indoor and outdoor air. The range of current indoor guideline values between 8 ppb and 100 ppb ($0.008\text{-}0.1\text{ppm}$) is also provided. (Source: Salthammer 2013.)

More recent studies note that mean formaldehyde levels in homes and dwellings were generally within $20\text{-}40\mu\text{g}/\text{m}^3$ in Europe, Canada, the US and Japan (Nielsen, Larsen and Wolkoff 2013). However, the same review observes higher mean concentrations in China of $240\mu\text{g}/\text{m}^3$ (Nielsen, Larsen and Wolkoff 2013). Furthermore, in public buildings in Europe, mean concentrations of formaldehyde have generally fallen below $25\mu\text{g}/\text{m}^3$ (Wolkoff and Nielsen 2010), meaning the general levels in public buildings and offices in Europe and the US are now lower than in dwellings (Nielsen, Larsen and Wolkoff 2013; Wolkoff and Nielsen 2010). Nevertheless, these same studies reiterate the important relationship between indoor concentrations of formaldehyde and air exchange rate, and estimate that air exchange rates need to increase by 30% in homes with new formaldehyde sources (Wolkoff and Nielsen 2010). They also emphasise that in new Californian homes with low formaldehyde emitting materials, half the conventionally needed exchange rates were sufficient to keep the formaldehyde levels low (Wolkoff and Nielsen 2010).

Although legislatively there is now agreement that very significant reductions in formaldehyde levels are essential, with regulation in many countries, there is discussion in the research community on the exact safe levels and the adverse health effect of low level formaldehyde exposure. Although not conclusive, these discussions indicate that the point of significant reduction regulation is not necessarily the point when all conclusions are available. As with lead and asbestos, further adjustment of the limits set might be needed as better understanding of any adverse health effects from low levels of exposure become available. Disagreements in the available literature also reveal the problem of having only partial understanding of the mechanisms formaldehyde exposure triggers inside the human body, leaving room for new discoveries in future.

One on-going problem well illustrated by formaldehyde is that reductions in levels (attributed to ventilation) in commercial and public buildings took place much earlier and more successfully than in domestic spaces. Therefore, in addition to strategies proven effective in non-domestic contexts, there is a need to develop effective strategies for indoor domestic spaces. Such a lack is illustrated by local examples. Although New Zealand is a leading producer of zero formaldehyde composite wood, due to exports in 2011 the product was only available locally at special request. The 2006 New Zealand standard limits formaldehyde in particle boards to less than 0.5mg/L for E0 (so called 'zero' boards), less than 1.5mg/L for E1 and less than 4.5mg/L for E2 (AS/NZS 1859.1:2004, Feb 2006 amendments). A 2012 conversation with the yardman in a building materials retailer revealed the E label was not displayed for the MDF stocked, and the sales assistant was neither aware of which E value they had in stock, nor of such classification. Moreover, use of formaldehyde in cosmetics is also still allowed in New Zealand and only amounts over 0.05% require a warning that the product 'contains formaldehyde' (Environmental Risk Management Authority, 2006).

3.3.4 Vinyl, PVC and plasticisers

Another significant group of VOC or SVOCs is related to indoor use of the family of vinyl products, with concerns being raised about the use of PVC as a base material and phthalate plasticisers as additives to it. World production of polyvinyl chloride (PVC), which is a significant consumer of phthalates, is around 40 million tons, and forms the second largest plastic by volume after polyethylene (PE) (Akovali 2012). About 70% of PVC consumption worldwide is in the construction industry in applications such as pipes, wiring, cladding, flooring and wallpaper (IHS Chemical 2011; Akovali 2012). Some of these rely on use of plasticised PVC (pPVC in flooring, wiring and wallpaper), while others use unplasticised PVC (uPVC, in pipes and cladding). PVC was first invented in 1872, but its importance was not fully recognised until 1926 (Akovali 2012). In 1933 vinyl flooring was displayed at the Century of Progress Exposition in Chicago, but it did not become commercially available until the end of World War Two (Vinyl in design 2013). Subsequently, vinyl flooring largely overtook the use of linoleum. The latter was invented and patented in 1845, and first manufactured in Scotland in the 1860s (Vinyl in design 2013), and is made from renewable materials such as linseed oil, pine rosin, cork dust, wood flour and mineral fillers (Akovali 2012).

PVC is produced through polymerisation of vinyl chloride monomer (VCM) (Akovali 2012), and there are serious concerns about the health effect of VCM, which is genotoxic (Kumar et al. 2012), a known human carcinogen, and is toxic for immune and cardiovascular systems, liver, and organ development (ATSDR 2013). The Greenpeace group has advocated the complete phasing-out of PVC globally because of its manufacturing by-products and the complex environmental issues which surround its disposal (Akovali 2012). The IHS 2011 review of the world consumption of PVC reports noticeable reductions (IHS Chemical 2011). While they interpreted these as reflecting the 2007/8 recession, some of the changes were hard to explain in this way. For example, in 2007-9 PVC consumption in the US and Canada declined by 33%, but in 2010 improved only 1%, with another 2.5% expected in 2011 (IHS Chemical 2011). Unfortunately, at the world scale this makes little change, due to the increased use of PVC in Asian countries, which use 80% of world consumption (IHS Chemical 2011).

However, for indoor air quality the most significant concern in relation to PVC is plasticisers, which generally come in form of phthalates. Phthalates are a group of aromatic chemicals containing a phenyl ring with two attached and extended acetate groups (ASTDR 2013). They are added to polyvinyl chloride (PVC) or other plastics to increase their flexibility and transparency, and are used in proportions as varied as 10-60% of final PVC products (Liu and Little 2012b). Flexible polyvinyl chloride (PVC) accounts for 80-90% of world plasticiser consumption (IHS Chemical 2011). Because they are not part of the chain of polymers that make plastics, they can be slowly released from these products (ASTDR 2013; Liu and Little 2012b). In architecture the main use of plasticisers is for vinyl flooring, while they can be found in a wide variety of everyday products including vinyl upholstery, shower curtains, food containers, cling wraps, toothbrushes, toys, tools, automobile parts, adhesives and sealers (Liu and Little 2012b; ASTDR 2013). They are also used in cosmetics, insecticides, and aspirin (ASTDR 2013). Although in terms of chemistry they form their own subgroup, at a more general level they can be seen as part of the semi-volatile organic compounds (SVOCs) group (Liu and Little 2012b; Xu et al. 2012). In addition to phthalates, other plasticisers currently in use include aliphatics, epoxy, terephthalates, trimellitates, polymeric, and phosphates (IHS Chemical 2013). In recent years the consumption of phthalates has decreased from 88% of all plasticisers in 2005, to 78% in 2012, and is forecast to further decrease to 75.5% by 2018, with China accounting for nearly 38% of world consumption in 2012 (IHS Chemical 2013). Between 2011-2018 world consumption of phthalate plasticisers is forecast to have reduced growth of 2.4%, due to lower-molecular-weight phthalates, such as DEHP, being replaced by nonphthalates (IHS Chemical 2013).

As with other VOCs, there is much variation in the way the harmfulness of phthalates is acknowledged by different organisations. For example, ECHA includes eight phthalates in their list of substances of very high concern (Table 3.2), while ATSDR only lists four (Di(2-ethylhexyl)phthalate (DEHP), Di-n-butyl phthalate, Di-n-octylphthalate (DNOP), and Diethyl phthalate; ATSDR 2013). Generally phthalates are recognised as toxic for reproduction, and systematic inclusion of phthalates in the list of substances of very high concern has only started since 2008 (Table 3.2; ECHA 2013).

Table 3.2: Summary of key information on phthalates from ECHA's list of substances of very high concern. (Source: ECHA 2013.)

Phthalate	Year of classification	Reason for inclusion	More specific reasons
Bis(2-ethylhexyl)phthalate (DEHP)	2008	Toxic for reproduction	May impair fertility; May cause harm to the unborn child
Dibutyl phthalate (DBP)	2008	Toxic for reproduction	May cause harm to the unborn child
Benzyl butyl phthalate (BBP)	2008	Toxic for reproduction	May cause harm to the unborn child
Diisobutyl phthalate (DIBP)	2009	Toxic for reproduction	May cause harm to the unborn child
Bis(2-methoxyethyl) phthalate	2011	Toxic for reproduction	
n-pentyl-isopentylphthalate	2012	Toxic for reproduction	May impair fertility; May cause harm to the unborn child
Diisoentylphthalate (DIPP)	2012	Toxic for reproduction	May impair fertility; May cause harm to the unborn child
Diethyl phthalate (DPP)	2013	Toxic for reproduction	

Historically, different phthalates have received more prolific use in different periods. Di(2-ethylhexyl)phthalate (DEHP) is a short chain phthalate frequently found in older PVC products, until in 1999 the European Union regulated against its use in toys, and this was followed by regulations for other products (Holmgren et al. 2012). Since then, longer chain phthalates such as di-iso-nonyl phthalate (DINP) have been used more and there is hope that the 2005 European Union ban of use of all phthalates in toys that can be put in a baby's mouth will have the same positive effect, and that development of non-phthalate plasticizers could follow (Holmgren et al. 2012). Because of this historical background, DEHP is more researched than other phthalates.

There is still limited epidemiological evidence related to phthalates, and decisions to classify these chemicals as being of very high concern are mainly based on animal studies. Studies of the health impact of DEHP on rats have established that it is an endocrine disruptor with antiandrogenic activity, and it suppresses testosterone-related processes (Martinez-Arguelles et al. 2013). Once DEHP is absorbed the lining of the gut metabolizes it into mono-2-ethylhexyl phthalate (MEHP), which has antiandrogenic activity ten times greater than DEHP (Martinez-Arguelles et al. 2013). When biomonitoring of concentrations of phthalate metabolites were undertaken in the general population using blood and urine, the blood results suggested that over 75% of the US population is exposed to phthalates, while for urine this was as high as 95% (Xu et al. 2012). DEHP and its metabolites have been found in semen, saliva, amniotic fluid, umbilical cord blood, human milk and baby formula, and it is estimated that today most humans are exposed to it at levels of 3-30µg/kg/day from various products (Martinez-Arguelles et al. 2013). Animal studies have shown that acute exposure to DEHP in utero disrupts the organogenesis of androgen-dependent tissues by

inhibiting testosterone production in a dose-dependent manner (Martinez-Arguelles et al. 2013). Due to this mechanism, DEHP has the potential to influence many other aspects of development, and studies have found that in utero exposure to DEHP induces long-term cardiovascular changes in the male offspring, and affects the behaviour of young adult and elderly male rats (Martinez-Arguelles et al. 2013). When similar animal studies tested the impact of a combination of phthalates (BPA, DEHP, and DBP), they found that the impact increased in subsequent generations, leading to third generation offspring having pubertal abnormalities, and developing obesity, testis and ovarian disease (Manikkam et al. 2013). This was to such a degree that the researchers concluded that ancestral environmental exposures could be generating transgenerational inheritance of disease, often with adult onset (Manikkam et al. 2013).

As with lead and asbestos, early animal studies generally fail to quantify the impact lower doses and more complex combinations of factors have on human health, and consequently research findings such as those now available for older phthalates should be considered as only entering the third phase, where the dose effect is evaluated. From that perspective, it is good that changes have started to be implemented even without conclusive epidemiological evidence for human exposures. However, the fact that some international organisations have classified phthalates as substances of very high risk is only part of the process, as it takes much longer for risk to be integrated into regulations world-wide. For example, an article from 2009 commented on challenges with integrating such regulative changes into the NZ context (Consumer NZ 2009). Echoing the 2005 European ban of phthalates in children's toys that can be put into a baby's mouth, a similar regulation took effect in the US in 2009, while in NZ at that date phthalates were only regulated in cosmetics (Consumer NZ 2009). The article explained that because different possible sources of phthalates are regulated by different bodies (the Ministry of Consumer Affairs is responsible for toy safety, while food packaging comes under the Food Standards Australia New Zealand, and the New Zealand Food Safety Authority), a series of individual evaluations and decisions must be made before phthalates can be consistently removed from the NZ market (Consumer NZ 2009). Even then, the chances of imported products containing phthalates remain. These are all features of substances that are making the transition from second into third phase of recognition.

Nevertheless, with the classification of phthalates as substances of high concern, some labelling schemes have responded quickly. For example the Blue Angel label specifies that 'no plasticising substances from the class of phthalates may be used in the manufacture of floor coverings,' but also that floor coverings 'shall not contain more than 0.1% by mass of phthalates as impurities' (Der Blaue Engel 2011). In August 2013, several flooring retailers in Wellington were phoned and asked about the environmental labels of the products they sell. None could explain what they had in stock and none knew of the Blue Angel label.

When releases of phthalates from pPVC in interiors were evaluated, it was established that because of saturation and sorption processes, and because these establish an equilibrium over a long period of time, a very small amount of pPVC emits almost as many phthalates as a large area, and that this

did not change with increased ventilation rates (Afshari et al. 2004). Therefore, Afshari et al. (2004) concluded that 'if there is any surface material in an interior that contains plasticisers, it is impossible to avoid the phthalates in indoor air.' Similar difficulties with saturation, sorption and long equilibrium states were observed by others (Xu et al. 2012). Once emitted into the indoor air, phthalates find their way into household dust (Gevao et al. 2012; Bornehag et al. 2005). Studies of dust samples for phthalates have established that vinyl flooring should be considered a source of non-dietary exposure to phthalates and that, just as with lead paint dust, children and especially toddlers are more at risk than adults (Gevao et al. 2012). DEHP was generally reported as the most predominant phthalate found in these dust studies (Gevao et al. 2012; Bornehag et al. 2005).

Because the epistemological evidence around the impact of phthalates on human health is still limited, it seems reasonable to expect future discoveries in this area. Current studies confirm that during the second half of the 20th century vinyl flooring contained DEHP in combination with other phthalates (Gevao et al. 2012; Bornehag et al. 2005). Therefore, it seems likely that as the second and third generation of offspring from those exposed to such flooring are born, more adverse health effect on humans could be expected. This is particularly noteworthy, as increases in human obesity and reproductive difficulties are both potentially triggered by phthalates.

3.3.5 Conclusions on second and third phases

This overview of key issues related to indoor air quality and VOCs, with more detailed consideration of formaldehyde and phthalates indicates that in the last 10-15 years this area has experienced great changes. Regulations against formaldehyde and phthalates have started to appear in developed countries, as part of a shift that has led to recognition of a broader range of health risks. Current regulations are similar in character to those seen in the late 1970s and early 1980s for lead and asbestos, with continuing discussion of safe levels and applications. For lead and asbestos, this was the point when more sophisticated research and better understanding of lower dose impacts started to appear, leading subsequently to more stringent regulations against these substances. Therefore, significant new discoveries are still possible (especially when dealing with lower dose exposure and epistemological evidence of mechanisms of impact on human health) and re-negotiation of regulation levels are likely to follow. Consequently, current regulations should be expected to undergo further adjustments.

One of the main conclusions is that the stories of formaldehyde and phthalates are still unfinished, making it harder to assess whether responses to these substances were more accelerated than for lead and asbestos. Since the end of World War Two formaldehyde and phthalates have appeared in everyday objects, and the introduction of regulations against their use in the early 2000s indicates the process took at least half a century, with probably another decade or longer before it is in the final stages. Considering the history of the human use of lead and asbestos, this seems to be an improvement. However, if only uses of lead and asbestos since their more accelerated industrial use

are considered (from the late 19th or early 20th century), this acceleration is mild at best, and half a century seems a very long period for exposing people to harmful substances.

Furthermore, formaldehyde and phthalates are not the only new substances introduced into the everyday human environment mid-20th century, and successive regulation against a number of other chemicals could happen in years to come. So far human society has worked through eliminating the most obvious hazards, and if such patterns continue, recognition of substances with less obvious or even less adverse health impacts could continue over a long period. The section that follows looks at such substances.

3.4 First phase: VOCs from carpets, replacement chemicals and nanoparticles

The first phase deals with early recognition of health risks associated with a particular substance, when early indications of plausible or likely adverse health effects are articulated, this being the point of reasonable 'suspicion' that a particular substance could be harmful. Based on such 'suspicion' more research is then undertaken to prove or disprove it, which leads to more articulation of health effects, and potentially triggers recognition and progression towards second and third phases. The key question of this section is whether it is possible to observe any indications in current practices that substances 'suspected' of being hazardous are held back from introduction into everyday use. In this section, two types of 'suspected' hazards are reviewed: substances that have been 'suspected' for a while and newly developed substances.

3.4.1 On-going suspicion – VOCs from carpets

While the risks associated with formaldehyde, phthalates and PVC are reasonably well established much more confusion surrounds VOCs from carpets. During the 1980s, when sick building syndrome was observed, carpets were often seen as a contributing factor. In fact, one study evaluated the direct impact on workers' productivity of exposure to fumes from a 1980s' carpet sample 20 years later, showing the adverse effect still held strong (Wargocki et al. 1999). One relevant observation from that experiment was that the sample did not present elevated total VOCs (TVOCs), but rather elevated levels of certain individual VOCs, in this case acetone, acetic acid and aldehydes, ketones and organic acids (Wargocki et al. 1999). Some literature has since concluded that because the irritant potential and toxicity of individual VOCs vary widely, evaluation of VOCs through a combined measure of TVOCs can no longer be supported (ASHRAE 2009, 10.10). However, in contemporary carpet related regulations TVOCs are still reported in some sources, some are expressed in relation to individual VOCs, and some combine both approaches, suggesting poor regulative protocols.

Table 3.3 compares leading European voluntary labelling schemes for how they define TVOC levels (Katsoyiannis, Leva and Kotzias 2008). In addition to varying levels, these schemes also use different testing chambers, test durations and report results in different units. To evaluate the importance of such differences, one study tested four carpet samples using various testing chambers and periods, concluding that differences of as much as 75% were possible (Katsoyiannis, Leva and Kotzias 2008). They concluded that establishing a clearer pan-European regulating protocol for carpets would be simpler for all and could even prove more cost effective for manufacturers (Katsoyiannis, Leva and Kotzias 2008).

Table 3.3: Emissions requirements (or test chamber concentrations) of leading European voluntary labelling schemes for carpet materials. (Source: Katsoyiannis, Leva and Kotzias 2009.)

	AgBB Germany μgm^{-3}	CESAT France μgm^{-3}	M1 Finland $\mu\text{gm}^{-2}\text{h}^{-1}$	LQAI Portugal $\mu\text{gm}^{-2}\text{h}^{-1}$	Nature Plus Europe μgm^{-3}	Blue Angel Germany /Europe μgm^{-3}	Austrian Ecolabel $\mu\text{gm}^{-2}\text{h}^{-1}$	GUT Germany /Europe μgm^{-3}	Emicode EC1 Europe μgm^{-3}
TVOC after 3 days	10000 μgm^{-3}	5000 μgm^{-3}		5000 $\mu\text{gm}^{-2}\text{h}^{-1}$		1200 μgm^{-3}		300 μgm^{-3}	(10 days) 500 μgm^{-3}
TVOC after 28 days	1000 μgm^{-3}	200 μgm^{-3}	200 $\mu\text{gm}^{-2}\text{h}^{-1}$	200 $\mu\text{gm}^{-2}\text{h}^{-1}$	200–300 μgm^{-3}	360 μgm^{-3}	380 $\mu\text{gm}^{-2}\text{h}^{-1}$		
Formaldehyde (HCHO)	28d: 120 μgm^{-3}	28d: 10 μgm^{-3}	28d: 50 μgm^{-3}	28d: 10 μgm^{-3}	28d: 36 μgm^{-3}	28d: 60 μgm^{-3}	–	10 μgm^{-3}	1d: 50 μgm^{-3}

There are similar issues in New Zealand, where two voluntary schemes currently operate: one through the Carpet Institute of Australia (2013) and one through Environmental Choice New Zealand (2013), with numerous differences between them. Table 3.4 compares levels of individual VOCs listed by these schemes with the official classification of the same chemicals for their impact on human health. One observable feature is that some of the VOCs listed are recognised as substances of very high concern (e.g. benzene and formaldehyde), many have different lower levels of recognition, while some do not appear on any lists (e.g. 4-phenylcyclohexene and 2-ethylhexanoic acid). Therefore, there is great variety for the wide range of chemicals used in carpets in their recognised impact on human health, representing different phases of recognition.

For the purpose of discussion of first phase substances, 4-Phenylcyclohexene (4PCH) is a good example of the complexities encountered when evaluating the health impact of less recognised chemicals. Already in the early 1990s, research on emissions from carpets established that 4PCH was one of the VOCs emitted from new carpets, ‘responsible for new carpet odour’ (ASHRAE 2009, 11.9), and differences were observed between different technologies used for backing and presence or level of 4PCH emissions (Beekman, Maurissen and Johnson 1996; Singhvi et al. 1990). Generally, 4PCH is a by-product of the polymerization process between styrene and butadiene (main components of SBR latex) and ASHRAE recommends that it should only be tested for carpets and fabrics with SBR latex backing (ASHRAE Standard 189.1-2011). However, 4PCH is found in carpets

with SBR latex backing and laminated fabric backing (Katsoyiannis et al. 2008). Recent studies have found only a small proportion, up to 30%, of carpet samples with no 4PCH and no clear relationship could be observed between different carpet and backing materials and presence of 4PCH (Katsoyiannis et al. 2008; Wilke, Jann and Brödner 2004). This, together with evaluations of 4PCH in some paper printing technologies (Landy et al. 2004) seems to indicate that the use of 4PCH has expanded from just being related to SBR latex backing.

Table 3.4 shows the results of a search through the official organisations on VOCs from carpets, yet, these sources provide very little information on 4PCH (Table 3.4). A PubMed database search returned only a small number of articles which related to animal tests of 4PCH for acute toxicity, and which made no conclusive observations (Beekman, Maurissen and Johnson 1996). However, search of the PubChem Compound database under the BioActivity summary returned six 'inactive' items, which indicate that 4PCH is genotoxic in human embryonic kidney cells (PubChem Compound 2013). In addition, Toxnet: toxicology data network indicated that reports were produced in the early 2000s evaluating acute toxicity of 4PCH in animals, but these could not be accessed. Therefore, currently it seems unlikely that the 4PCH impact mechanisms on human health are understood. However, absence of clear adverse effects does not mean that 4PCH should be considered safe, simply because there are only a small number of studies and no clear adverse effects. Furthermore, the available information indicates an adverse health effect is possible, and more research is needed to explain this. Nevertheless, recently 4PCH has been introduced into the food packaging industry (Landy et al. 2004) and therefore exposure of the general population to it is likely to increase.

This treatment of 4PCH is very characteristic of many substances currently in use. While chemicals that produce acute toxicity at relatively low levels are increasingly becoming recognised as unhealthy, with subsequent regulation of these, currently there are no good mechanisms for evaluating the health effects of chemicals that are less aggressively adverse to human health. This means that lessons from phthalates are still not absorbed, because absence of very clear acute toxicity does not mean absence of adverse effect. Indications of in utero toxicity for kidney tissue clearly belong to this type of less obvious impact. Therefore, VOCs that are commonly used in carpet production but not found in lists of high risk chemicals should generally still be approached with caution.

Similar patterns can be observed with a number of other everyday chemicals. For example, water-based paints and varnishes are generally considered safer than their solvent-based equivalents. However, there is an increasing body of research recognising the toxicity of common solvents used in water-based products, even at very low levels (Lin et al. 2013; Spee et al. 2012). 2-Butoxyethanol, also known as ethylene glycol monobutyl ether ($\text{BuOC}_2\text{H}_4\text{OH}$) is an organic solvent used in water-based paints and surface coating products (ASHRAE 2009, 11.9). It is listed in California Occupational Safety and Health Regulations as a hazardous substance (CAL/OSHA 2013), although in 2004 the EPA removed it from its list of hazardous air pollutants (EPA 2004). Others have observed that

Table 3.4: Comparison between regulated levels of VOCs in carpets in New Zealand, and the classification of the same chemicals for impact on human health. The Australian Carpet Classification Scheme (ACCS) follows ISO 10580:2010, and all ECS Level carpets have to comply with this; Environmental Choice New Zealand for synthetic carpets (document for wool does not set VOC levels); US Green Label Plus, the Carpet and Rug Institute. The AU and US scales provide a 24 hour emission VOC emissions rate immediately after carpet manufacture in $\mu\text{g}/\text{h}/\text{m}^2$, while the NZ scale has a loose definition. (Sources: Carpet Institute of Australia 2013; Environmental Choice New Zealand 2013; Carpet and Rug Institute (US) 2013; ECHA 2013; IARC 2013; CAL/OCHA 2013; IRIS 2013; PubChem Compound; ATSDR 2013.)

Substance Description	AU ACCS Max emiss. (24 hr) $\mu\text{g}/\text{h}/\text{m}^2$	NZ Env. Choice for syn. carpets $\mu\text{g}/\text{m}^3$	US Green label plus Max emiss. (24 hr) $\mu\text{g}/\text{h}/\text{m}^2$	Classification by: -ECHA -IARC -CAL/OSHA	Health effects	General use
Benzene C_6H_6	55	30	55	-1 ECHA 2008 -1 IARC 2012 - Cal classified	Benzene is carcinogenic (IARC 1982). Prolonged exposure at levels below 1ppm ($3.2 \text{ mg}/\text{m}^3$) can lead to mutagenicity and carcinogenicity. Concerns for fertility also mentioned.	Available in petrol, normal traffic pollution and close to petrol stations. Also in some paints, car interior accessories, and perfumes.
Formaldehyde CH_2O	10	16	16	-1 ECHA 2012 -1 IARC 2012 -Cal classified	Carcinogenic	Numerous uses in building materials, mainly as part of gluing agents, and chemical treatments. In carpets used as biocide/antimicrobial
Toluene $\text{C}_6\text{H}_5 - \text{CH}_3$	280	150	280	-2 ECHA 2004 -3 IARC 1999 -Cal classified	Possible acute, system and specific organ toxicity due to inhalation or dermal exposure, neurological and cardiovascular toxicity, concerns for fertility and developmental effects and spontaneous abortions due to inhalation	In high-octane blending petrol, as solvent for paints and coating, gums, resins, oils, rubber and adhesives, as an intermediate in the preparation of many chemicals, dyes, pharmaceuticals, detergents and explosives, for printing and manual cleaning
Styrene C_8H_8	410	220	410	-Not classified -2B IARC 2002 -Cal classified	Harmful by inhalation, sensitizer; toxic for nervous system, liver and eyes; conclusively observed to be toxic to fertility and toxic to reproductive development, some strong relations to carcinogenesis	Used in plastics, latex paints and coatings, synthetic rubbers, polyesters and styrene-alkyd coatings. In construction in pipes, fittings, lighting fixtures, synthetic marble, flooring, carpet backing, moulded furnishing.
Acetaldehyde $\text{C}_2\text{H}_4\text{O}$	20	4.5	130	-Not classified -2B IARC 1999 -Cal classified	Could be respiratory sensitizer, and carcinogenic for oral and bronchial tumours, possible skin sensitisation, aspiration hazard and possible reproductive toxin Other: Probable	Natural product of combustion and photo-oxidation of hydrocarbons, industrial use as intermediate, used in silvering of mirrors, leather tanning, denaturant for alcohol, fuel mixtures, hardener for gelatine

					carcinogen (Carpet Institute of Australia) Endocrine-disrupting chemical, carcinogen, teratogen, and causes allergic airway inflammation (Kawano et al. 2012)	fibres, as flavouring agent, in cosmetics, in glue and casein products, preservative for fish and fruit, in paper industry, in carpets used as biocide/antimicrobial
Vinyl Acetate $C_4H_6O_2$	400	100	190	-Not classified -2B IARC 1995 -Cal classified	Acute toxicity oral and dermal; skin irritation, respiratory sensitisation, reproductive toxicity, suspected carcinogenesis for oral exposure	Used to make polyvinyl acetate adhesives for paper, wood, glass, metals and porcelain, also in latex water paints, coatings for paper, textile and leather, base for inks and lacquers, in cosmetics, pharmaceuticals, food additives and pesticides
Naphthalene $C_{10}H_8$	20	4.5	8.2	-Not classified -2B IARC 2002 -Cal classified	Limited evidence of adverse health effects, mainly lungs for inhalation	Used in manufacture of phthalic anhydride which is used as intermediate in the production of phthalate plasticizers, resins, dyes, pharmaceuticals, insect repellents, also used in baby oils
Caprolactam $C_6H_{11}NO$	120	100	130	-Not classified -4 IARC 1999 -Cal classified	No carcinogenic effect observed, possible skin sensitisation, aspiration hazard and possible reproductive toxin, more concerns regarding toxicity than carcinogenesis (IRIS)	Primarily used in manufacture of synthetic fibres and resins (nylon 6), bristles, film, coating, synthetic leather, plasticizers, paint vehicles, cross-linking agent for polyurethanes
1-Methyl-2-Pyrrolidone C_5H_9NO	300	160	300	-Not classified -NA -Cal classified	Respiratory and skin sensitisation, aspiration hazard, concern that it may damage fertility or the unborn child due to oral exposure	Used as a solvent for resins and acetylene, as paint stripper
Nonanal $C_9H_{18}O$	24	13	24	-Not classified -NA -NA	Skin and eye irritation, possible skin sensitisation, reproductive toxicity and germ cell mutagenicity	Used in flavours and perfume production
Octanal $C_8H_{16}O$	24	7.2	13	-Not classified -NA -NA	Skin and eye irritation	Used as flavouring, in perfumery, in preparation of synthetic citrus oils
2-Ethylhexanoic Acid $C_8H_{16}O$	46	25	46	-NA -NA -NA	Some indications of oral toxicity (PubChem Compound)	Chemical intermediate in manufacture of resins for baking enamels, lubricants, detergents, flotation aids, and corrosion inhibitors; catalyst for polyurethane foaming
4-Phenylcyclohexene $C_{12}H_{14}$	50	2.5	50	-NA -NA -NA		

IARC evaluates only carcinogenesis to humans (group 1 – carcinogenic; group 2A – probably carcinogenic; group 2B – possibly carcinogenic; group 3 – not classifiable; group 4 – probably not carcinogenic); ECHA and CAL/OSHA classify priority substances due to toxicology and/or carcinogenesis, thus ‘no classification’ means that at this point substance is not recognised as needing classification. Substances that could not be found for either organisation were noted as NA (not available).

2-butoxyethanol has been related to poor indoor air quality complaints (Rella, Sturaro and Vianello 2012). Jointly these observations indicate that for the last ten years, 2-butoxyethanol has been on the point of first phase recognition as risk, while still present in many products.

The problem is most research efforts are focused on more recognised hazards and providing sufficient knowledge to lead to effective removal of these, while borderline hazardous substances receive marginal research attention. Unfortunately that does not mean that they are safe, but rather that they are not well understood.

3.4.2 Replacement and new substances

One important area of new development is substances that replace those phased out as hazardous. More recently, replacements for formaldehyde, phthalate plasticisers and fire-retardants have been developed. For phthalates and fire-retardants early observations show that regulations against one set of such chemicals produced an increase in use of other chemicals from the same family. For phthalates the change was from shorter chain phthalates (such as DEHP) to longer chain phthalates (such as DINP) (Holmgren et al. 2012), and to a number of non-phthalate plasticisers (Section 3.3.4). For fire-retardants the change was from a polybrominated diphenyl ether (PBDE) fire-retardant mixture PendaBDE to more prolific use of tris(1,3-dichloroisopropyl) phosphate (TDCPP), a suspected human carcinogen (Stapleton et al. 2012). Unfortunately, in both cases the replacement chemicals are simply less researched and less well understood for their health effect, despite comments that they are 'suspected' for adverse health effects, potentially putting them in the first phase, while TDCPP is at least in the second phase of recognition (Holmgren et al. 2012; Stapleton et al. 2012). This implies that many substances which are introduced as replacements for eliminated risks could also be seen as being in the entry stages of the same process of recognition of health risks. Figure 3.7 illustrates this cycle.

Similarly, although many formaldehyde-free products are increasingly available, PubMed currently reports only a very small number of studies on their health impact, indicating replacements are introduced without much evaluation of their health effect. However, there are some exceptions. For example, one study explored the health impact of the change from a phenol-formaldehyde bonding agent in fibreglass insulation to a carbohydrate-carboxylic acid binder, observing that in-vitro this binder did not impact the biosolubility of glass wool insulation, but also noted that droplet sizes had an impact (Potter and Olang 2013). Droplet size of the bonding agent, which greatly varied in the samples studied, seems controllable by careful manufacturing. This indicates that much more sophisticated research is needed in these early stages of development of new materials, if they are to be reliably safe.

Figure 3.7: Cycle of introduction or replacement substances into testing for adverse impact on human health. (Source: Author.)

One area of recent development is materials that use nanoparticles. With the technology that enables design at scales unprecedented in the past, a range of completely new material characteristics is becoming available for the first time. Unfortunately, there are already warnings about nanoparticles. Researchers have remarked that nanoparticles are likely to impact the human body similarly to micro particles, the best known of these being the asbestos family (Donaldson and Poland 2012; Sanchez et al. 2009; Pacheco-Blandino, Vanner and Buzea 2012). If learning from the experiences with asbestos, the problem is the shape and size of particles and their biopersistence within the human body. For asbestos it was the long, thin shape and very long biopersistence that produced inflammation and subsequent onset of disease after a long latency. Because this knowledge is available, it seems reasonable to use it when developing new materials with similar features. However, texts that deal with design and the exciting opportunities nanotechnology offers fail to mention risks associated with such particles (Yeadon 2011), indicating the same mistakes could be repeated.

3.5 Chapter conclusion

Although this chapter records some acceleration in the way substances now in the second and third phase of recognition are progressing towards elimination, the overall impression is that this progress is generally still slow. The experience with lead and asbestos showed that it can take a long time before the total impact is fully understood. The experiences with formaldehyde and phthalates could unfortunately be just ‘the very tip of the iceberg’ because they are only the most recognised risks from the great array of chemicals introduced into everyday use since the mid 20th century. The actions observed with first phase substances indicate that potentially very limited learning from past mistakes has occurred. Substances that are ‘suspected’ harmful are readily used, and their use often increases while the recognition of risks also increases.

Unfortunately, the scientific understanding of these risks is still partial, and if proof of harmful affect is needed prior to any action, such proofs do not exist for many of the substances. One aspect of concern is the very limited understanding of effects these substances create when people are exposed to their various combinations. One estimate suggests that if only three chemical combinations were to be comprehensively evaluated, it would need 166 million tests, and take 11,000 years, assuming 15,000 tests per year (Armstrong 2007, 61). Evaluating 11 chemical combinations would take a million times longer than the universe has existed (Armstrong 2007, 61). Therefore, currently assuming there is sufficient scientific knowledge on the health risks associated with building and furnishing materials is unrealistic, and all professional activities have to develop work strategies that acknowledge this limitation.

The solution to this problem is the precautionary principle, and the literature sources that adopt this idea are the popular works related to building biology or direct personal experiences discussed earlier (Baker-Laporte, Elliott and Banta 2008; Thompson 2004; Hobbs 2003; Bower 2000; Bower 1989). In fact, these can act as ‘whistle blowers’ for the first phase of recognition, because they do not have to adhere to academic nor regulative protocols, provide the most comprehensive lists of potential risks, and offer useful practical advice on their avoidance. Their only problem is that precisely because of their character they might not be taken seriously by many. If the predominant logic is that ‘suspicion’ is not enough, but rather a proof is needed prior to any change, these works fail to provide such proofs.

However, this idea that the point of ‘suspicion’ is insufficient for taking action opens a new question: could this lack of acknowledgement be due to psychological factors? Similar propositions have been made when evaluating people’s difficulty with grasping climate change issues (Stern 2011; Gifford 2008). If so, evaluation of people’s views about materials could prove to be an important part of the puzzle, and could help foster future change. Additionally, for the general population finding even the available limited scientific information could prove impossible, because much of the relevant discussion is taking place in research papers, rather than literature for the general public. Many architects could also be affected in this way. Therefore the studies that follow evaluate the

perception of building and furnishing materials in relation to health in an attempt to identify some predictors that could be underpinning the trends observed.

Part II: Core study

Chapter 4

Introduction to the core study

4.1 Introduction

Part II discusses the core study in terms of the study approach, survey design, recruitment, sample characteristics, descriptive and inferential results, and discussion of these. The core survey received 247 responses from three countries (61 from New Zealand (NZ) general population, 65 from NZ architectural academics and practitioners, 60 from the United States of America (US) general population, and 61 from the United Kingdom (UK) general population), and forms the main research component of this thesis.

Human Ethics approval was obtained for all work from the Human Ethics Committee of Victoria University of Wellington. It is important to emphasise that effectively the core survey consists of six different surveys, some separated because they are very different samples, or used different questionnaires, but each with much the same core, making a large part of the results comparable (Table 4.1). The shared core was a health rating of a comprehensive list of 28 building and furnishing materials, which together with the health rating of participants' homes, attitudes, two standard psychological tests and a set of demographic questions created a set of results which, it was hoped, could reveal some useful patterns. The core study is exploratory, and although possible predictors were anticipated, the aim was to let the data reveal its own trends.

This chapter introduces the core study, aiming to report on all activities related to it which preceded data collection. In reality experiences from the pilots and early surveys are also discussed in terms of the extent to which they influenced subsequent refinement of the survey tools. This chapter explains how the core study relates to the research questions and the approach of the rest of the thesis.

Table 4.1: Distribution of participants by sample group.

NZ general long	24 participants	61 NZ general participants	247 participants in total sample
NZ general short	37 participants		
NZ architectural academics	18 participants	65 NZ architects	
NZ architectural practitioners	47 participants		
US general short		60 US participants	
UK general short		62 UK participants	

One of the most significant bodies of literature discussed in this chapter is the psychological literature on personality traits, values, and environmental concerns. These psychological concepts are introduced, their relevance for the study explained, and possible outcomes are illustrated based on the results from other surveys. These illustrations identify types of possible findings, rather than the exact findings of this survey. The chapter also establishes that any hypothesis at this stage is tentative because of the exploratory nature of this study.

As stated in the thesis introduction, the key questions of the core study are:

1. How informed, or knowledgeable, is the general population about the risks to human health associated with building and furnishing materials? and
2. Are there any observable predictors of the views expressed?

Both questions directly relate to the two main questions of this thesis.

4.2 Survey design

This section deals with the design and development of the core survey questionnaire. It is important to emphasise that this questionnaire was originally developed only with the NZ sample in mind. While from the outset the core survey was intended to include the NZ general and the NZ architects sample, the international samples appeared as a solution to the poor NZ general response rates. Therefore, this section primarily deals with what was supposed to happen, but also acknowledges the reality of what did happen. This section explains how the early survey design evolved in response to limitations when it was tested, leading to a process of successive reductions and shortening of the questionnaire. This means the NZ long survey could be seen as a step in the development (a pilot) of

the NZ short survey, which was subsequently used as a basis for the international samples and the two NZ architects samples. These modifications are also discussed in this section. Generally, when using the survey with the international samples modifications were kept to a minimum, in order to retain good comparability with the NZ general data; similarly most of the NZ short general survey was contained in both the NZ architects questionnaires.

For some parts of the questionnaire it was possible to identify existing literature that could inform the survey directly. This was true of the standard psychological tests. However, for most, a new questionnaire had to be developed. Therefore, this section is organised in a way that acknowledges these two different conditions, by discussing first the general and the standard psychological questions, and then the newly developed questions. This is followed by a brief discussion of specific questions that only appeared in the US and UK surveys. Other small differences in the question format or wording for the US and UK surveys are discussed throughout the text, where relevant.

All survey questions fall into the following five broad groups:

- Group 1: General demographic and house characteristics;
- Group 2: Individual psychological questions;
- Group 3: Health rating of materials;
- Group 4: House health rating with explanations (including current practices); and
- Group 5: Attitudes (including current views).

The first two groups can be seen as sample characteristics, because they are uniquely expressive of individual participants. In psychology and statistics these are called independent values or invariants, and are assumed not to be prone to changes in the course of the survey, and in fact many of them either do not change over time (e.g. gender) or only change over reasonably long periods of time (e.g. age or number of children in a household). The next two groups, the health rating of materials and the house health rating with explanations, represent the dependent values or variants. The independent values (such as gender, age or high score on a particular personality trait) could influence the dependent values (health rating of a particular material or house health rating), and precise relationships such as these could help identify predictors of certain views about materials. The last group deals with attitudes which could act as mediators between independent and dependent variables, thus in terms of analysis these can take the role of either.

This organisation of survey questions is maintained both here when explaining the survey questionnaire design and in the subsequent chapters which report on and analyse results. However, it is important to note that this was not the order in which the questions were asked in the questionnaires (Appendices 1-2). For the three general samples, the survey questionnaire was organised to start with general background questions (group 1). This was followed by the house health rating and its explanation (group 4) and attitudes (group 5) because it was anticipated that participants would find these to be an easy transition towards questions on the health rating of

materials which required more knowledge (group 3). Finally, the standard psychological tests (group 2) were at the very end, because it was thought participants would find these easy and more interesting. Although at the very end, this section was completed by all participants in the NZ general sample and generally had good completion rate in all general samples. The two surveys for the NZ architects had a different order, which placed greater emphasis on professional rather than individual/personal questions.

4.2.1 Group 1: General demographic and house characteristics

General demographic characteristics included: gender, age, education, occupation, and cultural background (defined as an open entry question for the US and UK samples). For the NZ long survey a question on approximate total household income was included, but some of the participants explicitly contested the question and it was subsequently removed (Appendix 1). For house and household characteristics, participants were asked the age of their house (with given bands in NZ, but open entry for the US and UK samples), which suburb/town it was in, ownership status (owned, rented, other), number of people in the household, and whether anybody in the household suffered from asthma or other chronic respiratory problems or suffered from allergies. The US and UK questionnaire also include questions on dwelling type and predominant material as a basis for evaluation of comparability with the NZ samples, where individual houses were targeted and most were built in timber. These were two multi-choice questions and read:

1. Is your home: house; apartment or flat; or other ____; and
2. Is your home predominantly: heavy masonry (brick, concrete); timber frame; or other ____.

As seen in the next chapter, overall the survey participants reported most often living in houses rather than other dwelling types. Because this was a very strong trend, especially in NZ, throughout the text dwellings are discussed as houses, unless specific characteristics that differentiate between them are considered.

4.2.2 Group 2: Individual psychological tests

Based upon existing knowledge in psychology, it was possible to identify three well established systems useful for the core study. These are personality traits (McCrae and John 1992; Goldberg 1993), values (Davidov, Schmidt and Schwartz 2008; Roccas et al. 2002), and environmental concerns (Schultz 2001).

4.2.2.1 Five personality traits

Since the early 1990s, the five personality traits (discussed as the Five-Factor Model by McCrae, as the Big Five by Schmitt, and the OCEAN's five by Gosling) have received much research attention in psychology. In 1987, McCrae and Costa proposed that the diverse ways personality traits were

conceptualised and studied at the time should be organised into a better system. They offered the Five-Factor Model of Personality, and in 1992, McCrae and John argued for its validity (McCrae and Costa 1987; McCrae and John 1992). Although there has been much progressive development of testing tools (see section 4.2.2.7), the essence of the Five-Factor model has remained: the five-factors or the five personality traits are each defined as two opposing dimensions: agreeableness – antagonism, extraversion – introversion, conscientiousness – undirectedness, emotional stability – neuroticism, and openness to experiences – lack of openness to experiences (McCrae and Costa 1987; McCrae and John 1992). In literature either both or only one of the extremes are discussed, while the other is implied through the low scoring of its opposite. For example, a person who scores high on emotional stability is by implication scoring low on neuroticism, and vice versa.

The relevance of the five personality traits is that the system does not group people into types, but rather interprets each individual as a unique set of scores or tendencies, with higher or lower scores for each different trait (Figure 4.1). However, when evaluating a group of people, their combined high/low scores for the five personality traits have been shown to correlate to many other tendencies, such as values (Roccas et al. 2002), political orientation (Carney et al. 2008), environmental concerns (Swami et al. 2010), the way people use and display their personalities in interiors (Gosling 2008), and health and diet (Möttus et al. 2013). For example, Carney et al. (2008) have found that political liberals appear to be more open, tolerant, creative, curious, expressive, enthusiastic, and drawn to novelty and diversity in comparison with conservatives, who appear more conventional, orderly, organised, neat, clean, withdrawn, reserved, and rigid. These tendencies were further interpreted as reflecting respectively personality traits of openness and conscientiousness (Carney et al. 2008). Similarly, occupants scoring high on conscientiousness tend to use their space well, and keep it clean and organised, while occupants scoring high on openness tend to make their spaces more distinctive, more decorated and include large numbers and wide varieties of books and magazines (Gosling et al. 2002; Gosling et al. 2005; Gosling 2008). High scores on the awareness of the healthy diet dimension have been associated with high scores on agreeableness and conscientiousness, while the convenient diet dimension was associated with low openness and high neuroticism, and preference for sweet food was associated with low openness (Möttus et al. 2013).

Therefore, use of the five personality traits helps when studying differences in responses within a group of people. Using this established research tradition, it was reasonable to assume that people scoring higher on some of the personality traits could also exhibit a greater level of understanding of health risks associated with building and furnishing materials, greater openness to learn about those risks and, ultimately, greater inclination to act and make changes in their own spaces.

Furthermore, expanding research in the five personality traits has established that there are predictable patterns in the way personality traits relate to age, gender, culture and even regional differences. Generally, the observed trend is that with age agreeableness and conscientiousness generally increase while extraversion, openness and neuroticism generally decline, although there

are conflicting findings over the exact periods of life when the changes are most accelerated (Chan et al. 2012; McCrae et al. 2000; Soto et al. 2010).

Figure 4.1: The five personality traits profiles for Ruby and Mimi. (Source: Gosling 2008: 39.)

When it comes to gender differences, Costa, Terracciano and McCrae found that women tend to score higher than men on agreeableness and neuroticism, with the scores split between different facets of extraversion and openness, with women scoring higher on warmth and men on assertiveness, and similarly women scoring higher on openness to feelings, with men tending to score higher on openness to ideas (Costa, Terracciano and McCrae 2001). Schmitt et al. (2008) used the Big Five Inventory when comparing the personality trait scores across 55 countries, and showed that women reported significantly higher levels of neuroticism, agreeableness, extraversion and conscientiousness than men. This was most pronounced for the neuroticism – emotional stability scale, where women scored higher on neuroticism (lower on emotional stability) in 49 nations (Schmitt et al. 2008). For agreeableness, women scored higher in 34 nations, but for extraversion and conscientiousness the scores were more even, with women scoring higher 25 and 23 times respectively. Gender differences in openness were decidedly mixed across cultures. In 37 cultures, men scored higher than women in openness to experiences (in 8 cultures this difference was statistically significant), but in 18 cultures, women’s self-reported openness to experience was higher than men’s (in 4 cultures this difference was statistically significant) (Schmitt et al. 2008). Both studies were cross-cultural and found that gender differences were stronger in Western societies than in more traditional societies, though a solid theoretical explanation for this is still lacking (Costa, Terracciano and McCrae 2001; Schmitt et al. 2008).

Finally, in the last ten years, research on personality traits has started to show there are clear inter-relationships between the personality traits and culture (McCrae 2001; Schmitt et al. 2007; Rentfrow, Gosling and Potter 2008). The research revealed members of a particular culture may be

more prone to endorse particular personality traits or to use extreme categories (McCrae 2001), and there are even solid indications of regional differences in the prevalence of personality traits (Rentfrow, Gosling and Potter 2008).

Therefore, it seems observable differences in the five personality traits across age groups, gender and culture, need to be taken into account when evaluating the personality trait scores of any sample group. Furthermore, given the expectation of different scores on certain personality traits because of some basic demographic characteristics, the latter have to be considered when evaluating the health rating of materials in the core survey.

4.2.2.2 Values

Although in the last twenty years values and environmental concerns have also received much attention in psychology research, compared to the five personality traits these fields of study are currently less clearly established. Therefore although these are also well recognised and established systems, there are fewer possible comparisons and greater limits to the existing knowledge in these areas.

Research on personal, basic values has also developed significantly in the last twenty years (Davidov, Schmidt and Schwartz 2008; Roccas et al. 2002), mainly using the theoretical framework proposed by Schwartz in 1992. Values differ from the personality traits in that they are stable individual preferences that reflect socialisation (Bilsky and Schwartz 1994) and they describe goals that people consider important and wish to pursue (Roccas et al. 2002). Cross-cultural comparisons have established that although the individual attributes importance to different values, the same general motivational structure organises these values across cultures (Davidov, Schmidt and Schwartz 2008). Values are also often seen as mediators between personality traits and the real positions people take, such as political orientation, and their consequent behaviours (Caprara, Vecchione and Schwartz 2009).

Values are conceptualised as forming a circular motivational continuum, expressive of two higher order dimensions (Figure 4.2; Schwartz 1992). The two dimensions consist of two pairs of mutual opposites: self-enhancement vs. self-transcendence, and openness to change vs. conservation (Davidov, Schmidt and Schwartz 2008). These are sometimes discussed as four value categories: self-enhancement, self-transcendence, openness to change, and conservation (Schultz et al. 2005). When the relationship between individual basic values and political orientation was researched, results strongly indicated that the higher an individual scores on universalism values, the more their preference is for the political left, while a higher score on security values goes with more preference for the political right (Caprara, Vecchione and Schwartz 2009; Caprara et al. 2006). Similarly, when values were explored in relation to the five personality traits, agreeableness correlated most positively with benevolence and tradition values, openness with self-direction and universalism

values, extroversion with achievement and stimulation values, and conscientiousness with achievement and stimulation values (Roccas et al. 2002).

Figure 4.2: The theoretical structure of relationships among motivational types of value (10 values and 2 dimensions). (Source: Biskly and Schwartz 1994.)

4.2.2.3 Environmental concerns

Study of environmental attitudes and behaviour was developed during the early 1990s, based on the ten basic values as articulated by Schwartz in 1992 (Schultz et al. 2005; Stern, Dietz and Kalof 1993). This theory focused on environmental attitudes and behaviours as outcomes of awareness of harmful consequences to valued objects (Schultz et al. 2005; Stern, Dietz and Kalof 1993). Subsequent research has identified that the environmental concerns that people express group around values attributed to impact on themselves, other people, or plants and animals (Schultz 2001). Therefore in 2001, Schultz proposed study of environmental concerns in three groups: biospheric (big picture, future of the planet), egoistic (my personal concerns) and altruistic (other people's well-being).

When exploring the relationship between environmental concerns and basic values, Schultz found that the egoistic concern was positively correlated with self-enhancement and negatively with self-transcendence, while the opposite trend was observed for both the biospheric and the altruistic concerns, which were negatively correlated with self-enhancement and positively correlated with self-transcendence (Schultz 2001). Although this implies strong similarities between the biospheric and altruistic concerns, Schultz's (2001) detailed analysis clearly differentiated between the two in that they are expressive of the degree to which a person perceives interconnection between themselves and other people (altruistic), or between themselves and nature (biospheric). Furthermore, subsequent research has shown that these relationships hold well when tested both

within their original US context and across other cultures, although the correlations were relatively weak and the strength and significance of these correlations varied greatly across the nations examined (Schultz et al. 2005).

When Swami et al. (2010) evaluated a number of possible socio-demographic and individual predictors for their impact on environmental concerns ratings in a British general population sample, they found the biospheric concern was the only one of the three to be significantly predicted by the factors they assessed (Swami et al. 2010). They found the ratings for the biospheric concern increased with age, and with more left-wing political orientation, and that these positively correlated with scores in agreeableness, conscientiousness, and negatively correlated with scores for emotional stability, and Machiavellianism (Swami et al. 2010). They found fewer relationships for altruistic and egoistic concerns, and none included the five personality traits (Swami et al. 2010). However, gender appeared an important predictor for these ratings, as women gave higher scores for both altruistic and egoistic concerns than men (Swami et al. 2010). For the altruistic concern, age, political orientation, and Machiavellianism also showed a significant relationship in the same pattern as for biospheric concern (Swami et al. 2010).

4.2.2.4 Proenvironmental behaviour

Another important aspect of study of environmental issues in psychology deals with proenvironmental behaviour, recognising the difference between intention and action. When evaluating the variance in proenvironmental behaviour, Schultz et al. (2005) found only a small proportion of it could be explained by values and environmental concerns, with correlations between values and environmental behaviour reasonably weak. Thus, Schultz et al. (2005) hypothesized that this weak link comes from Schwartz's norm-activation model, which predicts that an altruistic behaviour is more likely to occur when a person recognises the possibility of harm to a valued other, and ascribes responsibility to themselves for these harmful consequences (Schultz et al. 2005). When this model was tested, results generally supported the idea that norm activation took place for self-transcendent values, but not for self-enhancement values (Schultz et al. 2005; Swami et al. 2010).

However, the more complex value-belief-norm theory of environmentalism proposed by Stern (2000) asserted that there are many more factors that influence the process between proenvironmental value and behaviour (Figure 4.3). In this model the causal chain moves from relatively stable elements of personality and belief structure, through the process of norm activation to the sense of obligation to take proenvironmental actions before any real behaviour take place. The key point emphasised by Stern (2000) is that at any point in this process new information or other influences can contribute to accelerated activation or disinterest. This complexity of significant external influences makes it hard to predict exact outcomes.

Figure 4.3: A schematic representation of the value-belief-norm theory of environmentalism. (Source: Stern 2000.)

It is relevant that the three concepts discussed here make a progression from very stable individual psychological constructs, for example the five personality traits which are considered as substantially genetically predisposed (McCrae et al. 2000), via values, which are reasonably stable expressions of socialisation, to environmental concerns, which are less stable and used as mediators towards further removed active proenvironmental behaviour. Considering the concepts as being a progression helps in evaluation of their individual usefulness and limitations when interpreting the survey results.

4.2.2.5 Evolving field of values and environmental concerns

While the five personality traits have been developed over the last twenty years, their core structure has not changed, and the main scales used are reasonably comparable. However, there is less certainty in the way values were conceptualised over the same period, and as recently as 2012, Schwartz et al. asserted a need for redefinition of the basic individual value system to include all 19 key facets, rather than their summary into 10 values (Schwartz et al. 2012; Schwartz 1992). Environmental concerns and attitudes have been having an even more turbulent time, with more development resulting from a lack of conceptual clarity (Schultz et al. 2005). The early scales have also been criticised for low correlations with proenvironmental behaviour, low reliabilities, inconsistencies across measures, lack of an integrating theoretical perspective (Schultz 2001), and the fact new scales are still under development (Snelgar 2006).

In fact, the whole area of human views on the environment, as reflected in psychology literature, can be seen as being in process of evolution. For example, Stern has proposed that biospheric concern could potentially evolve into a more separated out factor in human psychology (Stern 2000). Similarly, Schultz et al. observed that respondents generally rate global environmental problems as more serious than local problems, and that this indicates that although the environmental problems are recognised as serious on a global level, locally the impact is not yet readily apparent (Schultz et al. 2005). If recognition of such a threat happened, it has been speculated that self-enhancement could become positively related to environmental attitudes (Schultz et al. 2005).

4.2.2.6 Conclusion

Based on the literature review, it was possible to conclude that use of the five personality traits, basic personal values and environmental concerns could provide a good cross section of individual psychological parameters potentially influencing the level of knowledge and behaviour related to building and furnishing materials at home. Given that, as explained, these psychological parameters can be seen as a progression from innate, very solid individual predispositions to being more choice driven, they provide a good range which could capture any relevant correlations with the views and level of knowledge about building and furnishing materials. However, it is essential to remember that even environmental concerns have been reasonably difficult to correlate with specific proenvironmental behaviours, due to other complex mediators. With building and furnishing materials being even further removed from the individual psychological core, and often strongly influenced by their availability and economic constraints, it could be that only a low level of correlation will emerge. Nevertheless, if any clear patterns and trends can be identified these could be a valuable contribution to understanding the mechanism individuals use to negotiate these problems.

Furthermore, it is essential to emphasise the exploratory nature of the survey, and in that light, the objective of this section was not to argue a theoretical basis for a particular set of assumptions, but rather to establish a reasonably complex set of psychological concepts which could be likely to capture any significant individual psychological differences. Based on the research discussed here it seems probable that when tested some of the psychological concepts could be related with participants' views about building and furnishing materials. Especially promising is the existing work on the five personality traits and personal spaces; if personal spaces can reflect personality traits, then the materials used in the same space could potentially do the same. However, it was important to acknowledge that some studies reviewed here found socio-demographic parameters more predictive of environmental concerns (Swami et al. 2010). Therefore, it is essential to keep an open mind, as the key discoveries could be in the areas that were not anticipated in the survey design.

4.2.2.7 Individual psychological tests used in the core survey questionnaire

When evaluating which psychological test scales to use for measuring the five personality traits, basic values, and environmental concerns, it was determined that for this exploratory study reasonably stable and well established scales would be an advantage. Therefore, two key criteria were adopted for the selection of tests in the core survey:

- 1) They should be reasonably short; and
- 2) Reasonably established within the existing literature.

The scales selected responded well to these criteria.

Ten Item Personality Inventory (TIPI)

Originally the Five-Factor Model used the Neuroticism-Extraversion-Openness Inventory, or NEO Personality Inventory (McCrae and Costa 1987), which was subsequently revised into a 240-item Revised NEO Personality Inventory or NEO-PI-R, designed to operationalize the five-factor model of personality (Costa and McCrae 1995). This was subsequently shortened into three well-established and widely used instruments: the 44-item Big-Five Inventory (BFI, 1999), the 60-item NEO Five-Factor Inventory (NEO-FFI, 1992), and Goldberg's 100 Trait Descriptive Adjectives (TDA, 1992) (Gosling, Rentfrow and Swann 2003). In 2003, Gosling, Rentfrow and Swann developed a very brief measure of the Big-Five personality domains, the Ten Item Personality Inventory (TIPI). This very brief inventory is based on two pair statements, which oppose each other. Each contains two adjectives and it only takes several minutes to administer (Gosling, Rentfrow and Swann 2003).

For the purpose of this survey the very brief Ten Item Personality Inventory (TIPI) was used (Appendices 1-2) because of its brevity and the fact that it has been shown to be robust (Gosling, Rentfrow and Swann 2003; Jonason, Teicher and Schmitt 2011). However, the limitations of such a short instrument are acknowledged even by its creators, in that it is less reliable and correlates less strongly with other variables than longer multi-item measures, and that it is unable to measure individual facets of multi-faceted constructs (Gosling, Rentfrow and Swann 2003). Although this scale has been successfully translated and tested in languages other than English (Muck, Hell and Gosling 2007; Romero et al. 2012), a broad scale cross-cultural application has not yet been done. At the time of the questionnaire design, no cross-cultural comparison was planned. Therefore, while it was reasonable to assume that this instrument would be robust enough for the NZ study, there was a chance that some of the international comparisons could be limited or even impossible. At the time of the questionnaire design, the advantages of using such a brief measure were determined to be outweighing the anticipated disadvantages.

The ESS Human Value Scale

In 2002-3, the European Social Survey (ESS) included a shorter 21-item ESS human values scale which was based on the earlier 40-item Portrait Values Questionnaire (PVQ; Davidov, Schmidt and Schwartz 2008). When used in the ESS survey, due to space limitations some items were dropped and others revised to encompass additional ideas to preserve coverage of the ten different values content (Davidov, Schmidt and Schwartz 2008). When tested, it performed well (Davidov, Schmidt and Schwartz 2008), but does not appear to have become a popular scale in psychology. However it was considered adequate for this study. Unfortunately with its 21 items it was still the longest psychological scale used and when shortening the survey for the NZ short version, it was removed. Later it was reintroduced for the follow-up trial and these results combined with results from the NZ long sample are discussed in chapter 9.

Measure of Environmental Motives

In 2001, Schultz developed a new scale Measuring Environmental Motives based around the three factor model for environmental values: egocentric, altruistic and biospheric. This scale tested well in confirmatory tests (Schultz 2001). Although alternative scales have since been proposed, maintaining the same three factor model, but providing longer wording for rated items (Snelgar 2006), the Measure of Environmental Motives was selected here because it is briefer and offered better comparability with the existing literature.

4.2.3 Group 3: Health ratings of materials

The health rating of materials can be seen as the very core of this survey, and therefore much consideration was given to its development. This development started with a descriptive listing of materials commonly found in NZ homes. These were considered as relevant for the survey for three reasons:

- 1) The participants were likely to be most familiar with these materials, and thus be more likely to rate them;
- 2) These materials would be the ones most likely to be potentially impacting on the health of participants, which should increase their interest in them; and
- 3) Finally, when making future purchase choices the participants would probably be choosing from the same pool of materials.

Furthermore, it was considered that participants might find structural materials especially hard to rate, as these are often covered by other materials. For example, wood, particleboard, or concrete subfloors could all be covered by wall-to-wall carpet or vinyl. Particleboard and MDF are often 'covered' by another material. Therefore, structural, less visible, materials were separated from the furnishing, more visible, materials.

When developing early draft questionnaires, much consideration was given to the relationship between the materials participants have at home and their rating of these. It was anticipated this information would be evaluated in relation to house age and prevalence of materials (see later, section 4.3), and it would thus be possible to evaluate whether participants knew much about the materials in their homes. This was developed through two matrices of questions which contained a variety of materials probably found in NZ homes. Tables 4.2 and 4.3 show fragments of the descriptive tables from these draft stages.

Table 4.2: Draft survey questionnaire: Descriptive questions about building materials (fragment of a table). The question read: 'Please think of your home and note down the materials that best describe it. Please mark with (✓) if you know, or question (?) if you are unsure.'

	Living room	Dining room	Family room	Kitchen	Master bedroom	Kid's bedroom 1	Kid's bedroom 2	Nursery	Bathroom	Laundry	Other, please specify _____	Other, please specify _____
Walls												
Gib												
Woodboards												
Plywood												
Veneered hardboard												
Brick												
Concrete												
Concrete blocks												
Plaster over brick or concrete												
Other, please specify _____												

Table 4.3: Draft survey questionnaire: Descriptive questions about furniture materials (fragment of table). The question read: 'List as many different materials as you have. If more than one piece of furniture is made out of the same materials, please write their number.'

	Kitchen cupboards	Kitchen cupboard doors	Kitchen bench top	Dining table	Bookcase/shelves	Sideboards or entertainment units	Sofa (s)	Coffee or side table	Desk	Dresser, drawers or night tables	Bed 1	Bed 2
Wood												
MDF												
Plywood												
Those could be:												
Unfinished, natural												
Painted												
Varnished with polyurethane												
Oiled												
With wood veneer												

In addition to these descriptive tables, participants were asked to provide health rating of materials on a five point Likert scale in the range: unhealthy 1-2; neutral 3; 4-5 healthy, with an option 'I don't know 0.' The intention was to use a scale that had an equal positive and negative range, with neutral as an option. A five point scale was expected to provide stronger groupings than a longer scale. The

format of this question was from the outset very similar to the final health rating of materials (Appendices 1-2) although the list of materials underwent many changes.

Another type of question was also evaluated at this draft stage. The question read: 'Which of the following substances would you consider to be unhealthy for indoor use in your home? (tick as many as appropriate).' This was accompanied with a list of the following substances: formaldehyde, water-based glue, solvent-based glue, oil-based paint, acrylic paint, plant/mineral paint, conventional (solvent-based polyurethane), water-based polyurethane, wood oils, air fresheners, antibacterial sprays. This question was removed in subsequent development on the basis that it could be leading the participants to select as unhealthy substances which they would otherwise not recognise as hazards. Therefore, part of this list was moved into the health rating of materials (varnishes and paints), and others dropped (e.g. formaldehyde, air fresheners and antibacterial sprays). A similar question was reintroduced when designing the questionnaire for NZ academics and NZ practitioners.

Once all the draft survey questions were brought together, they generated a questionnaire of ten pages, which was considered too long. The descriptive section was three pages, while the rating occupied one and a half pages (the remainder were the psychology and general questions). A subsequent version, the pilot survey questionnaire was developed to reduce the size, especially in the descriptive and health rating sections. In order to achieve this, the health rating of materials was combined with the descriptive account of the prevalence of particular materials in the participants' homes. The final two columns of the health rating table asked participants to tick if they had the particular material in their home, and if present in more than one room to write the number of rooms containing the particular material. The resulting survey questionnaire was six pages long, but in very small fonts (9 and 10pt), and when piloted, it took about an hour to complete. Therefore, further reductions were made.

The NZ long survey questionnaire (Appendix 1) had substantial reductions to the health rating of materials section. The two tables which separately rated the house and furniture materials were merged, reducing repetition as some materials, such as wood, appeared in both sections. Unfortunately, much of this reduction was done at the expense of furniture and furnishing materials. All soft furniture was taken out, significant reductions were made in the curtain section, and carpet and rug materials were merged with several items removed. The main reason for this was to eliminate items that were neither particularly healthy nor unhealthy, and many furnishing materials fall into that category. The new version also tried to simplify the question on prevalence of materials in participants' homes, given that this part of the pilot survey was often left incomplete. Therefore, rather than asking for number of rooms containing a particular material, participants were asked to select whether they had 'lots' or 'some' of the particular material in their homes. When tested, this questionnaire took about 40 minutes to complete. This version was distributed as the NZ long general survey, but received a fairly low response rate (see later, section 4.3.5), which indicated the need for another revision.

The next reduction became the NZ short questionnaire (Appendix 2). In contrast to earlier reductions, this was substantially based on 23 received responses. Generally any items that had poor responses from the NZ long sample were either modified or taken out. One area was the health rating of wood and particleboard with a series of different treatments. Although quite relevant from the perspective of factual differences, given that these treatments make the materials more or less healthy, it was recognised that the participants were leaving many of these questions unanswered. Similar reductions for the same reasons were made when merging other materials into broader categories, such as merging two types of wood oil treatments into one, and grouping several synthetic carpet materials into one item.

In addition, it seemed reasonable to assume that the overall length of the survey questionnaire could have contributed to the poor response rate, and therefore the two pages of health rating of 66 materials from the NZ long questionnaire were reduced to one page of 27 items. As before, generally the materials that were neither particularly healthy nor unhealthy were eliminated, and one whole group of materials used for blinds was taken out. The question about prevalence of the particular materials in the participants' homes was often left unanswered by the NZ long sample and therefore it was taken out, further simplifying the questionnaire.

With the reductions achieved in the health rating of materials and other parts of the questionnaire, the NZ short survey was piloted, it took 10-15 minutes to complete and generally all questions were answered. The 27 items that remained for the health rating of materials (later reduced to 26 for the international samples, by removing 'Artex/'cottage cheese' rough ceiling' because it received a high proportion of 'I don't know' ratings in NZ samples) seemed to capture many of the key differences between materials without being too long. Unfortunately, the reductions necessary to get to this point eliminated two components that were initially considered relevant: the final list focused more on the health rating of building rather than furnishing materials, and asked no questions about the materials in participants' homes. These compromises should be seen as necessary sacrifice of more qualitative information for better quality of quantitative data, because of the increase in response rates and their quality.

4.2.4 Group 4: House health rating with explanations

The house health rating question remained the same throughout the development of the questionnaire. It read 'What health rating would you think your house deserves as it is today?' The answers were captured by a six point Likert scale: 'very poor,' 'poor,' 'fair,' 'good,' 'very good,' and 'excellent' (Appendices 1-2) It was also from the outset followed by the open entry question: 'Briefly explain the main reasons for your assessment.' The intention of this question was to invite participants to qualify their own subjective criteria for their house health rating. It was speculated that the responses could provide relevant insights on what people see as important for a home to be healthy. A similar approach was used by others when developing research tools on new subjects, for

example Schultz (2001) used the open entry question ‘What is the environmental problem that concerns you the most and why?’ while developing the three-factor model of environmental concerns. The received responses were coded and from there it was possible to identify three clusters of environmental attitudes (egoistic; altruistic; and biospheric; Schultz 2001).

In the NZ short and the subsequent questionnaires, this question was followed by another open entry question: ‘Overall, what do you consider to be the most important health improvement currently needed in your home?’ As with the previous question, it allowed participants to report on their own views, and in contrast to the previous question which qualified and explained the views about the house as it was, this question enabled participants to express what was needed, regardless of how practically possible these changes might be. Therefore, it was hoped this question would capture more of what is seen as ‘ideally’ needed.

For these open entry questions to be most effective, for all general samples these questions were placed early in the survey, as the first question group following the general demographic questions, before any of the core questions of the survey could influence participants’ views in any significant way.

It should be noted that although unchanged in wording the question about most important health improvement currently needed in participants’ home had a different place in the NZ long questionnaire (Appendix 1). There, it was part of a series of questions that recorded participants’ current practices. Unfortunately these questions received few completed answers and were therefore either removed or redesigned. Once reduced and simplified, the current practice section asked participants only to list any materials that they might avoid purchasing, and the materials they have removed from their home, for health reasons (Appendix 2).

4.2.5 Group 5: Attitude and current views

As discussed earlier in this chapter, in psychology attitudes refer to the collection of beliefs and behavioural intentions a person holds regarding an issue (Schultz et al. 2005). As such they can be seen as one of the mediators in the progression from personality traits and values, as more stable constructs, to actual behaviour. For the purpose of this study, attitudes could help measure some of the possible factors mediating this process. Although the attitude items for this survey had to be developed anew without any significant basis in existing literature, it was reasonable to anticipate that some of the items included could prove to be significant when explaining individual views.

The questions about attitude were organised into a series of subgroups and each was rated on a 5 point Likert scale, from 1 as ‘strongly disagree’ to 5 as ‘strongly agree’, with 3 as ‘neutral,’ and an additional ‘not applicable’ option. On a very general level, the seven attitudes used in the NZ short

questionnaire (Appendix 2) can be seen as containing two groups of 'external' and 'internal' items. Within the group of 'external' items were three statements on the level of trust participants held for different sources that could be monitoring health related to building and furnishing materials. These are (numbers reflect order in the questionnaire):

- A3: I feel reassured that if a product was not healthy for me and my family it would not be on the market.
- A4: I trust that the government and/or other bodies are controlling how healthy the products that are on the market are.
- A5: I trust that my architect/builder has used healthy materials when working on my home.

In addition to these, one statement asked about the level of confidence in sustainable materials as being healthy:

- A6: I believe that sustainable materials are good for my health and the health of my family.

Of the three 'internal' items, two asked about personal attitude towards healthy homes and learning about these, while the third asked about finance. These statements are:

- A1: Living in a healthy home is important to me.
- A2: I would appreciate learning more about what are the healthier options.
- A7: Finance is the major obstacle for me to make substantial changes to my home.

It should be acknowledged that the A7 item was not truly a question about attitude. It was introduced into the NZ short survey after the general question about income was removed (which was done in response to feedback received from NZ long survey participants). Therefore, rather than asking for an objective measure this question asked for a subjective assessment, which was also potentially more likely to be reflective of a real personal situation.

Prior to reductions for the NZ short questionnaire, when ten items were removed, the list of attitude items did not change much (Appendices 1-2). Of the ten items on attitude that were included in the NZ long questionnaire but not in subsequent versions, four groups were designed as follows:

- Group 1 (A_{long} 5-8): Criteria for preference when choosing materials: preference for natural vs. human-made; choosing look and practicality over healthiness of materials; would healthiness be considered if equal price, or not.
- Group 2 (A_{long} 10-13): Level of knowledge.
- Group 3 (A_{long} 14): Single question about preference for making home improvements.
- Group 4 (A_{long} 15-16): Assumed similarity in views of partner.

The reasons for taking these items out varied. Group 1 had some repetition, group 2 was very similar to another set of self-evaluation questions and removing the former would reduce the time needed to complete the survey. Groups 3 and 4 were aimed at participants who would be interested in the follow-up trial, but this was removed here and later partly re-introduced in the follow-up trial survey (Part III).

The group of questions on current views asked participants to:

- Self-evaluate their own level of knowledge about health risks at home compared to others in the same country, such as more/less/about the same as most other New Zealanders/Americans/British people.
- Indicate sources they would approach if searching for more information on how healthy products are, such as ask the people working in the shop; ask friends and family; research; or not try to find out more.
- Indicate where they would expect the public should learn more about risks associated with building and furnishing materials, such as from the people that they know; news; or government making legislative changes.
- Indicate the level to which price would be a constraint, such as ready to pay extra regardless of price difference; or only if less than 10%/30%; not ready; or readiness would depend on what it is for.
- Indicate the level of readiness to make changes, such as ready to make changes; only if simple/affordable/everyone else was doing it; or would not make changes.

These questions changed very little during the successive shortening of the survey.

4.2.6 Conclusion

This section has explained the process of development and refinement of the core survey questionnaire through a series of iterations to shorten it. It has also established that through this process some of the key intentions had to be sacrificed, mainly dealing with questions about the prevalence of materials in participants' homes. This sacrifice made it impossible in subsequent analysis to explore the health ratings of materials with actual use or absence of the same materials in participants' homes. This change removed one level of objective criteria, ultimately strengthening the reliance on self-declared data from the participants.

4.3 The NZ general sample selection and response rates

Early in the core study design it was decided to target a particular sample rather than aim for a random sample. The main reason for this was because house characteristics, which formed part of the study, can be observed from publically available sources, such as Quotable Values, Wellington City Council, and Google Maps (www.qv.co.nz; wellington.govt.nz; maps.google.co.nz). Therefore, one level of information could be obtained without asking participants any questions. This approach also enriches the survey-based approach with another layer of data acquired by observation, and

similar practices have been recommended by sources critical of solely survey-based research (Beam 2012).

The overall purpose of the survey was the prime consideration when selecting the target sample of the NZ general population for the core survey. While the survey would evaluate the level of knowledge about materials at home, it was hypothesised this might not be very high. The best way to challenge this assumption was to select a sample likely to be knowledgeable, and with the ability to make changes to their homes. Thus, a sample with a higher proportion of homeownership and higher purchasing power was more useful. Similarly, higher education might correspond to a higher level of knowledge and openness to learn about building and furnishing materials. Therefore, although much effort was invested into developing a sample that was representative of the general NZ population, distortions that included a higher prevalence of homeownership, higher purchasing power/income and higher education were all considered more advantageous than distortions in the opposite directions. That means that low income areas and areas with a high prevalence of rental housing were not targeted for the survey, because their residents were considered not to be in a position to make many changes to their living environment easily.

Early in the study design Wellington was identified as the main study area, for convenience and reduced cost for conducting a survey. The surveys were dropped off into selected mailboxes, saving postage, and this proximity also made it easier for participants to join in the planned follow-up sessions. Additionally, during the process of sample selection driving through and walking past the selected houses was a useful strategy for general visual evaluation of the building materials involved.

For consistency, it was decided to invite participation from whole streets, which at times made shorter streets easier to target. However, given the poor response rates received from the NZ long survey and difficulties with targeting whole streets, for the NZ short survey a large section of a long street was also included.

A combination of information, predominantly combining publicly available information on properties with direct observation, was used to evaluate possible streets. Some information was sourced from the 2006 NZ Census website, but more was found through the neighbourhood information section of the Quotable Values website. When tested, the Quotable Values website neighbourhood seemed to include the same properties as the 2006 NZ Census meshblocks (a meshblock is the smallest area unit for which NZ Census collects data), making this the prime source of more comprehensive data. The Quotable Values website has since been changed and some of the information freely available in 2012 is no longer there. In addition, Wellington City Council information on properties was also used, especially the part on rates, which included the capital value of the properties and the aerial view with boundary information. Complementing this, Google maps and Google walkthrough were used. Taken together, this publicly available information generally provided a complete demographic

picture at the level of around 50-200 neighbouring houses concerning house age, value, aerial view and often front view of the property. All of these were evaluated when selecting the sample.

4.3.1 Homeownership and income for the NZ general sample

As established, the focus for the sample was homeowners, especially those with the financial means to make changes to their living environment. Therefore, all samples were selected for the proportion of homeownership to be as high as possible, with 60% homeownership identified as minimum for a particular area to be included in the sample. However, diversity in income was considered to be an advantage, as long as the high proportion of home ownership was maintained and higher rather than lower incomes were considered to be more helpful.

When evaluating how representative Wellington was of all of New Zealand, it was observed that in the 2006 NZ Census, the Wellington region had the highest median personal income of all NZ regions (\$28,000 for Wellington region, compared to \$26,800 for Auckland region as the second highest; NZ Census 2006). However, when analysing the median personal income across smaller units, more variety was observed in Wellington (NZ Census 2006). For example, although median personal income for Wellington City was \$32,500, for Porirua City and Kapiti Coast District it was \$26,300 and \$23,000 respectively (NZ Census 2006). These differences were even stronger when looking into the area units. When searching for area units with low median personal income, it quickly became clear that the areas with the lowest income also had a very low proportion of homeownership. Ascot Park in Porirua and Linden in Tawa were identified as two area units with low median personal income (\$24,800 and \$25,600 respectively) and a reasonable proportion of homeownership (51% and 64% respectively owned or owned by the occupants' family trust; NZ Census 2006). Area units with high median personal income were Wadestown, Ngaio and Te Kainga part of Khandallah, with \$47,700, \$44,700 and \$44,300 respectively (NZ Census 2006). However, even in these areas the prevalence of homeownership was not guaranteed to be high, with Wadestown having only 60% homeownership (owned directly or through the family trust), although the median household income was over \$100,000 (the highest bracket of household income in the NZ Census 2006 and the Quotable Values website as reported in 2012).

Therefore, it was determined that although the Wellington region did have the highest median personal income in the country, there was sufficient diversity in income levels within the region. This was further supported by the recognition that homeownership only corresponded with lower-mid level incomes, rather than with very low incomes, and the Wellington Region offered examples of the former with a reasonably high proportion of home ownership as well as a good diversity for higher incomes.

4.3.2 Diversity of house age and construction technologies

Diversity of house age and construction technologies was considered to be an advantage, because it could capture any relevant differences in participants' views related to the type of house they select. It seemed plausible that participants' views about materials could be related to the materials used in their house as someone considering a particular material harmful might avoid living in a house which contained it. People might also be more interested in knowing how healthy the materials they have in their homes are.

Although the history of construction technologies is a relatively new field of study (Saint 2005-6), certain periods have tended to use certain technologies more than others. This means clusters of houses occur built around the same time often of very similar materials and technologies. For example, picturesque medieval timber frame houses or modern houses with expansive glass and metal joinery are quite different, yet common within their own historical contexts. For 20th century New Zealand homes some key dates relate to the use of lead-based paint, asbestos, particleboard and other wood composites, many of which are no longer in common use. The following thresholds can be observed for these materials:

- Lead-based paints

During the 1960s, lead content in paint started to decrease ('Resene Innovation in a can' 2011). Properties built after 1970 are generally considered to have low lead content paint, but there is evidence that some built between 1970 and 1980 were painted with lead-based paints (Ministry of Health 2008).

- Asbestos

In 1938 James Hardie Ltd established the first asbestos cement plant in Auckland (Department of Labour 2005, 35). From then started the New Zealand use of asbestos as a levelling compound under linoleum and vinyl. This application ended around 1973 (Pers. Com. 2011). The rules on the removal of these levelling compounds was not fully regulated until well into 1990s, presenting a hazard for workers and people disturbing these old floor coverings (Department of Labour 2005, 25).

During 1950s to 1970s, asbestos-cement was used in many sheeting applications in cladding and roofing. This peaked in the mid 1970s and ended in 1987, following the 1983 decision to phase out use of these materials (Department of Labour 2005, 35).

Between the 1950s and 1970s, sprayed asbestos was generally used in industry, but also in form of Artex ceilings in homes (Department of Labour 2005, 36).

- Particle board

Locally produced particle board became available in New Zealand in the early 1960s (Shearer 1961). However, the use of particle board for subfloors became more prevalent towards the end of the 1960s and the early 1970s and is still used (Pers. Com. 2011).

Therefore, it is broadly possible to claim that house age generally corresponds to the use of particular materials and technologies and that by using house age as a guide it is possible to group houses into categories of higher/lower likelihood of prevalence of certain health risks associated

with building and furnishing materials. Therefore, house age was one of the key criteria when selecting for diversity in houses. Table 4.4 illustrates the key differences in terms of materials and technologies used in relation to house age.

Table 4.4: Chronological summary of key technological changes in NZ house construction systems. The intensity of colour indicates intensity of risk from a particular substance.

	Period	Summary of key technological characteristics	Lead in paint	Asbestos	Composite wood
1	Before 1919	Lead in paint common and possibly in very high amounts. Fairly traditional houses, very likely to have been altered since or in need of some modernisation.			
2	1920-1949	Asbestos under linoleum starts to appear; lead in paint common. Fairly traditional houses, very likely to have been altered since or in need of some modernisation.			
3	1950-1969	Asbestos possible; lead in paint common but decreasing. Many early modern features, but many houses of this age might have been altered since.			
4	1970-1989	Asbestos possible early in the period, especially in cladding/roofing; lead in paint possible but unlikely; wood composites such as particle board flooring likely but toxic outgassing should have decreased. Many modern features, but need for major maintenance work and some modernising probable.			
5	1990-2004	Much use of wood and other composite materials; still outgassing; no asbestos; no lead in paint; might have some structural and water tightness issues*			
6	Since 2005	Much use of wood and other composite materials; still outgassing; no asbestos; no lead in paint; reflective of the 2004 Building Act change, should be structurally sound and watertight.*			

* Houses built since 1990 are generally modern in terms of facilities and layout, but for style they divide into modern and traditional, with different personalities tending to choose one or other.

4.3.3 Diversity in demography

Although many aspects of diversity in demographic characteristics could be considered relevant, for the purpose of the core study these were grouped around three key criteria:

- Level of household income, which directly influences the level of choice an individual or household might have in relation to building and furnishing materials;
- Level of education which could correlate with the overall level of knowledge and the outlook towards learning; and
- The stage of family life, as a family caring for young children could put more emphasis on the quality of their living conditions. Focusing on the family stages could also contribute to a good age distribution in the selected sample.

Table 4.5 was developed to explain the targeted characteristics of the sample in terms of demography.

Table 4.5: Summary of key targeted differences in demographic characteristics.

		Income					
		Low/mid income	Mid income		High income		
Ages/family stages	Young children	Low/mid income and young children	Mid income and young children		High income and young children		
			Mid education	High education	Mid education	High education	
	Teen children	Low/mid income and teen children	Mid income and teen children		High income and teen children		
			Mid education	High education	Mid education	High education	
	Children left home	Low/mid income and children left home	Mid income and children left home		High income and children left home		
			Mid education	High education	Mid education	High education	

4.3.4 Combined diversity in demography and house characteristics

The key objective when selecting the NZ general sample was to identify a sample that reflected as much as possible diversity in both demographic and house characteristics. As already established for house characteristics, house age provided much relevant information, while for demographic characteristics income was the most significant. Table 4.6 compares these key parameters in relation to the selected samples.

Table 4.6: House age and income, compared by suburb for sample selection.

	Before 1919	1920-1949	1950-1969	1970-1989	1990-2004	Since 2005
Low/mid income		Porirua Tawa	Porirua Tawa	Porirua Tawa	Does not really exist	Does not really exist
Mid income	Island Bay Kelburn	Island Bay Kelburn	Ngiao Khandallah	Churton Park Wilton Northland	Churton Park Brooklyn	Churton Park
High income	Kelburn Island Bay	Kelburn Island Bay	Khandallah	Khandallah		

Wherever possible, streets with houses of around the same age were sourced that contained higher and lower incomes. For example, older houses, built before 1915, were sourced from Island Bay and Kelburn, representing mid and higher incomes, younger people with younger families and older people with older families (possibly children left home), and a different distribution of occupations (Table 4.7). Additional samples from both suburbs were found to provide an even wider diversity of house age and demography. However, for some house ages the very high or the very low incomes were hard to find, especially when considering homeownership as a priority. For example older houses were not found with a high proportion of ownership in low income groups, possibly because of their higher maintenance costs. Similarly, very high income groups were hard to find in houses built in the 1940s-60s.

Table 4.7: Comparison of observable demographic differences for two samples of houses of about the same age (data from Quotable Values 2012).

	Kelburn	Island Bay
Average house age	Before 1915	Before 1915
Average age	38	28
Average number of household members	2.8 people	3.4 people
Median total household income	>=\$100,000	\$75,600
Proportion of house ownership (or owned through a family trust)	78%	62%
Professionals	63%	41%
Technicians and trades	11%	27%
Clerks, services and sales	22%	23%

Table 4.7 provides a very basic summary of a much more complex set of demographic and house characteristics that were considered during the sample selection process. Data was sourced and analysed to give a very diverse sample for the survey drop-off. The intention was to use that data together with the survey results to enable observations that would not be possible from either in isolation. For this approach to be effective a response rate of about 50% was hoped for, but only 16% was achieved. Unfortunately, with such a low response rate, it was not possible to consider the responses as a reliable indication of the selected samples, and therefore, it was concluded that this

more comprehensive interpretation was impossible as part of this study. This is unfortunate, because the sample selection system developed could have enabled very diverse and good quality analyses by combining a good balance of self-declared individual and local group quantitative data.

4.3.5 Response rates from the NZ general samples (N 61)

For the NZ general sample, the survey was generally paper-based and delivered through the mailbox drop-off. Overall, the NZ general responses in both sets were of very good quality, with only one very incomplete response rejected. The success rate was very low, only 16% overall (Table 4.8). Others have observed general response rates of over 30% for paper based surveys (Kaplowitz and Hadlock 2004; Anseel et al. 2010). This inspired experiments with different methods of approaching potential participants. Flier invitations to take part in the survey online proved very unsuccessful (3 responses to 700 flier invitations), but approaching people through a parenting group achieved reasonably good recruitment numbers, 14 responses from 35 people (Table 4.8). Although the inclusion of the parenting group sample could indicate a higher proportion of families with young children, as seen in section 5.1, this was not the case, because this sample was a good fit with the distortion of the other parts of the NZ general sample.

It was easy to compare the success rate of the two prepaid mailbox drop-off, each of about 100 packs, which only differed in the version of the survey questionnaire. The NZ short questionnaire was slightly more successful than the NZ long questionnaire (19% vs. 17% response rate). The least successful approach was the attempt to collect survey responses personally without providing postage, with only a 10% response rate. This outcome was surprising, given that the targeted sample of 60 households was approached more than once: first with the survey pack and scheduled collection time, and followed later by reminders for any non-responses and setting up another collection time. Others have observed that reminders and prior notice can lead to increased response rates (Kaplowitz and Hadlock 2004). One issue was the privacy of mailboxes, which made them less than ideal as the point for picking up completed survey packs.

Given the nature of the survey, information on the reasons for not starting or abandoning the survey are unavailable. However, some unfinished or partly finished questionnaires were returned by the Mainly Music group and for almost all of these the responses ended at the section on the health rating of materials. Together with the overall poor response rates, this suggests the relative complexity of the questionnaire could be behind the low response rates. Specifically, it seems the health rating of materials was difficult, possibly due to lack of articulated opinions about building and furnishing materials in the general population.

Other research on response rates has established that higher response rates can be obtained when the survey topic is highly relevant to the population surveyed (Anseel et al. 2010). Therefore, the poor response rates received from the NZ general population surveys could be seen, at least in part,

as indicative of general disinterest or articulated lack of knowledge on this topic. Although difficult to prove, this observation is significant and should be noted when considering the data obtained in subsequent chapters.

Table 4.8: Response rates for different recruitment methods for the NZ general sample.

Method of recruitment	Responses	Response rate
NZ long	N 24	
~60 mailbox drop off, no postage included (Porirua and Tawa)	6 responses	10%
~100 prepaid mailbox drop-off (Ngaio/Khandallah, Churton Park, Kelburn, Island Bay)	17 responses	17%
~500 flier invitation to take online survey (about half Porirua, half Churton Park)	1 response (+1 email comment on survey = participant ‡)	0.2%
	1 paper pilot	
NZ short	N 37	
~100 prepaid mailbox drop-off (Northland, Wilton, Khandallah, Kelburn, Island Bay)	19 responses	19%
~200 flier invitations (half Brooklyn half Kelburn), 50 of those with reminder (Kelburn)	1 response (none from reminders)	0.5%
Mainly Music parenting group (Karori-based)	14 responses	
	1 paper pilot 1 online pilot	
	1 online response from re-approached participant ‡	
Total number of ~260 mailbox drop-offs	42 responses	16%
Total number of ~700 flier invitations	3 online responses	0.4%

The detailed sample selection process developed for the NZ general sample was intended to give a reasonably high level of diversity in both demographic and house characteristics. Unfortunately, some of the most enticing sample selection strategies were ineffective due to poor response rates, leading to further sacrifice of more qualitative aspects of the survey. Therefore, it should be noted that two sets of completely unrelated parameters (need to reduce complexity of the survey questionnaire in order to try and increase response rate and the poor response rate which still resulted and made the sample poorly representative of the targeted sample) usefully coincided in strengthening the quantitative features of the core survey at the expense of development of more qualitative features.

4.4 Sample selection and response rate for the US and UK samples

Due to problems with poor response rates, the price per NZ general response was higher than anticipated. For the 36 prepaid responses, the price was well over \$4 per response, without factoring in petrol, time and similar factors. Therefore, purchasing responses through Qualtrics for US\$5 per response seemed a reasonable next step. To cover the costs sponsorship was obtained from industry (see acknowledgments) that enabled purchase of two samples comparable in size to the NZ general sample, one from the US (for US\$5 per response) and one from the UK (for US\$6 per response). Together with the NZ architects sample, this produced four samples of about the same size (Table 4.1).

The process of purchasing responses through Qualtrics was fast and simple, and responses were available a couple of days later. However, the quality of responses varied greatly and overall were not as complete and considered as those obtained from the NZ general sample (Chapter 5).

US (60 participants): Of 68 US participants who started the survey, 3 did not complete and all left the survey too early to provide relevant responses. Of the 65 completed responses 5 participants used random letters for all open end textual responses, making the data of limited use and were therefore removed as unreliable. Thus, 60 responses became the final sample. Of these 51 (85%) answered all questions, 8 (13.33%) answered 90%, and 1 (1.66%) 80% of questions. For the US sample mean response time duration was 9 minutes.

UK (62 participants): Of 73 participants who started the survey, 61 completed, and there were 12 partial completions of which 1 had almost completed the questionnaire, while the other 11 only did the introductory questions. Excluding the latter gives 62 responses. Of these, 44 (70.97%) completed the survey, 16 (25.81%) completed 90%, 1 (1.61%) completed 80% and 1 (1.61%) completed 70%. For the UK sample mean duration response time measured by Qualtrics was 11 minutes.

4.5 Sample selection and response rate for the NZ architects samples

The NZ architects were surveyed using two slightly different questionnaires for the two samples: academics (N 18) and practitioners (N 47). Calling this sample the NZ architects sample is somewhat misleading and is a compromise for easier reading of the text. It is important to note that interior architects/designers, building scientists and other groups expected to know more about building and furnishing materials were also included.

4.5.1 The NZ academics (18 participants)

For this survey participants were either approached individually (using the email addresses listed on the organisational website) or by asking the organisation to distribute the invitation to take part in the survey through the organisational mail lists. The key organisations were the three that provide professional qualifications in architecture in New Zealand: Victoria University of Wellington, University of Auckland and Unitec. For Victoria and Auckland it was possible to approach academics directly and 57 invitations were sent, after excluding academics who teach in areas not directly related to the survey, such as landscape architecture and urban planning. Unitec was approached through invitations and reminders sent to the heads of architecture and interior architecture. Of these, 11 responses were received from Victoria University (33% response rate), 4 responses were from Auckland University (17% response rate), and 1 from Unitec.

Architecture and interior architecture related courses are also offered through a number of smaller programmes, and an attempt was made to identify and approach many of these. Specific programmes in these areas are offered through Massey University, Wellington; AUT, Auckland; CPIT, Christchurch; Weltec, Wellington; and Otago University, Dunedin. These were approached through emails to heads of departments, or directly by name. Other programmes teaching building science related subjects were also evaluated, but it was determined not to include these because they were not directly related to architecture. Of all smaller organisations, two responses were received, one from Weltec and one from CPIT.

There were thus 18 responses. However, 32 participants started the survey but 14 (43.75%) only answered the initial questions. This high proportion of non-completions even amongst academics could be indicative of the survey requiring careful consideration. A private conversation with an academic at Victoria University indicated that for them the survey was not easy and straightforward, because they were aware of the lack of clarity in the existing literature, they abandoned the survey part way through, something that might explain the low response rate. Of all responses from academics only 2 (11.11%) answered all the questions, 9 (50%) answered 90% of questions, 4 (22.22%) answered 80%, and 2 (11.11%) answered 70% and 60%. For the NZ academic sample the mean duration for completing the surveys was 16 minutes.

4.5.2 The NZ Practitioners (47 participants)

The NZ architectural practitioners were approached through three organisations: the New Zealand Institute of Architects (NZIA), The Designers Institute (DINZ) and Building Biology and Ecology Institute (BBE). The email invitations were distributed through the usual mailing lists of these organisations. The NZIA has around 3,000 members and approximately half are registered architects working in NZ (NZIA 2013). The DINZ has 848 members, specialising in different aspects of design including interior design, industrial design, graphic design and interactive design, and consequently, they were asked to distribute the invitation to members specialising in spatial design (DINZ 2013). Rather than being membership-based, the BBE mailing list includes a self-subscribed combination of

clients, previous students in building biology and architects interested in healthier building practices (BBE 2013).

Of the 47 received responses, only 22 (46.81%) participants named the organisation through which they received the invitation to participate in the survey. However, when the dates of invitation distribution of the invitation were compared to when the survey was done it was clear that at least 32 participants responded to the invitation through the NZIA (which was distributed much earlier than the other two), only 2 participants came through the DINZ, 8 through the BBE, while for 5 participants it was not clear how they came to take part in the survey. The response rates are still low, and if considering the total number of NZIA members, only 1% responded. This indicates a very high level of self-selection, given that the participants chose to respond or not to the survey. The NZIA declined the request to send a reminder, and therefore it was decided not to send reminders through either of the other two organisations.

Of all practitioners 62 participants started the survey. Of these, 15 responses were removed because they had very little content (10 only engaged with the first question, and 5 only had basic introductory information without doing the actual survey), leaving 47 participants, of which 39 completed the survey. Of 8 partial completions, 5 only did the introductory part and the rating of materials, 1 stopped half way through, while 2 answered almost all the questions. This gives a total of 47 participants who have completed all or most of the survey, and a 76% completion rate.

In this sample, nobody completed 100% of the questions, 26 (55.32%) participants completed 90%, 12 (25.53%) completed 80%, and 2 (4.26%) 70% of the survey. The duration mean time was 32 minutes, with 22 or just under half of participants (46.8%) taking between 14 and 20 minutes. The relatively poor completion rates could be explained by open entry questions receiving very poor response rates, as the survey for practitioners was the most complex one. The possibility of such an outcome was considered in the survey design but it was felt that the advantages of having such questions superseded the disadvantages.

4.5.3 Challenges with using Qualtrics

There were technical difficulties with distributing the invitations to take part in the surveys to both NZ academics and NZ practitioners, and almost all of these relate to the practical difficulties of not being able to test the distribution without doing it. For the NZ academics, those from the School of Architecture at Victoria University were the first to be approached. Each academic was to be sent a personalised email invitation through Qualtrics, however once these were generated, the system took the last name as a template for all. This mistake was only revealed in feedback from the academics, which soon followed. A group email was then sent out explaining the problem, but not recognising that the link in the second email was only set to work for one invited participant (the first email had incorrect names, but correct links). This was also fixed and followed with another

email to all. Although this was clearly far from a professional start to data collection, when evaluating how this succession of events could have affected response rates this should be considered in relation to the advantage of repeat approaches, which have generally been recognised to help stimulate awareness favourably (Anseel et al. 2010), thus perhaps making these mistakes not significant, given the high Victoria University response rate.

For all subsequent distributions these problems were easily avoided. However, when the survey invitation was sent through the NZIA, two participants sent emails to the author explaining they experienced difficulty accessing the Qualtrics website the first afternoon of the invitation distribution. Whatever the problem was, it was not permanent (it could be related to temporary website problems or overloading the survey), but this could have decreased the level of responses.

When evaluating the final response rates of the NZ academics and practitioners, it is hard to estimate the exact extent to which these technical difficulties created a negative impact. However, it is worth noting that anybody not very experienced in conducting surveys online must be prepared to learn through mistakes and that these could come at the price of some responses. On the positive side, it is worth acknowledging that these responses required no financial investment and only a reasonably small number of emails and phone calls to obtain agreement from the organisations to distribute the invitation to take survey. Therefore, it was a reasonably cost and time effective way of obtaining data.

4.6 Conclusion

From the previous discussions it is possible to conclude that all NZ samples had a fairly low response rate, which indicates a likely self-selection of participants. Therefore, it is possible to assume that the people who were more interested in these surveys, or simply more supportive of research efforts of others (as indicated in Part III), were the ones undertaking the survey. The same trend is observable with the proportionally low response rates observed for NZ academics and especially the NZ practitioners. Others have observed that this process of self-selection due to low response rates distorts the sample (Beam 2012). Finally, if following the works of others, it should be noted that the samples obtained through Qualtrics could be distorted (Kaplowitz and Hadlock 2004; Anseel et al. 2010). Therefore, it is impossible to assume that opinions expressed in these samples are strongly reflective of the general populations they were supposed to represent, and much care is taken in the subsequent chapters to analyse and interpret the results in this light.

Discussion in this chapter has provided information about the approach and design of the core survey, the sample selection and the key aspects related to response rates. This information prepares for the subsequent chapters which deal with results and analysis of the core survey.

Especially significant for these discussions are the decrease in questionnaire and sample selection features that could enable more qualitative analysis, and the observable significant differences in samples. The next chapter deals with the samples' characteristics, and examines and quantifies differences between samples. Together with this chapter, it thus provides background information for the results and their analysis in the chapters that follow.

Chapter 5

Sample characteristics

This chapter introduces the general characteristics of the samples obtained from the core surveys. As explained in the previous chapter, the core survey was effectively six different surveys, which had many of the same questions (Table 4.1 in Chapter 4). Discussion of the sample characteristics in this chapter identifies the key differences between samples and areas where the samples have poor comparability. It also evaluates the extent to which these samples are a good representation of popular views in their countries of origin.

In this chapter, general demographic characteristics are discussed based on the responses received to group 1 and 2 questions. Group 1 included questions on gender, age, level of education, ethnicity and cultural background, and also reports on personal health (asthma and allergies), and basic information about the home, such as home ownership, dwelling age, and for the international samples, dwelling type (house or apartment/flat) and construction system (masonry or timber frame). Group 2 included individual psychological characteristics measured through use of the personality traits and environmental motives.

Unfortunately, this chapter establishes that the resulting samples have significant limitations for comparability both between them and as representative of the sampled population. Although general population samples were obtained from three different countries, these seem to come from quite different sections of society, differing in distribution of gender, age, level of education and other important features. Therefore, they are more appropriate as complements to one another in building a more complete demographic picture rather than as a good representation of their countries of origin, or as mutually cross-culturally comparable. However, even this more complete demographic picture is tentative, given that cross-cultural differences could be playing a role in the

differences observed between samples. This relatively low level of comparability of the samples has made it harder to draw conclusions in the subsequent analyses, leaving many of the most interesting observations in the range of tentative speculations (Chapters 6-8).

Another important assessment in this chapter evaluates the adequacy of the sample for answering the core research question. While the surveys have been designed to evaluate the existing level of knowledge, the initial assumption was that lack of knowledge was more likely than high levels of knowledge. Therefore, if the sample is distorted, a sample that could potentially exhibit a higher level of knowledge was considered a better distortion. Therefore, more mature, more educated, financially more secure participants who own their homes and have the ability to make changes to them, have been identified as the sample which is more likely to exhibit a higher level of knowledge than younger, less educated, financially insecure participants who rent their homes and have limited control over them.

5.1 General demographic characteristic

5.1.1 Gender

All three general samples were predominantly female: 62% for NZ general and the US samples and 68% for the UK sample. In other surveys, especially in countries in Europe, North America, and Australia and New Zealand, samples have often been found to be predominantly female, in proportions that are comparable with those in these three samples (Schmitt et al. 2007).

However, the NZ mailbox drop-off resulted in a much higher proportion of male participants, which seems worth discussing. The New Zealand long sample (N 24) obtained through the mailbox drop-off captured 54% male participants; the NZ short mailbox drop-off sample (N 23) was mildly female dominant (61% female); while the sample from the parenting group Mainly Music (N 14) was very strongly female (93%) (Table 5.1). Therefore, it is this sample from Mainly Music that makes the gender division in the NZ general sample comparable with the other two general samples; without it, the gender distribution for the two NZ general samples obtained through the mailbox drop-off was more equal (54% female vs. 46% male). Although it was hard to draw conclusions from this because of the significant differences in the way the NZ and the US/UK samples were obtained (mailbox drop-off vs. purchased through Qualtrics), the higher presence of male participants in the NZ general sample should be noted. It suggests that the questionnaire about building and furnishing materials was possibly passed on to the male household members. Interestingly, in the sample from Mainly Music this was what happened with the one male participant, who does not attend the group although his wife does. The higher presence of male participants in the NZ long sample further suggests that the longer and more detailed survey questionnaire about building materials was seen as belonging in the male domain, while the shorter version was more approachable for women.

Therefore it is possible to speculate that this could be one reason for the poor NZ mailbox drop-off response rates.

On the other hand, male predomination in the NZ architects sample (69% of participants) was expected. Thus female predomination in the general samples and male in the NZ architects sample somewhat balanced each other, producing a fairly balanced 56%/44% female/male for the total sample. However, it is important to note these differences in gender distributions throughout the discussion. Furthermore, 40% of all male participants in the total sample came from the NZ architects sample. This implies that any observations that relate to gender could be based on differences between samples. For example, 40% of male ratings for the total sample would be from the NZ architects, making that sample more educated in architecture, while the opposite could be said for the total female sample. Consideration of these sample characteristics has been taken when analysing results in the subsequent chapters.

Table 5.1: Comparative gender distribution by sample.

		Female	Male	Total
1	NZ general long	11 46%	13 54%	24
2	NZ general short mailbox drop-off	14 60%	9 40%	23
2	NZ general short Mainly Music	13 93%	1 7%	14
2	NZ general short	27 73%	10 27%	37
3	NZ general combined	38 62%	23 38%	61
4	NZ arch academics	6 33%	12 67%	18
5	NZ arch practitioners	14 30%	32 70%	46
6	NZ arch combined	20 31%	44 69%	64
7	US	37 62%	23 38%	60
8	UK	42 68%	20 32%	62
9	Total sample	137 55%	110 45%	247

Because of the significance of the sample gender balance for section 7.3, it should be noted that the NZ architects sample was not only male dominated but varied regarding gender distribution between different groups within this sample. The biggest group of participants in this sample responded to the invitation through the NZIA, making half of the NZ architects sample (49%), and

was strongly male dominated (81%/19%). The group of academics was more balanced, with two thirds of participants being male (67%/33%), while the group of participants invited through the DINZ and BBE show a more balanced distribution with a slight female dominance (53%/47%), which contributed to improving the gender balance in the overall NZ architects sample.

5.1.2 Age

None of the participants were under 20 years or over 75 years old, thus these age groups were excluded from the following analyses.

The total sample was strongly in the 35 and 65 age groups (Table 5.2). The NZ architects sample had a slightly higher average age than the three general samples, but when tested this trend was not significant. Participant ages were further grouped into 20-49 years old as younger and 50-75 years old as older (Table 5.3). Although these are very broad age categories and it could be argued that 49/50 years old as the break point between the groups is high, this split gave two groups of participants reasonably well balanced in size being 56%/44% younger/older. They also dealt with the problem of data incompatibility, because the NZ general long survey had less separated age groups than the subsequent surveys.

Table 5.2: Age in four groups compared by sample, with WHO world standard population distribution (WHO 2001) and the 2006 NZ census data (Statistics New Zealand 2006).

Please indicate your age group	20-34 years old	35-49 years old	50-64 years old	65-75 years old	Total
NZ general short	4 12%	13 39%	13 39%	3 9%	33 100%
NZ arch academics	2 11%	7 39%	6 33%	3 17%	18 100%
NZ arch practitioners	6 13%	17 36%	19 40%	5 11%	47 100%
NZ arch combined	8 12%	24 37%	25 38%	8 12%	65 100%
US	13 22%	23 38%	22 37%	2 3%	60 100%
UK	14 23%	24 39%	21 34%	2 3%	61 100%
Total sample (without NZ long)	39 17%	84 36%	81 35%	15 6%	219 100%
WHO world standard population distribution adjusted for the age range used	38%	32%	22%	8%	100%
2006 NZ population census age distribution adjusted for the age range used	30%	35%	25%	10%	100%

When evaluating how representative this sample was of the general population two sources were consulted: the World Health Organisation age standardisation (WHO 2001), and the NZ population census (Statistics New Zealand 2006) (Tables 5.2 and 5.3). They show that although the standardised age distribution of the WHO would expect a 70%/30% split between younger and older age groups, this was not true of the NZ population based on the 2006 census which had a 65%/35% split. Nevertheless, all samples tended to be older than these proportions, with a stronger grouping of participants in the 50-64 age group than general statistics would indicate (Table 5.2). Therefore, it was possible to conclude that the four big samples are comparable with one another in terms of age, although they are all older than the average population.

Table 5.3: Age in two groups compared by sample, with WHO world standard population distribution (WHO 2001) and the 2006 NZ census data (Statistics New Zealand 2006).

Please indicate your age group	20-49 years old	50-75 years old	Total
NZ general combined	24 53%	21 47%	45 100%
NZ arch combined in big groups	32 49%	33 51%	65 100%
US in two groups	36 60%	24 40%	60 100%
UK in two groups	38 62%	23 37%	61 100%
Total sample in two groups	130 56%	101 44%	231 100%
WHO world standard population distribution in two age groups	70%	30%	100%
2006 NZ population census in two age groups	65%	35%	100%

For the NZ general sample it should also be noted that the question of age was poorly formulated for the NZ long survey, and consequently only about half of the participants provided information on this, so for 12 responses, or 20% of the NZ general sample, this information was missing. Of those who provided their age, there was only 1 male participant younger than 50 in the NZ general sample, and more than half the female participants younger than 50 were recruited through the Mainly Music parenting group. These features are relevant for some of the subsequent analyses.

5.1.3 Level of education

The samples were not mutually comparable in the distribution of education levels (Table 5.4). 75% of NZ general participants had university or higher education, while only 32% of the combined US and UK sample had the same level of education. The proportion with university and higher education in the US and UK samples was similar to the general statistics for all three countries (Table 5.5, note that the proportion was lowest for the UK). It is reasonable to assume that the observed differences are expressive of the differences in the way samples were obtained. Although every effort was taken for the NZ general sample to be a good representation of NZ society, this was one area where it failed, as a higher proportion of more educated participants responded to the invitation to take the survey.

Table 5.4: Level of education compared by sample.

	High-school	Trade qualification	Bachelor or Honours degree	Master or Doctoral degree	Other	Total
NZ general long	3 13%	5 21%	9 38%	6 25%	1 4%	24 100%
NZ general short	3 8%	3 8%	24 65%	7 19%	0 0%	37 100%
NZ general combined	6 10%	8 13%	33 54%	13 21%	1 2%	61 100%
US	24 40%	9 15%	18 30%	4 7%	5 8%	60 100%
UK	21 34%	18 30%	10 16%	7 11%	5 8%	61 100%
Total from 3 general samples	51 28%	35 19%	61 34%	24 13%	11 6%	182 100%
Total from 3 general samples in two groups and 'other' adjusted	90 50%		91 50%			181 100%
NZ architects combined	2 3%		63 97%			65 100%
Total sample grouped in two big groups	92 37%		154 62%			246 100%

Table 5.5: National data from the Organisation for Economic Co-operation and Development (OECD) on proportion of tertiary level educational attainment in general population for age group 25-64, in NZ, US and UK, in 2006 (OECD 2009).

Country	Tertiary level in 2006	
NZ	38.3%	
US	39.5%	28% Bachelor's degree or higher
UK	30.5%	

The NZ architectural academics and practitioners did not have this question since all would have to have obtained a bachelor degree, and many of the academics would also hold postgraduate degrees. However two participants who received an invitation through the BBE mailing list did have lower educational levels, as seen from the job title they provided. This additional large group of participants with bachelor or higher degrees makes the total sample much more educated than average, with 62% having a bachelor degree or higher level of education. Although this high presence of more educated participants could be seen as decreasing the comparability of the data with the general population, as already explained this distortion is suitable for answering the research questions.

Another relevant feature of the sample was that the three combined general samples had a higher proportion of higher education in the younger sample (Table 5.6). This could be due to the relative absence of very young participants, high division age, or the general increase in the level of education for the younger groups compared to what was common for the older groups.

Table 5.6: Comparison between age groups and educational level for the three general samples.

For the three general samples	Lower education (high-school or trade qualification)	Higher education (Bachelor or higher University education)	Total
Younger 20-49 years old	40 42%	56 58%	96 100%
Older 50-75 years old	42 62%	26 38%	68 100%

5.1.4 Nationality, ethnicity and cultural background

The responses to the question on cultural background differed significantly between samples. This was substantially because the question was a multi-choice question for all NZ samples, but an open ended question for the US and the UK samples. Furthermore, the wording of the question was not the same in the different questionnaires. The question in the two NZ samples read: 'What best describes your cultural background?' While the US and the UK samples had a broader open ended question: 'What nationality/ethnicity best describes you?' As a result of these differences, the NZ responses are more grouped, while the US and the UK responses mixed nationality, ethnicity and race, making responses not perfectly comparable even within their own group.

For the NZ general sample (Table 5.7), 88% of participants identified themselves as 'New Zealand European', only one participant as Maori or Pacific People, and six selected the option 'other' identifying themselves as Asian, American, European, and mixed (Asian/Mexican, Asian/European). For the NZ architects sample, the trend was similar, but with a higher proportion of 'other': 83% selected NZ European, 2 (3%) selected Maori or Pacific People, and 9 (14%) selected other and specified Pakeha (3 times), Scottish, New Zealand, USA, Australian European, and European non NZ. Therefore it was possible to conclude that all NZ samples were predominantly NZ European, with a higher level of differences in the NZ architects sample, although this could be due to use of a different wording (such as Pakeha).

Despite the differences in the questions, it was clear that the US and the UK samples also predominantly attracted participants from their main cultures (Tables 5.8 and 5.9). For the UK 93% reported different terms that referenced the main culture, such as white British/UK (44%), British (25%), English (11%), white (7%) and Scottish (7%). Only 4 (7%) reported other backgrounds such as American, French, Irish and British Asian. For the US sample race was more prominently used in replies although not asked for, which probably reflects the use of race for census and similar official US data (United States Census Bureau 2013, 2). Regardless of race, 86% of participants used words that made reference to the main culture, such as white or Caucasian (68%), American/US/USA (10%), Black/African American (8%). This compares well to official figures of the United States Census Bureau (2). Of the remaining 13%, 2 (3%) did not specify anything, and the remaining 6 (10%) specified different backgrounds such as Asian, Chinese, Japanese, other mixed, and other Native American.

Therefore it was possible to conclude that all of the samples could be considered as representative of the dominant culture with a relatively low prevalence of cultural minorities. This was adequate for this study.

Table 5.7: Responses from the NZ samples to question about cultural background.

	New Zealand European	Maori or Pacific People	Other	Total
NZ general long	21 91%	1 4%	1 4%	23 100%
NZ general short	31 86%	0 0%	5 14%	36 100%
NZ general combined	52 88%	1 2%	6 10%	59 100%
NZ arch academics	15 83%	0 0%	3 17%	18 100%
NZ arch practitioners	39 83%	2 4%	6 13%	47 100%
NZ arch combined	54 83%	2 3%	9 14%	65 100%

Table 5.8: US responses to question about nationality/ethnicity.

		Response	%
	US		
1	White or Caucasian	41	68%
2	American/US/USA	6	10%
3	Black/African American	5	8%
4	Asian/Chinese/Japanese	3	5%
5	Other (mixed, native American)	3	5%
6	NA	2	3%
	Total	60	100%

Table 5.9: UK responses to question about nationality/ethnicity.

		Response	%
	UK		
1	White British/UK or British White	27	44%
2	British	15	25%
3	English	7	11%
4	White	4	7%
4	Scottish	4	7%
6	British Asian	1	2%
5	Other (American, French, Irish)	3	5%
	Total	61	100%

5.1.5 Asthma and allergies

The question on asthma and allergies asked: ‘Does anybody in your household suffer from asthma or other chronic respiratory system problems?’ and ‘Does anybody in your household suffer from allergies?’ These questions were structured this way because it was anticipated that if anybody in the household had those conditions, all members of the household might be aware of such special needs. Therefore, the received responses should not be interpreted as the proportion of participants

with such conditions and cannot be compared to general statistics on prevalence of these health conditions. Rather, a higher rate than the general prevalence of these conditions should be expected, capturing the rate of familiarity with these conditions.

Of all the participants who answered the questions about asthma and allergies (N 238), 28% said asthma or other chronic respiratory system problems were present in their household and 43% that allergies were present. Of all participants 19% declared they had both asthma and allergies in their household, giving 51% of the total sample reporting one of the two conditions. Across the sample groups the frequency of reports of either condition was reasonably consistent, at around 50% of each sample, although the samples differed in frequencies of reports of individual conditions (Table 5.10). Generally the samples that had lower rates of one of the conditions had higher rates of the other. For example, the lowest reports of asthma were received from the NZ architects and the US samples, but the same samples had much higher reports of allergies (Table 5.10).

Table 5.10: Comparison of number of reports of asthma and allergies across sample groups.

	Asthma and allergies	No asthma	Yes asthma	N for asthma	No allergies	Yes allergies	N for allergies	Reported either	Reported both
3	NZ general combined	42 69%	19 31%	61	36 60%	24 40%	60	29 48%	13 22%
6	NZ arch combined	48 83%	10 17%	58	32 55%	26 44%	58	30 52%	6 10%
7	US	42 71%	17 29%	59	28 47%	32 53%	60	33 56%	16 27%
8	UK	40 67%	20 33%	60	41 67%	20 33%	61	30 50%	10 17%
9	Total sample	172 72%	66 28%	238	137 57%	102 43%	239	122 51%	45 19%

Some significant patterns were observed. Of all participants, women tended to report asthma or allergies more often than men. One-way between subjects ANOVA tests to compare the effect of gender on declared asthma and allergies confirmed that the difference was significant for asthma ($F(1,236)=4.351$, $p=0.038$, significant at $p<0.05$ level) and almost significant for allergies ($F(1,237)=3.238$, $p=0.073$). Younger and less educated participants tended to report asthma more often than older and more educated participants, who tended to declare allergies more often, but these differences between groups were not significant. Both conditions were reported more often by participants who rent their homes than those who own them, and this difference was significant for asthma. One-way between subjects ANOVA test to compare the effect of home ownership or renting on declared asthma resulted in $F(1,233)=5.484$, $p=0.020$ significant at $p<0.050$ level.

5.2 House characteristics

5.2.1 Homeownership

In the last couple of decades, homeownership rates have experienced a decline in many countries. In New Zealand, homeownership peaked at around 75% in the early 1990s, but by 2006 the NZ Census recorded 63% (Statistics New Zealand 2006). Similarly, homeownership rate in the UK peaked in 2001 achieving 69%, but has since fallen to 64% (UK Office for National Statistics 2013). Between 2007-2011 in the US the average homeownership rate has been around 66%, but dropped to 61% in 2011 (United States Census Bureau 2013, 1, 2). Therefore, in the three countries surveyed homeownership rates are reasonably comparable.

Table 5.11: Comparison of home ownership and renting rates across sample groups.

	Home ownership	Official homeownership rate	Owned	Rented	Other	Total
1	NZ general long	63%	22 96%	1 4%	0 0%	23 100%
2	NZ general short	63%	33 89%	4 11%	0 0%	37 100%
3	NZ general combined	63%	55 92%	5 8%	0 0%	60 100%
4	NZ arch academics	63%	14 82%	3 18%	0 0%	17 100%
5	NZ arch practitioners	63%	35 85%	5 12%	1 2%	41 100%
6	NZ arch combined	63%	49 84%	8 14%	1 2%	58 100%
7	US	61%	44 75%	14 24%	1 2%	59 100%
8	UK	64%	36 58%	26 42%	0 0%	62 100%
9	Total sample		184 77%	53 22%	2 1%	239 100%

As explained in the previous chapter, the NZ general sample was selected to capture a high proportion of home ownership, while no special pre-selection at this level was possible for the other three samples. The NZ general achieved home ownership of 92% (Table 5.11). A lower, but still high proportion of home ownership was reported by the NZ architects sample (84%). These figures are much higher than the national average of 63% (Statistics New Zealand 2006) and therefore indicate that given the low level of interest in the survey already discussed, it was participants who own

homes that tended to respond to the survey invitation. This feature should be noted as one difference between the samples here and the general population.

No UK or US sample selection was done on the basis of homeownership, as it was reasonable to assume that monetary incentives were provided by Qualtrics to participants of these surveys. Incentives like these have been shown to vary in their effectiveness depending on personal social and financial positions (Anseel, Livens and Schollaert 2010). Interestingly, the US sample has noticeably higher homeownership rates than official statistics, 75% vs. 61%, while the UK sample has lower homeownership rates than official statistics, 58% vs. 64% (Table 5.11). Nevertheless, a reasonably high rate of homeownership, adequate for subsequent analyses, was present in all samples.

5.2.2 Household size

The predominant intention of the survey was to capture families, assuming that people with children, and especially young children, might be more interested in the health impact of their home. In the selection of the NZ general sample, diversity in family stage was a goal not possible for the other samples. Achieved distributions (Table 5.12) indicate that the NZ general and US samples were more family-based, with an average of 3.18 and 3.02 people per household respectively, and also with the highest proportions of households with more than three people (56% and 58% of all households respectively). The difference between these two samples was that the US had a much higher proportion of single person households (15% vs. 5% respectively), while the NZ general sample had a higher proportion of two person households (38% vs. 16% respectively). For the NZ architects and UK samples the average number of people per household was lower (2.86 and 2.61 respectively), and the prevalence of households with more than three people was 43% and 41% respectively, and that of two person households was 37% and 34% respectively. However, the UK sample had the highest proportion of single person households in all four samples 21%, and across all samples it is clear that the UK and US samples had higher proportions of single person households than either of the NZ samples.

Table 5.12: Distribution of household size and average number of people per household for all samples.

	1 person household	2 people household	3+ people household	Total	Average number of people per household
NZ general	3 5%	23 38%	34 56%	61	3.18
NZ architects	5 8%	24 37%	28 43%	65	2.86
US	9 15%	16 27%	35 58%	60	3.02
UK	13 21%	21 34%	25 41%	61	2.61
Total	30 12%	84 34%	122 49%	247	2.92

5.2.3 House age

Distribution of the reported dwelling age varied greatly within the samples. For the NZ general sample, which was all Wellington based and selected to capture a good distribution of different house ages, it seems that this has been achieved (Chart 5.1, Table 5.13). However, it was impossible to apply the same criteria to the other three samples and consequently these all exhibit different trends. The two groups within the NZ architects sample exhibited two different trends worth observing. The NZ academics were strongly grouped in the oldest two house categories (58%) with another subgroup in reasonably new houses built since 1990. In contrast, the NZ practitioners had a reasonably consistent distribution, with a modest increase in reasonably new houses built since 1990 (34%).

The US sample showed a clear tendency for more houses in each newer house group (Table 5.13, Chart 5.1), while the UK sample had a clear peak in the post World War Two period, with a decrease since (Table 5.13, Chart 5.1). The same trend was observed in the official UK statistics (Table 5.14) (UK Department for Communities and Local Government 2013). Due to the potentially very wide geographical distribution of the US and UK samples, it is impossible to compare these distributions to official statistics, because the chances of distortion of the sample are high. However, some general trends should be noted, such that the US and a proportion of the NZ architects sample live in newer houses, the UK strongly peaks in the post World War Two period, and the NZ general sample has a more even distribution.

Table 5.13: Distribution of house age for all samples.

	When approximately was your home built?/How old is your house?	Before 1919	1920-1949	1950-1969	1970-1989	1990-2004	Since 2005	Total
1	NZ general long	7 32%	4 18%	3 14%	3 14%	1 5%	4 18%	22 100%
2	NZ general short	7 19%	9 24%	8 22%	9 24%	4 11%	0 0%	37 100%
3	NZ general combined	14 24%	13 22%	11 19%	12 20%	5 8%	4 7%	59 100%
4	NZ arch academics	5 29%	5 29%	1 6%	1 6%	4 24%	1 6%	17 100%
5	NZ arch practitioners	3 8%	8 21%	8 21%	7 18%	8 21%	5 13%	39 100%
6	NZ arch combined	8 14%	13 23%	9 16%	8 14%	12 21%	6 11%	56 100%
7	US	2 4%	2 4%	5 10%	21 40%	20 38%	2 4%	52 100%
8	UK	9 15%	15 25%	17 29%	10 17%	8 14%	0 0%	59 100%
9	Total sample	33 15%	43 19%	42 19%	51 23%	45 20%	12 5%	226 100%

Chart 5.1: Housing age % per sample.

Table 5.14: The UK dwelling age from the UK Department for Communities and Local Government (2013).

UK	% of dwellings
Pre 1919	20.8%
1919-1944	16.5%
1945-1964	19.8%
1965-1980	21.0%
1981-1990	8.4%
Since 1990	13.4%

5.2.4 Construction system and type of dwelling

The prevalence of particular construction systems and dwelling types varies between different countries. In New Zealand timber frame and detached suburban houses are predominant (Petrović 2003), and there was no reason to ask the participants these questions. However, these questions were included in the US and UK survey questionnaires as a way of checking comparability with the NZ samples.

The US and UK samples had comparable proportions of single unit vs. multi-unit dwellings 73/74% vs. 19/20%, respectively (Table 5.15). This further compares well to official statistics of 26% of housing units in multi-unit structures in the US between 2007-2011 (United States Census Bureau 2013, 2), and 20% flats in England between 2011-12 (UK Department for Communities and Local Government 2013). The NZ general sample was selected to avoid any apartments or flats, because generally people have less freedom to make changes to such structures. Therefore, for the purpose of subsequent analyses, it should be noted that the US and UK samples had higher proportions of multi-unit dwellings, and thus, possibly less control of their housing environments.

Table 5.15: Comparison of dwelling type for the US and UK samples.

	House	Apartment or flat	Other	Explanation for other
US	43 73%	11 19%	5 8%	4 x mobile home 1 x hotel
UK	45 74%	12 20%	4 7%	4 x semidetached

Table 5.16: Comparison of construction system for the US and UK samples.

	Masonry (brick, concrete)	Timber frame	Other	Explanation for other
US	28 47%	26 44%	5 8%	4 x metal 1 x I don't know
UK	60 98%	0	1 2%	NA

The US sample reported approximately equal proportions of heavy masonry and timber frame construction systems, something that did not change when the four metal frame responses were merged with the timber frame group, given that the infill and cladding materials would be similar for both (Table 5.16). However, as expected the UK sample reported a high predominance of masonry constructions, 98% (Table 5.16). These reports indicate that the US and UK samples do not compare well with the NZ samples when it comes to personal experience with different materials, with the US being somewhat more similar to the NZ samples in terms of construction systems. These differences are observed when relevant in the subsequent analyses.

5.3 Individual psychological tests

5.3.1 Personality traits

As anticipated in the survey design, the personality traits ratings received from the participants showed relevant variation firstly between sample groups and secondly in relation to gender (Tables 5.17, Charts 5.2-5.11). For the purpose of this study it was reasonable to assume that only very small differences would be observed for age, because of the strong grouping of participants' ages.

Table 5.17: Means for five personality traits per sample group.

	NZ general	NZ architects	US	UK	3 general samples	Total sample
	N 61	N 60	N 60	N 62	N 182	N 246
Extraversion	4.16	4.02	3.96	3.68	3.93	3.95
Agreeableness	5.16	4.61	5.28	5.02	5.15	5.02
Conscientiousness	5.83	5.47	5.62	5.30	5.59	5.56
Emotional stability	5.53	5.16	4.88	4.40	4.94	4.99
Openness	5.07	5.80	5.28	4.65	4.99	5.19

When evaluating the differences between different cultural samples, it is relevant to note that it is only in the last ten years that research on personality traits has started to show there are clear interrelationships between the personality traits and culture (McCrae 2001; Schmitt et al. 2007; Rentfrow, Gosling and Potter 2008). Therefore, there is a reasonably limited body of work with which to compare these results. Schmitt et al. (2007) compared the five personality traits self-description across 56 nations, including all three national samples here. However, their study used the longer 44-item Big Five Inventory (BFI) and the results were normalised to be comparable with the US results as a baseline, as a score of 50 was attributed to the US sample for each trait. As result, it is hard to compare their results with the results from this survey, as proportional differences could have been distorted by these other factors.

Nevertheless, charts 5.2-5.11 provide visual comparison of the results and indicate that the personality traits measured in the sample here compare well with other samples from the same nations. It should be noted that this good comparability was not necessarily expected because the samples Schmitt et al. (2007) obtained for the three nations were generally students, with a small proportion of the general population in the UK sample (their NZ sample N 274/students; US sample N 2793/students; and UK sample N 483/students and community; Schmitt et al. 2007). In contrast,

all samples here were from the general population and were therefore older. The NZ architects sample is not expected to be comparable, as it probably captures occupational differences.

When compared in this way the national personality traits scores from the core survey and Schmitt et al. (2007) are comparable for three of the five personality traits: extraversion, emotional stability and openness. For extraversion and emotional stability, the highest mean score came from the NZ general sample, followed by the US and UK samples respectively (note that emotional stability and neuroticism are opposites; Table 5.17, Charts 5.2-5.3, 5.8-5.9). For openness, the US sample had the highest score, closely followed by the NZ general sample and then the UK sample (Table 5.17, Charts 5.10-5.11). For agreeableness and conscientiousness greater differences were observed (Table 5.17, Charts 5.4-5.7). For agreeableness, the US sample had the highest score, followed by the NZ general sample and the UK sample, which is reasonably comparable with the results from Schmitt et al. (2007), with the difference in second and third places possibly due to difference in age, and reflecting the differing proportions of younger vs. older adults in samples. For conscientiousness, however, the difference was much greater, with the NZ general sample scoring highest, followed by the US and the UK samples in this study, while in Schmitt et al. (2007) the US scored highest followed by the UK and NZ. Some of this difference could be due to the sampling process. This is because the very low response rate for the NZ general survey makes it probable that only the most conscientious participants have responded. This sample was also the oldest, while the NZ sample in Schmitt et al. (2007) consisted exclusively of students, and increase in conscientiousness with age has already been noted in the previous chapter (section 4.2.2). Therefore, the observed differences might have been expected.

It was possible to conclude that overall, the UK sample scored lower on four of the personality traits and about the same as the US and NZ samples for agreeableness. More than anything else this indicates that the UK sample tends to provide lower ratings as a general characteristic. Work by McCrae et al. (2001) observed that some national samples tend consistently to provide lower ratings, when compared to other nations. Here it is important to observe that the UK sample had a trend for generally low ratings even on personality traits, therefore, lower ratings of materials in this sample should be considered in this light.

Chart 5.2: Extraversion from survey. **Chart 5.3: Extraversion from literature.** **Chart 5.4: Agreeableness from survey.** **Chart 5.5: Agreeableness from literature.** **Chart 5.6: Conscientiousness from survey.** **Chart 5.7: Conscientiousness from literature.**

Chart 5.8: Emotional stability (reverse of neuroticism) from survey. **Chart 5.9: Neuroticism (reverse of emotional stability) from literature.** **Chart 5.10: Openness from survey.** **Chart 5.11: Openness from literature.**

As explained in the previous chapter (section 4.2.2), some significant differences based on gender have been observed in scores for the five personality traits. This data was evaluated for such differences using a series of one-way between groups ANOVAs and the results are summarised in tables 5.18-5.19. (Although t-tests could also be used for a test of this kind, other literature recommends one-way ANOVA because they deal better with statistical significance (Green and Salkind 2011: 180), and therefore ANOVA tests have been used for between group differences in this thesis.) The results were consistent with other literature (Chapter 4): female participants scored higher on agreeableness for each of the three general samples and when one-way between groups ANOVAs for the total sample and the three general samples were computed, this difference was significant for both (Tables 5.18-5.19). Similarly, for emotional stability male scores were higher for each of the three general samples and when one-way between groups ANOVAs were computed, this

difference was significant for the total sample (Tables 5.18-5.19). The remaining three personality traits had less clear patterns, and it is relevant to note that for the UK sample almost no differences were found for these personality traits based on gender (Tables 5.18-5.19).

For conscientiousness males provided higher scores in both the US and the NZ general samples. For extraversion female scores were higher for the NZ general sample, but males were higher for the US sample, while for openness this was reversed with the male scores being higher for the NZ general sample. However, when combined, the means for extraversion were higher for males in the total sample and the three general samples, but only for the latter was this difference significant when one-way between groups ANOVAs were computed. These inconsistencies should be seen within the context of inconsistent findings in this area in other research literature (Chapter 4), and it should be noted that the very brief Ten Item Personality Inventory (TIPI), which was used here has not yet been fully researched in relation to gender and cross-cultural comparisons. This very brief measure could perform less reliably for such comparisons.

Table 5.18: Female and male means for five personality traits from the total and three general samples, with assessment of statistical significance of that difference. Results on significance of one-way between subject ANOVA tests provided for all materials in column that had higher mean.

		Total sample		3 general samples	
		Female	Male	Female	Male
		N 137	N 109	N 117	N 65
Extraversion	Mean Sig.	3.96 .928	3.94	3.90	3.98 .708
Agreeableness	Mean Sig.	5.21 .002**	4.77	5.31 .010**	4.87
Conscientiousness	Mean Sig.	5.51	5.62 .466	5.46	5.80 .043*
Emotional stability	Mean Sig.	4.79	5.25 .008**	4.79	5.19 .066
Openness	Mean Sig.	5.11	5.28 .272	5.00 .002**	4.99

For all: Maximum number of participants specified at the top; ** p is significant at p<0.01 level (highlighted yellow); * p is significant at p<0.05 level (highlighted yellow).

Table 5.19: Female and male means for five personality traits received from the four samples, with assessment of statistical significance of that difference. Results on significance of one-way between subject ANOVA tests provided for all materials in column that had higher mean.

		NZ general		NZ architects		US		UK	
		Female	Male	Female	Male	Female	Male	Female	Male
		N 38	N 23	N 20	N 44	N 37	N 23	N 42	N 20
Extraversion	Mean	4.26	3.98	4.33	3.87	3.77	4.26	3.69	3.66
	Sig.	.529		.269			.189	.916	
Agreeableness	Mean	5.29	4.96	4.61	4.60	5.45	5.00	5.20	4.61
	Sig.	.234		.978		.141		.057	
Conscientiousness	Mean	5.62	6.20	5.83	5.31	5.46	5.87	5.32	5.26
	Sig.		.041*	.145			.173	.845	
Emotional stability	Mean	5.37	5.80	4.78	5.33	4.70	5.15	4.36	4.50
	Sig.		.132		.057		.245		.717
Openness	Mean	5.00	5.20	5.86	5.77	5.41	5.07	4.64	4.66
	Sig.		.508	.676		.365			.960

For all: Maximum number of participants specified at the top; ** p is significant at p<0.01 level (highlighted yellow); * p is significant at p<0.05 level (highlighted yellow).

The NZ architects sample does not fit well with the patterns observed in the general samples (Tables 5.17-5.19, Chart 5.2-5.11). Some of these differences were expected, for example this sample scoring highest in openness (Chart 5.10), but some were a surprise, like the lowest score for agreeableness (Chart 5.4). However, when evaluated for expected gender differences, given that this sample was predominantly male, the score for agreeableness from the male NZ architects (mean 4.60) was comparable with that of the UK males (mean 4.61), and close to that of the NZ general sample (mean 4.96). It was the female participants in the NZ architects sample that provided a lower than expected score for agreeableness (mean 4.61, comparable with the UK males and just 0.01 point higher than the male NZ architects). The emotional stability and extraversion scores from the NZ architects were close to those from the NZ general sample while the score for conscientiousness supported the earlier speculation that particularly conscientious participants responded to the NZ general survey. Seen in this way, the differences exhibited by the NZ architects sample are within the range of what might be expected, noting that women in this sample scored significantly lower on agreeableness than other female participants, and in a range comparable to male scores.

Overall, it was possible to conclude that although the survey samples presented some notable individual characteristics, generally they reflect well patterns that have been observed in other research on personality traits. This is a significant observation, because it means at the level of the five personality traits, the samples discussed here exhibit characteristics that are to be expected, making any conclusions comparable with those from others.

5.3.2 Other individual psychological tests

It was possible to investigate the two other psychological factors, environmental concerns and cross-cultural differences, in more detail but this was deemed unnecessary, based on the results of others. As discussed in the previous chapter (Section 4.2.2), existing research has observed female participants tend to rate environmental concerns higher than male participants (Swami et al. 2010). That trend was also clear in the samples here (Tables 5.20-5.21, Chart 5.12-5.13). Subsequent analyses did not show environmental concerns as significant predictors, which is why they are not developed here in more detail. It is simply worth noting that the NZ architects sample provided the most proenvironmental ratings, with the highest received ratings for biospheric concerns, reasonably high ratings for altruistic concern, and lowest ratings for egocentric concerns (Chart 5.12). This could either indicate that the professional discussions on sustainability have elevated environmental concerns within this group when compared to the general population, or simply that more pro-environmentally oriented professionals chose to respond to the survey invitation. More research would be needed to evaluate the former, because this could be a significant suggestion that educational efforts make a positive difference in elevating proenvironmental concerns.

When the opportunity arose to purchase responses through Qualtrics from anywhere in the world, it was believed that responses from countries other than New Zealand could provide insights in cross-cultural differences. As result the US and the UK samples were purchased. Unfortunately, the great differences observed between the samples at the level of general demographic characteristics meant cross-cultural differences between samples could not be analysed. This is why that aspect of the study was not developed further.

Table 5.20: Female, male and total means for environmental concerns for the total sample and three general samples, with assessment of statistical significance of that difference. Results on significance of one-way between subject ANOVA tests provided for all materials in column that had higher mean.

		Total sample			3 general samples		
		Female	Male	Total	Female	Male	Total
		N 137	N 109	N 246	N 117	N 65	N 182
Biospheric	Mean	5.88	5.36	5.65	5.78	5.24	5.59
	Sig.	.001**			.004**		
Egocentric	Mean	5.76	5.14	5.49	5.76	5.27	5.58
	Sig.	.000**			.007**		
Altruistic	Mean	6.16	5.53	5.89	6.12	5.39	5.86
	Sig.	.000**			.000**		

For all: Maximum number of participants specified at the top; ** p is significant at $p < 0.01$ level (highlighted yellow); * p is significant at $p < 0.05$ level (highlighted yellow).

Table 5.21: Female, male and total means for environmental concerns for the four samples, with assessment of statistical significance of that difference. Results on significance of one-way between subject ANOVA tests provided for all materials in column that had higher mean.

		NZ general			NZ architects			US			UK		
		Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total
		N 38	N 23	N 61	N 20	N 44	N 60	N 37	N 23	N 60	N 42	N 20	N 62
Biospheric	Mean	5.78	5.27	5.59	6.53	5.56	5.87	5.97	5.37	5.74	5.60	5.05	5.43
	Sig.	.148			.008**			.058			.061		
Egocentric	Mean	5.68	5.08	5.45	5.75	4.92	5.19	6.19	5.60	5.96	5.44	5.10	5.33
	Sig.	.081			.025*			.021			.272		
Altruistic	Mean	6.38	5.45	6.02	6.40	5.78	5.98	6.40	5.46	6.04	5.64	5.24	5.52
	Sig.	.001**			.071			.002**			.209		

For all: Maximum number of participants specified at the top; ** p is significant at $p < 0.01$ level (highlighted yellow); * p is significant at $p < 0.05$ level (highlighted yellow).

Chart 5.12: Comparison of environmental concern means per sample.

Chart 5.13: Comparison of environmental motives for gender, for total sample and three general samples combined.

5.4 Summary of sample characteristics and conclusion

The NZ general sample was predominantly female (62%) mainly due to participants recruited from Mainly Music. The sample was about evenly split between young (53%) and older people, and participants were predominantly university or higher educated (75%). 92% own their homes, and on average there were 3.18 persons per household (5% single, 38% couple, 56% three or more people per household). Dwelling age was evenly distributed across the sample. It was also the most conscientious sample.

The NZ architects sample was predominantly male (69%), with an even age split (51% older) and almost all more educated. 84% of them owned their homes, with on average 2.86 people per household (8% single, 37% couple, 43% three or more people per household). Dwelling age had two peaks, one around 1920-49 and one since 1990. They also scored highest on environmental concerns, especially on biospheric concern.

The US sample was predominantly female (62%), younger (60%), with lower education (45%). 75% of the participants owned their homes, with an average 3.02 people per household (15% single, 27% couple, 58% three or more people per household). Most lived in newer houses built since 1970, and the majority lived in houses (73%). Almost the same proportions of participants lived in dwellings of masonry and timber frame (47% vs. 44%). This sample tended to provide highest ratings for most things, which is even clearer when analysing the health ratings of materials (Chapters 6 and 7).

The UK sample was predominantly female (68%), younger (62%) and with lower education (64%). Each of these trends was strongest in this sample. Only 58% of the participants owned their homes, with the lowest number of people living in the household (average 2.61), and with the highest proportion of people living alone (21%) (34% couples, 41% three or more people per household). Dwelling age clearly peaked between 1920 and 1969. 98% of participants lived in masonry dwellings, of which 81% were houses (of which 7% were reported as being semi-detached) and 20% flats. This sample tended to provide the lowest ratings for most things.

Therefore it was possible to observe that the US and the UK samples were more like each other than the two NZ samples. The big differences in the proportions of highly educated and younger/older participants are enough to make these two pairs of samples hard to compare. Furthermore, there are noticeable differences between the US and the UK samples, again limiting their comparability. The US sample had a much higher portion of participants with families and living in houses they own, while the UK sample had the highest proportion of participants who live alone and rent. Therefore, any analysis of the responses received from the three general samples should take account of these differences. The NZ architects sample was expected to differ from the general samples, and has been treated as such throughout the subsequent analyses.

This chapter has shown that there are significant differences between samples and it is useful to understand these before interpreting other results from the survey. Overall, the samples are neither suitable for cross-cultural comparisons, due to too numerous differences, nor adequate to complement each-other in building one complex picture, due to possible cross-cultural distortions. Although inability to compare direct conclusions is seen as a limitation, it should be emphasised that the high level of variability within the total sample indicates their usefulness for the main analyses of this study. The lack of clear comparability on most of the parameters evaluated in this chapter indicates that this is a good, varied sample for evaluation of what the general population thinks about building and furnishing materials and whether there are any predictors of such views. The next chapter, therefore starts with the analysis of health ratings of materials.

Chapter 6

Results for health rating of materials

This chapter deals with the main objectives of the core study, and the thesis, which were to measure what people think about materials commonly used in homes. A survey dealing with the health rating of building and furnishing materials was developed as the main tool for this and this chapter is the first of two dealing with the results from its use. In this chapter the focus is on the results and their descriptive analysis, while the next chapter continues with the inferential analysis of the results. The analyses that follow primarily consider the characteristics of the distribution of health ratings and differences in ratings between materials and sample groups.

This chapter opens with a series of significant observations about the overall patterns in health ratings of materials. This is followed by a detailed discussion of results for each group of materials and individual materials. Although all discussion is based on descriptive statistics, one-way between subjects ANOVA tests were used where relevant to evaluate differences between samples. However, the results of ANOVA tests were omitted, for ease of reading, when they were not adding to the discussion. In the discussion section a combination of key general and specific observations are brought together. This chapter provides some conclusions, but leaves much analysis and more concluding for the subsequent chapter.

6.1 General features of health ratings of materials

6.1.1 Healthy vs. unhealthy materials

The literature discussed in part I clearly indicates a lack of agreement on where even experts would place many materials on the risk scale. Regulations provide a possible answer, but chapter 3 established that these are often behind scientific knowledge. On the other hand, scientific

knowledge is usually hard to source and unlikely to directly impact people's views. Due to such difficulties in this field, and because of the exploratory nature of this study, the results themselves are used to inform an assessment of the benchmark for healthy/unhealthy materials.

However, even while trying to remain unbiased, some principles should be acknowledged. As seen in section 2.3, sustainability literature promotes the principle of using more traditional and more natural materials, such as natural wood, brick, and stone, with the idea that these are generally likely to be healthier. If approached from the opposite perspective, the same principle can be seen as suggesting general avoidance of synthetic substances and materials. Given the discussion in chapter 3 on significant delays in recognition of level of harmfulness of such substances, general avoidance of all that has not been proved as harmless seems sensible. Thus, assumptions here are that more natural materials are healthier and more synthetic materials less healthy.

In addition to these general principles some specific substances and materials are currently suspect for their harmfulness, although still generally available. Products that use formaldehyde and phthalate plasticised vinyl are at the top of such lists (Section 3.3). In domestic spaces these are likely to be found in particleboard and MDF, and vinyl flooring. For the purpose of studying people's views, in the questionnaire these materials were paired with their healthier equivalents of wood and linoleum.

Coating, varnish or paint systems could also offer a wide array of risks. In general terms, because of the solvent content solvent-based products are more recognised health risks, while water-based products are considered more harmless because they use less aggressive solvents. However, this should be seen in relation to potential issues with these less aggressive solvents (Section 3.4.2). Thus, more natural alternatives such as plant and mineral based paints and wood oils (depending on solvent component) could be seen as healthier, although this is hard to verify because many such products have not been tested as much as more conventional products.

Finally, carpets were considered in relation to two concurrent but inherently unrelated risks: VOC emissions, and dust mites and similar irritants. Section 3.4.1 showed a wide range of VOCs can be emitted from carpets, but there is general agreement that emission decreases over time, although the exact rate of decrease has not yet been scientifically established. Dust mites and similar irritants have generally been considered in relation to asthma and similar respiratory problems, and therefore recommendations against older carpets and carpet underlays can be found on Asthma Foundation international websites. In general, the older the carpet the fewer VOCs (perhaps) but greater level of dust mites, and reverse is true for newer carpet (higher levels of VOCs emissions are likely from the underlay but there should be fewer dust mites). Given these complex differences 7+ year old carpet underlay can simultaneously be seen as very unhealthy (due to dust mites) and not too bad due to low VOC content.

Where relevant, characteristics such as these were considered when evaluating the received health ratings of materials, though this is kept to a minimum, with the focus on data presenting its own case.

6.1.2 General characteristics of health ratings of materials and uncontroversially healthy and unhealthy materials

Chart 6.1 compares the means from the total sample compared with the overall mean for all materials of 3.36. This overall mean indicated that materials were generally rated as neutral towards healthy. Of the 28 rated materials, 5 materials had a mean rating over 4 (glass; tiles; wood; natural carpet materials and metal), 8 materials had a mean rating under 3 (7+ year old carpet underlay; solvent-based polyurethane; fibreglass; oil-based paint; particleboard and MDF; inner wall spray foam insulation; stain, dust, moth protection built into carpet; and low/zero formaldehyde particleboard and MDF), while the remaining 15 materials received means between 3 and 4. Therefore, generally participants differentiated between more healthy and less healthy materials.

Based on means it was possible to observe clear groupings of very high or very low ratings. For the purpose of analyses in this chapter these extreme rated materials were used as the benchmarks for healthy and unhealthy materials. Although the purpose of this thesis was not to make conclusive recommendations on which materials are clearly healthy or unhealthy, the materials that fell in these two groups of extreme ratings generally did not contradict the discussion of healthy and unhealthy materials in part I. Therefore for the purpose of clarity of analyses, these were established as uncontroversially healthy or uncontroversially unhealthy materials, forming two groups. The first was the top six rated materials (glass, tiles, wood, natural carpet materials, metal and wool insulation) and the second the bottom six rated materials (old carpet underlay, solvent-based polyurethane, fibreglass insulation, oil-based paint, particleboard and MDF, inner wall spray foam) (Tables 6.1 and 6.2).

Admittedly, the bottom six materials list somewhat differed between the total sample and the NZ architects sample (Table 6.3). The main difference was that in the latter sample fibreglass insulation was not in the bottom six, despite the fact its mean was significantly lower than the mean from the total sample. Rather, carpet with stain, dust and moth protection (mean 2.13) fell into the bottom six ratings from the NZ architects sample. For the top ratings the NZ architects concurred with the total sample for five materials (metal did not appear in their survey).

Table 6.1: Uncontroversially healthy materials with their means and ratings from the NZ architects sample.

	Uncontroversially healthy materials	Mean total sample	Standard deviation total sample	Mean from NZ arch and order
5	Glass	4.50	0.78	4.62 (1)
10	Ceramic, porcelain or stone tiles	4.25	0.91	4.19 (3)
1	Wood	4.19	0.96	4.31 (2)
12	Natural carpet materials	4.07	1.04	4.03 (4)
4	Metal	4.03	0.97	NA
26	Wool	3.95	0.95	3.95 (5)

Table 6.2: Uncontroversially unhealthy materials with their means and ratings from the NZ architects sample.

	Uncontroversially unhealthy materials	Mean total sample	Standard deviation total sample	Mean from NZ arch and order
16	7+ year old carpet underlay	2.38	1.19	1.98 (3)
18	Solvent-based polyurethane	2.38	1.16	1.72 (1)
25	Fibreglass	2.62	1.21	2.25 (8)
21	Oil-based interior paint	2.64	1.12	2.15 (6)
2	Particleboard and MDF	2.68	1.14	2.03 (4)
28	Inner wall spray foam	2.69	1.19	1.95 (2)

6.1.3 Experts?

A frequently observed difference between sample groups was between health ratings from the NZ architects and the three general samples. In fact, the NZ architects sample (N 62) could be considered as more knowledgeable in this area. Therefore their 'more informed' ratings could be used as a baseline against which other opinions could be assessed. However, when exploring this further two other groups were identified as potentially better suited to provide a baseline for accurate health ratings of materials. The first group was called the 'experts' (N 40), and consisted of practicing architects and academics who specified that they teach construction, sustainability, or material related to building science (this eliminated academics teaching other subjects, designers, and draughtsmen who are all less likely to be making direct choices about materials). The second group were participants who responded to the invitation from the BBE (N 8).

For less healthy materials the 'experts' often had higher means than the NZ architects sample, while the BBE group often had the lowest ratings. This would imply that the BBE sample was possibly the most expert in this survey, which is somewhat surprising given only two participants in this subgroup were architects. Interestingly this concurs with the discussion on the role of building biology as leaders in recognition of the health risks associated with the building materials, even if not from an expert platform (section 2.4). Furthermore, this indicates that this group of 'whistle-blowers' has more proactive views than professional 'experts' in this sample. Table 6.3 also contains reference to the order of ratings materials received from the total sample and the NZ architects sample.

However, the BBE sample was too small to be useful for comparative analyses of the results (some tests are impacted by sample sizes), and because the NZ architects sample contained both the BBE sample and the 'experts', it was generally used as a baseline representative of a more knowledgeable group.

6.1.4 Indecisiveness

Standard deviations and 'I don't know 0' responses were also considered indicative of overall patterns in ratings. The average standard deviation was 1.08 and almost exclusively low standard deviations were paired with high ratings of materials; for example glass received the highest overall rating of 4.50 and had the lowest standard deviation of 0.78 and was followed in both by tiles (mean 4.25, SD=0.91), indicating that for these materials responses were most strongly grouped (Table 6.3). At the other extreme, lower overall ratings corresponded to an absence of clear groupings and much higher standard deviations. For example 7+ year old carpet underlay and solvent based polyurethane both had the same mean of 2.38 and high (but not the highest) standard deviations (1.19 and 1.16 respectively). The highest standard deviations were observed for vinyl (mean 3.29, SD=1.24), wall-to-wall carpet (mean 3.03, SD=1.22) and fibreglass (2.62, 1.21) indicating higher variance in these ratings, and thus a wider distribution of ratings.

Table 6.3: Comparison of means, standard deviation and order for all materials for the total sample, compared with means and order from the NZ architects sample and means from the 'experts' and BBE participants.

	Material	Mean total sample (order)	Standard deviation total sample	Mean NZ arch sample (order)	Means from 'Experts'	Means from BBE
	Structural/non-structural materials					
1	Wood	4.19 (3)	0.96	4.31 (2)	4.29	4.14
2	Particleboard and MDF	2.68 (24)	1.14	2.03 (24)	2.13	1.50
3	Low/zero formaldehyde particleboard and MDF	2.99 (21)	1.20	2.73 (17)	2.85	2.38
4	Metal	4.03 (5)	0.97			
5	Glass	4.50 (1)	0.78	4.50 (1)	4.52	4.63
	Floor covering materials					
6	Vinyl	3.29 (16)	1.24	2.48 (19)	2.45	1.50
7	Linoleum	3.57 (10)	1.18	3.49 (9)	3.67	3.00
8	Cork	3.70 (8)	1.11	3.83 (6)	3.80	3.50
9	Laminated wood	3.51 (13)	1.12	3.11 (14)	3.33	2.25
10	Ceramic, porcelain or stone tiles	4.25 (2)	0.91	4.19 (3)	4.10	4.50
11	Wall-to-wall carpet	3.03 (20)	1.22	2.54 (18)	2.72	2.17
	Carpet or rug materials and treatments					
12	Natural materials such as wool, jute, cotton	4.07 (4)	1.04	4.03 (4)	4.00	4.38
13	Synthetics such as nylon, polyester, polypropylene	3.08 (18)	1.07	2.75 (16)	2.88	1.50
14	Stain, dust, moth protection built into carpet	2.74 (22)	1.21	2.13 (23)	2.18	1.00
15	New foam carpet underlay	3.03 (19)	1.20	2.21 (21)	2.35	1.17
16	7+ year old carpet underlay	2.38 (28)	1.19	1.98 (25)	2.05	1.63
	Varnishes and paints					
17	Water-based polyurethane	3.42 (14)	1.00	3.02 (15)	3.05	2.38
18	Solvent-based polyurethane	2.38 (27)	1.16	1.72 (27)	1.82	1.00
19	Wood oils and waxes	3.53 (12)	1.02	3.52 (8)	3.58	3.38
20	Water-based acrylic interior paint	3.38 (15)	0.99	3.16 (12)	3.25	2.75
21	Oil-based interior paint	2.64 (25)	1.12	2.15 (22)	2.20	1.88
22	Plant and mineral paints	3.82 (7)	0.98	3.73 (7)	3.74	3.88
	Curtains/drapes					
23	Thermal or blackout lined curtains/drapes	3.66 (9)	1.09	3.17 (11)	3.24	3.13
24	Unlined/with separate lining curtains/drapes	3.56 (11)	0.98	3.25 (10)	3.18	3.38
	Insulation materials					
25	Fibreglass	2.62 (26)	1.21	2.25 (20)	2.35	1.63
26	Wool	3.95 (6)	0.95	3.95 (5)	3.97	3.88
27	Polyester	3.27 (17)	1.02	3.15 (13)	3.40	2.25
28	Inner wall spray foam	2.69 (23)	1.19	1.98 (26)	1.92	2.86

When designing the surveys it was anticipated that people might not have strong opinions about some building materials. Rather than trying to ‘force’ them to form opinions, the ‘I don’t know’ choice was provided to measure this tendency. This decision was made after assessing the increased likelihood that a proportion of participants might select ‘I don’t know’ rather than properly consider their response. Fortunately, this trend was not observed in the responses. Most respondents varied in their health ratings of materials, although some tended to select ‘I don’t know’ more often than others. The exception to this was five responses from the US sample which almost always selected ‘I don’t know’ for the health rating of materials. In retrospect, these responses should have been identified earlier and removed from the sample, but the fact that they contained data in other parts of the questionnaire obscured the poor quality of data in this important part.

Overall, the frequency of selecting ‘I don’t know’ varied between samples (Table 6.4). The NZ architects sample had no ‘I don’t know’ responses for almost half the materials rated (13 out of 27). The lowest level of indecisiveness for the NZ general sample was observed for two materials (glass and natural carpet materials) with no participants selecting ‘I don’t know.’ For the UK sample the lowest count was two ‘I don’t know’ responses (3%), and five in the US sample (9%). Therefore, the US and UK samples had a higher level of indecisiveness than the two NZ samples, with the NZ architects having the lowest overall rate of indecisiveness. Also, high scoring materials such as wood, glass, and natural carpet materials had low rates of indecisiveness.

However, and more importantly, a range of materials received more ‘I don’t know’ responses than other materials, with not very well known materials generally more often rated ‘I don’t know.’ While reasonable, this seems to have occurred about equally for less known materials, whether unhealthy or healthy. For example the highest ‘I don’t know’ ratings were given to ‘inner wall spray insulation’ and ‘plant and mineral paints’ (in NZ this was qualified by the local product name ‘such as Bio Paints’). These two were followed by new carpet underlay, stain, dust, moth carpet treatment, low/zero formaldehyde particleboard and MDF, which are all materials still under scientific examination (Section 3.4.2).

Furthermore, none of the uncontroversially healthy materials received a high level of indecisiveness rating, while all uncontroversially unhealthy materials received reasonably high indecisiveness rates. This could indicate that participants were less sure about providing negative ratings, thus often opting for ‘I don’t know’ instead of low ratings.

When undertaking inferential analysis, the ‘I don’t know’ responses were treated as ‘missing data’, to eliminate the computing impact of these in means and other analyses.

Table 6.4: Comparison of prevalence of 'I don't know' responses in health ratings of materials by sample. Order (highest to lowest) based on order of means from total sample.

Placement when rated	Material	NZ gen	NZ arch	US	UK	Total
1	Wood	0 0%	0 0%	5 9%	2 3%	7 3%
5	Glass	2 3%	0 0%	5 9%	2 3%	9 4%
11	Wall-to-wall carpet	1 2%	2 3%	7 12%	2 3%	12 5%
12	Natural materials such as wool, jute, cotton	0 0%	0 0%	10 17%	4 7%	14 6%
10	Ceramic, porcelain or stone tiles	3 5%	0 0%	10 17%	3 5%	16 7%
25	Fibreglass	2 3%	0 0%	8 14%	7 12%	17 7%
26	Wool	2 3%	0 0%	10 17%	5 8%	17 7%
9	Laminated wood	4 7%	0 0%	12 20%	2 3%	18 7%
4	Metal	2 3%		8 14%	4 6%	14 8%
13	Synthetics such as nylon, polyester, polypropylene	3 5%	0 0%	12 20%	4 7%	19 8%
6	Vinyl	5 9%	1 2%	9 15%	6 10%	21 9%
7	Linoleum	3 5%	1 2%	10 17%	8 13%	22 9%
21	Oil-based interior paint	3 5%	0 0%	11 18%	9 15%	23 9%
24	Unlined/with separate lining curtains/drapes	2 3%	5 8%	11 19%	5 8%	23 9%
19	Wood oils and waxes	6 10%	0 0%	12 21%	5 8%	23 10%
2	Particleboard and MDF	5 9%	0 0%	14 24%	5 8%	24 10%
20	Water-based acrylic interior paint	3 5%	0 0%	12 20%	9 15%	24 10%
23	Thermal or blackout lined curtains/drapes	3 5%	6 9%	10 17%	6 10%	25 10%
18	Solvent-based polyurethane	8 14%	0 0%	13 22%	7 12%	28 11%
17	Water-based polyurethane	5 8%	1 2%	14 23%	9 15%	29 12%
16	7+ year old carpet underlay	5 9%	4 6%	11 19%	10 16%	30 12%

27	Polyester	12 21%	1 2%	11 18%	6 10%	30 12%
3	Low/zero formaldehyde particleboard and MDF		3 5%	9 15%	12 19%	24 13%
8	Cork	2 10%	1 2%	17 28%	8 13%	28 14%
14	Stain, dust, moth protection built into carpet	12 21%	4 6%	13 22%	6 10%	35 14%
15	New foam carpet underlay	9 16%	5 8%	14 24%	8 13%	36 15%
22	Plant and mineral paints	13 24%	8 13%	12 20%	6 10%	39 16%
28	Inner wall spray foam	14 24%	7 11%	15 25%	11 18%	47 19%

Table 6.4 reports on all rated materials in the order of ratings that they have received (high to low), and this together with chart 6.1, which graphically reports the same information, form the background to subsequent references to the relative order placement of materials.

6.1.5 Patterns in variance of ratings

A high level of diversity in the distribution of the health rating of materials was observed. The key patterns are summarised as follows:

- Pattern 1: general agreement in the rating of a particular material demonstrated by a clear peak in part of the rating range (low, neutral or high) and low standard deviation, with this being fairly consistent between all samples (examples are wood, glass, and ceramic and porcelain or stone tiles).
- Pattern 2: a different rating for a material from NZ architects (academics and practitioners) (example is particleboard and MDF).
- Pattern 3: the rating distribution is fairly 'flat' with a reasonably high standard deviation. This trend often correlated with more participants selecting the 'I don't know' option. Both trends can be seen as measures of indecisiveness. The 'flatness' of the distribution almost always coincided with some level of Pattern 2. For example, the NZ architects rating peaked in a different part of the range from that of the other samples, so to a degree they cancelled each other out for the whole sample (example is low/zero formaldehyde particleboard and MDF).
- Pattern 4: a distribution with two peaks for a similar reason to Pattern 3, but without the cancelling out effect (examples are linoleum and laminated wood).

Lam and Stevens (1994) studied the impact of variance in responses in relation to scale content (high vs. low), intensity in wording used for extreme ends of the scale (strong vs. weak), and the psychological width of the rating scale (wide vs. narrow). In their results changes to any of the above characteristics corresponded to changes in the rating means, standard deviations and skews

received (Lam and Stevens 1994). Using their criteria, the scale used here is narrow (five, rather than seven or more points) and weak (using 'unhealthy' and 'healthy' for extremes rather than 'absolutely/strongly unhealthy' and 'absolutely/strongly healthy'). They observed that using a narrow rating scale produced higher item means and more negative item skew than a wide rating scale (Lam and Stevens 1994). Furthermore, the low polarisation of content, on a narrow scale with weak wording, produced the most even distribution of ratings, while there was much more polarisation of ratings when the content was more polarised (Lam and Stevens 1994).

Comparing the observations of Lam and Stevens (1994) with the patterns observed in these results, it seems Pattern 1 with its clear, high grouping of responses could reflect higher polarisation of content, which in this case means clear differences between the rated materials, while Pattern 3 with its fairly evenly distributed responses could reflect a low level of polarisation of the materials rated. For example, having items such as 'water-based polyurethane' and 'solvent-based' polyurethane' seems to have worked as a polarisation strategy with generally a higher diversification of ratings for both. The proximity of the health rating of 'wood' and 'particleboard and MDF' also supports polarisation, although this was not observed for the placing of vinyl and linoleum next to each other. References to these patterns are made where relevant throughout the text.

Unfortunately, the study of Lam and Stevens (1994) was based on a sample smaller than here (N 167 vs. N 247) and was not as culturally or demographically diverse, which implies that their observations should be considered carefully as other interpretations of these results might be possible.

6.2 Descriptive report on health rating of structural/non-structural materials

By design, this group contained a mixture of materials that were unlikely to be rated as posing risks to health, such as glass, metal and to a degree wood, and materials that were particularly important to be rated, such as particleboard and MDF and low/zero formaldehyde particleboard and MDF, as the health problems associated with these could be known to the general population. Consequently, the results for these two groups of materials are discussed separately.

Although histograms can be seen as the most accurate visual representation of results, during analysis line charts were found to make some trends much clearer. Therefore, all health ratings of materials are depicted with histograms, while line diagrams were used only when there was a specific trend to illustrate. Histograms contain a table of real counts of responses in each category, as represented on Y axis. The scale terms were abbreviated in those tables due to space limitations (UH 1 = 'unhealthy 1,' 2 = '2,' N 3 = 'neutral 3,' 4 = '4,' and H 5 = 'healthy 5'). All line diagrams use responses as percentages to makes them comparable.

6.2.1. Glass, wood and metal

The health rating for glass had the highest level of consistency of all rated materials in the survey. Glass was rated as healthy, with a mean of 4.50 and a standard deviation of 0.78 (Table 6.5; Chart 6.2). In the total sample only two participants rated glass as unhealthy (categories '1' and '2'), and there was a low level of indecisiveness, 9 (4%). Overall 63% of the total sample rated glass as 'healthy 5.' This pattern was consistent between the four samples.

Table 6.5: Mean, standard deviation and standard error for glass, wood and metal.

	Glass				Wood				Metal			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	59	4.49	0.78	0.10	57	4.32	0.77	0.10	58	4.18	0.92	0.12
NZ architects	65	4.62	0.68	0.08	62	4.31	0.92	0.12	*			
US	59	4.59	0.81	0.11	57	4.10	1.12	0.16	59	4.08	1.00	0.14
UK	62	4.30	0.81	0.11	62	4.00	1.01	0.13	62	3.84	0.97	0.13
Total sample	245	4.50	0.78	0.05	238	4.19	0.96	0.06	179	4.03	0.97	0.08

* NZ architects sample did not rate this material.

Wood also received reasonably consistent high scores although these were lower than for glass (Table 6.5; Chart 6.3). The overall mean was 4.16 with a standard deviation of 0.96. Only 11 participants (4.6%) rated wood in the unhealthy range, and only 7 participants (3%) were indecisive. Variations between samples were not significant, but indicate that wood was rated more highly by both NZ samples (means 4.32 and 4.31 for the NZ general and NZ architects samples respectively), than by the US and UK samples (means 4.10 and 4.00 respectively).

The unsolicited comments from the NZ general paper surveys remarked on wood rot, indicating that some participants considered the possible deterioration of wood when rating it, which could have produced more mid-range scoring. It also indicates that some participants struggled to focus on considering materials within the indoor context as specified in the survey introduction, where water damage is less likely.

Metal was also rated highly with reasonable consistency (Table 6.5; Chart 6.4), but with a much higher proportion of responses in the neutral category and a consequent lower mean of 4.03, and higher standard deviation of 0.97. Although some differences between samples were observed, such as means decreasing from the NZ general to the US and UK samples (4.18, 4.08 and 3.84 respectively), these were neither statistically nor nominally significant differences. Furthermore, it

was possible that similar weathering concerns (rust and oxidation) could have influenced the scores. (The NZ architects sample did not have this question.)

Chart 6.2: Health ratings for glass.

Chart 6.3: Health ratings for wood.

Chart 6.4: Health ratings for metal.

6.2.2 Particle board and MDF, and low/zero formaldehyde particleboard and MDF

The surveys asked for a health rating of particle board and MDF, without reference to formaldehyde levels, assuming that whatever was locally available was 'normal.' Because at the time of development and distribution of the questionnaires there had been no significant public discussion of the formaldehyde content of such products in New Zealand, the rating of 'low/zero formaldehyde

particleboard and MDF' was not included in the NZ general survey. However, for the US and UK samples, it was felt there had been discussion of the issues, due to the recent legislative ban on formaldehyde use in the US as discussed in part I, and thus it was included in these questionnaires. By pairing the materials (particleboard and MDF, and low/zero formaldehyde particleboard and MDF) it was hoped to measure the perceived difference between materials based on the levels of formaldehyde they contain.

The health ratings of particle board and MDF varied greatly, providing a more even response distribution (Pattern 3) (Table 6.6; Chart 6.5). Typical for this pattern, the indecisiveness rate is elevated with 10% of the total sample choosing 'I don't know' (24% of the US sample). Although the overall mean of 2.68 was one of the five lowest in the survey, the standard deviation was 1.14. This is one material where the NZ architects rating differed significantly from the other samples, with a mean 0.65 lower than the total mean and a lower standard deviation of 0.80, indicating a very strong grouping of these ratings. A line chart makes this clear (Chart 6.7).

Table 6.6: Mean, standard deviation and standard error for particle board and MDF, and low/zero formaldehyde particle board and MDF.

	Particle board and MDF				Low/zero formaldehyde particle board and MDF			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	57	2.79	1.08	0.15	*			
NZ architects	65	2.03	0.80	0.09	65	2.73	1.09	0.14
US	59	3.18	1.25	0.19	60	3.06	1.38	0.19
UK	62	2.93	1.16	0.15	62	3.27	1.10	0.16
Total sample	243	2.68	1.14	0.08	187	2.99	1.20	0.10

* NZ general sample did not rate this material.

The health ratings of low/zero formaldehyde particleboard and MDF were similar to ratings of the unqualified versions of these materials (Table 6.6; Chart 6.5), but with a higher overall mean of 2.99 and somewhat higher standard deviation of 1.20, possibly indicating that low/zero formaldehyde products were seen as healthier, but that many participants were uncertain about this. Indecisiveness was 13% overall. However, when those choosing 'I don't know' were considered, this was one of the rare questions where NZ architects selected this option (3 participants). This indecisiveness in the NZ architects sample contrasted with the ratings for particleboard and MDF where this did not happen, possibly indicating less perceived certainty about these newer products. Similarly the UK sample had an increase in indecisiveness (from 5 to 12 responses), although the US sample did the opposite (from 14 to 9 responses).

Comparing the ratings for normal and low/zero formaldehyde wood products the overall mean increased from 2.68 to 2.99, along with the standard deviation from 1.14 to 1.20, respectively. The greatest increase in the means for 'normal' and low/zero formaldehyde wood products was in the NZ architects sample (2.03 to 2.73 respectively), with a respective increase in standard deviation from 0.80 to 1.09. However, the US sample did not follow this general trend, with a decrease in the means for 'normal' and low/zero formaldehyde wood products from 3.18 to 3.06 respectively, but with a respective increase in standard deviation from an already high 1.25 to 1.38. Analysing the distribution showed that together with the decrease in indecisiveness for low/zero formaldehyde products (from 14 to 9 responses), there was an increase in 'unhealthy 1' ratings (from 5 to 10 responses). These surprising results either indicate a recognition of the problems associated with formaldehyde free products, or that inclusion of the word 'formaldehyde' negatively influenced the ratings, even though 'low/zero formaldehyde' was the descriptor. Again, the NZ architects ratings differed from the other samples, but only by a little. The NZ architects mean was only 0.26 lower than the total mean with a standard deviation of 1.09, indicating a more even distribution of these ratings (Charts 6.5,6.7). Comparing the two line charts for the 'normal' and low/zero formaldehyde wood products, it is clear the differences are less striking for the low/zero formaldehyde ratings. (The NZ general sample did not have this question.)

Chart 6.5: Health ratings for particleboard and MDF.

Chart 6.6: Health ratings for low/zero formaldehyde particle board and MDF.

Although there were some observable differences in means between the health ratings received for 'normal' and low/zero formaldehyde particleboard and MDF, to explore those further paired sample t-tests were conducted and a series of line diagrams developed comparing these ratings for each of the three main samples which rated low/zero formaldehyde products (NZ general sample did not have that question) (Charts 6.9-6.11). The tests and charts demonstrated the health ratings were very similar for the US and the UK samples but noticeably different for the NZ architects sample. For 94 participants from these samples, the paired-sample correlation was 0.565, $p=0.000$, significant at $p<0.05$ level. Similarly, the line diagrams show almost identical rating profiles for the US and the UK samples, although when the individual ratings were analysed they clearly showed that a majority of participants did not rate these materials the same. This strongly suggests that participants in these two general samples struggled to articulate the difference between the two materials, possibly even being unable to recognise what risk could be related with either.

Interestingly, although there is much clearer difference in two ratings received from the NZ architects sample (Chart 6.9), this difference does not appear very strong, and indicates that even if the risks from formaldehyde might be recognised, the quality of alternatives is not.

Chart 6.9: Health ratings for particleboard and MDF normal and low/zero formaldehyde from the NZ architects sample.

Chart 6.10: Health ratings for particleboard and MDF normal and low/zero formaldehyde from the US sample.

Chart 6.11: Health ratings for particleboard and MDF normal and low/zero formaldehyde from the UK sample.

6.3 Descriptive report on health rating of floor covering materials

Generally, most of the materials in this group exhibited bi-polar tendencies (Pattern 4). Like particleboard and MDF, the NZ architects health ratings strongly impacted on this bi-polarity, as their ratings peak to one side of neutral compared to the three general samples. These differences can be seen in the line diagrams. In fact the strong difference in ratings of the NZ architects was

present even when the overall bi-polar tendencies were not strong, as in the example of wall-to-wall carpet.

6.3.1 Vinyl and linoleum

Vinyl and linoleum appear to be hard to differentiate for many people, which is unfortunate given that vinyl is significantly more of a health hazard than linoleum (Section 3.3). This makes it useful to discuss their ratings comparatively (Tables 6.7; Charts 6.12-6.15). On average, vinyl was rated lower than linoleum, 3.29 compared to 3.57, and both had fairly high standard deviations (vinyl 1.24, linoleum 1.18), with vinyl having the highest standard deviation of all materials rated in the survey.

Table 6.7: Mean, standard deviation and standard error for vinyl and linoleum.

	Vinyl				Linoleum			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	58	3.31	1.21	0.17	58	3.52	1.18	0.16
NZ architects	65	2.48	1.23	0.15	64	3.49	1.33	0.17
US	60	3.90	1.03	0.14	58	3.79	1.05	0.15
UK	62	3.65	0.95	0.13	61	3.50	1.09	0.15
Total sample	245	3.29	1.24	0.08	241	3.57	1.18	0.08

However, the nominal difference between the ratings of the two materials was still small. Ratings of both vinyl and linoleum exhibited a strong tendency towards bi-polar distribution for all three general samples, indicating a level of confusion regarding the perceived healthiness of these materials (Charts 6.14-6.15).

Only the NZ architects exhibited a noticeable difference in the pattern of rating vinyl and linoleum (Charts 6.14-6.15). Their mean rating for vinyl was 2.48 (SD 0.15), and 3.49 for linoleum (SD 1.33), almost a whole point difference. Furthermore, although the NZ architects mean rating of linoleum was comparable with the means of the other samples (greatest difference of 0.3), there were larger differences in the mean rating of vinyl, with the NZ architects almost 1.5 points lower than the highest rating of 3.90 (SD 0.14) from the US sample. This difference was significant, as confirmed by a one-way between subjects ANOVA test conducted to compare the effect of sample on health rating of vinyl. There was a significant sample effect on the health rating, at the $p < 0.01$ level for the four samples [$F(3,220)=18.15$, $p=0.000$], with the NZ architects rating vinyl lower than the other samples.

Chart 6.12: Health ratings for vinyl. **Chart 6.13: Health ratings for linoleum.** **Chart 6.14: Health ratings for vinyl (line).** **Chart 6.15: Health ratings for linoleum (line).**

The similarity in health rating for vinyl and linoleum was even stronger when the means of the three general samples were considered (Tables 6.7). The average mean for vinyl from the three general samples was 3.62, and 3.58 for linoleum, a difference of 0.04, which translates into 6.25 points of difference in rating or 3 people (2%) rating linoleum a couple of points higher on the scale. Therefore, the difference in overall means for vinyl and linoleum were strongly influenced by the NZ architects mean rating. Nevertheless, in all samples some participants rated vinyl lower than linoleum, thus for them possibly exhibiting an understanding of the health risks associated with vinyl, but as the opposite trend in rating also occurred the overall means did not change.

These observations were tested for the impact of the NZ architects sample using two strategies: paired-sample t-tests were conducted and a series of line diagrams developed comparing the vinyl and linoleum ratings for each of the four main samples (Charts 6.16-6.19). The tests and charts demonstrated the health ratings were very similar for all three general population samples but noticeably different for the NZ architects sample. For 212 participants from the total sample, the paired-sample correlation was 0.515, $p=0.000$, significant at $p<0.05$ level. An average rating of vinyl and linoleum by line within samples was also developed as an approximate demonstration of the trend.

Chart 6.16: Health ratings for vinyl and linoleum from the NZ general sample.

Chart 6.17: Health ratings for vinyl and linoleum from the NZ architects sample.

Chart 6.18: Health ratings for vinyl and linoleum from the US sample.

Chart 6.19: Health ratings for vinyl and linoleum from the UK sample.

The high level of similarity in ratings for vinyl and linoleum in the three general population samples from three different countries implies these participants struggled to differentiate and understand the difference between vinyl and linoleum. Although only based on anecdotal evidence, it seems both materials are often called by the same name, being vinyl in NZ and linoleum in the UK. If this assumption is true, then the samples from the two countries might identify one of the two materials as healthier, and probably the one in popular local use. However, these assumptions are not confirmed by the survey results, with the strongly similar ratings of these materials in all three countries. This absence of any differentiating patterns, even between samples from different countries, is problematic given that vinyl is recognised for its adverse health effects, while linoleum has not raised such concerns.

6.3.2 Cork and laminated wood

When analysing the patterns of materials ratings for cork and laminated wood in terms of distribution they appear similar as with vinyl and linoleum (Table 6.8; Chart 6.20-6.21). The line charts 6.22-6.25 clearly show similarities in health ratings for cork and laminated wood, compared to the vinyl-linoleum average for each sample (for the NZ architects actual vinyl and linoleum ratings were used).

Table 6.8: Mean, standard deviation and standard error for cork and laminated wood.

	Cork				Laminated wood			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	21*	4.30	0.87	0.19	56	3.36	1.18	0.16
NZ architects	64	3.83	1.09	0.14	63	3.11	1.11	0.14
US	60	3.67	1.21	0.18	60	3.90	1.10	0.16
UK	62	3.34	1.04	0.14	62	3.75	0.96	0.13
Total sample	207	3.70	1.11	0.08	241	3.51	1.12	0.08

* NZ short sample did not rate this material.

Chart 6.20: Health ratings for cork.

Chart 6.21: Health ratings for laminated wood.

The general distribution for vinyl and linoleum was very similar to that of cork and laminated wood, especially for the US and UK samples. The NZ short sample did not have a question about cork which makes the NZ general sample smaller, and its mean of 4.30 less reliable. However, its ratings followed those of the NZ architects: cork was rated by both more highly than laminated wood, and more positively than by the US and UK samples (cork means of 4.30 and 3.83 compared to 3.67 and 3.34 for the NZ long, NZ architects, US and UK respectively), while laminated wood was rated lower (means of 3.36 and 3.11 compared to 3.90 and 3.75 for the NZ general, NZ architects, US and UK respectively) (Table 6.8). These differences could be related to differences in availability of products in local markets. For example, despite the recent development and diversification of laminate flooring ranges, this product is almost exclusively imported to NZ, and could thus be seen as not very common.

The similarities of the flooring materials ratings can perhaps be explained by the strong tendency of some participants to rate the majority of materials in the same way, somewhere between 'neutral 3' and 'healthy 5.' This situation seems consistent for materials without a strong differentiation of ratings, where participants seem un-opinionated and apparently 'indifferent' about the material's impact on health.

Observing this possible level of 'indifference' towards flooring materials is relevant, because during the questionnaire development it was assumed that while the general population might struggle to name the substructure supporting the flooring material (e.g. concrete slab, wood or particleboard subfloor), most people would be able to name, describe and probably have an opinion about the flooring they see on a daily basis. Therefore, the questionnaire was developed to focus on the materials people see in their homes. While it seems participants can recognise and name many of the commonly used flooring materials, the ratings indicate these materials were poorly differentiated when it comes to their impact on health. Vinyl and linoleum were treated as virtually

the same, while cork and laminated wood were also rated similarly. The exceptions in the flooring materials group were ceramic, porcelain or stone tiles and wall-to-wall carpet.

Chart 6.22: Health ratings for cork and laminated wood, compared with the average ratings for vinyl and linoleum for the NZ general sample.

Chart 6.23: Health ratings for cork and laminated wood, compared with the average ratings for vinyl and linoleum for the NZ architects sample.

Chart 6.24: Health ratings for cork and laminated wood, compared with the average ratings for vinyl and linoleum for the US sample.

Chart 6.25: Health ratings for cork and laminated wood, compared with the average ratings for vinyl and linoleum for the UK sample.

6.3.3 Ceramic, porcelain or stone tiles and wall-to-wall carpet

Ceramic, porcelain or stone tiles were rated jointly and received the second highest overall health rating with a mean of 4.25 and a low standard deviation of 0.91, both second only to glass (Table 6.9; Chart 6.26). The ratings were similar to glass and wood, but with a higher proportion of 'I don't know' responses (7% rather than 4% for glass and 3% for wood), and a slightly stronger negative rating than for glass (10 responses in 1-2 ratings, against 2 for glass). Four of those low ratings came from the NZ architects sample. In every other way, ceramic, porcelain or stone tiles received consistent and clear high positive ratings.

In contrast, wall-to-wall carpet had more diverse health ratings (Table 6.9; Chart 6.27), with a mean of 3.03, almost exactly 'neutral 3' and standard deviation of 1.22, the second highest in the survey.

Table 6.9: Mean, standard deviation and standard error for ceramic, porcelain or stone tiles, and wall-to-wall carpet.

	Ceramic, porcelain or stone tiles				Wall-to-wall carpet			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	58	4.30	0.89	0.12	57	3.53	1.24	0.16
NZ architects	64	4.19	0.94	0.12	62	2.54	1.04	0.13
US	60	4.48	0.79	0.11	57	3.11	1.27	0.17
UK	62	4.07	0.97	0.13	62	2.98	1.15	0.15
Total sample	244	4.25	0.91	0.06	238	3.03	1.22	0.08

Chart 6.26: Health ratings for ceramic, porcelain or stone tiles.

Chart 6.27: Health ratings for wall-to-wall carpet.

Furthermore, wall-to-wall carpet had different rating patterns in different samples, indicating a high level of diverse views (Chart 6.28). The NZ general sample had strong bi-polarity, with two almost equally strong peaks in neutral and healthy (19 and 18 responses respectively). A similar but much less pronounced trend was observed in the US sample which had a primary peak in 'unhealthy 2' to 'neutral 3' (16 and 14 responses respectively) and a secondary peak in 'healthy 5' (11 responses). In contrast, the NZ architects and UK samples peak in unhealthy to neutral and neutral respectively, and both had a very small number of high health ratings of carpet. These samples also had the lowest means for wall-to-wall carpets (2.54 and 2.98 for the NZ architects and UK samples respectively, compared to 3.11 and 3.53 for the US and NZ general samples respectively). This was especially clear in the NZ architects sample where negative to neutral ratings predominate, with only one participant rating wall-to-wall carpet as 'healthy 5.'

6.4 Descriptive report on health rating of carpet or rug materials and treatments

Generally, the health ratings of carpet and rug materials and treatments came in two clear groups. The materials, divided into natural and synthetics, received polarised responses indicating that natural carpet and rug materials were seen as healthier than synthetic materials, while the treatments and underlays had a much more even ratings distribution, resembling those of other flooring materials. Thus, the two groups are discussed separately.

6.4.1 Carpet and rug materials

The mean health ratings of 'natural materials such as wool, jute, cotton' were one whole point higher than 'synthetics such as nylon, polyester, polypropylene' (means 4.07 and 3.08, and standard deviations 1.04 and 1.07 respectively) (Table 6.10; Charts 6.29-6.30). From charts 6.29-6.30, it is clear that natural carpet materials were rated higher and that there was consistency in these ratings (means 4.44, 4.03, 3.98 and 3.80 and standard deviations 0.92, 0.98, 1.09 and 1.09 for the NZ general, NZ architects, US and UK respectively). However, the synthetic carpet materials were not rated low, but rather had a strong peak in 'neutral 3' and all four samples had the highest grouping of scores at this point. The UK sample had the strongest peak with almost half of the sample rating synthetic carpet materials 'neutral 3' (mean 3.21, SD 0.90), while the US ratings were grouped between neutral and healthy, producing the highest overall mean rating of 3.49 (SD 1.14). In contrast, the two NZ samples both rated synthetic carpet materials in the neutral to unhealthy range (means 2.98 and 2.75, for the NZ general and NZ architects samples, with the same standard deviation of 1.06). This trend in ratings was more pronounced for the NZ architects sample, which had the lowest mean rating for synthetic carpet materials.

The polarisation of mean health ratings between natural and synthetic carpet materials was stronger in the two NZ samples (just under 1.5 points for the two NZ samples compared with 0.5 points for the US and UK samples). This also relates to the tendency of the NZ sample to give high ratings to other natural materials.

The early surveys particularly polarised the health ratings given to carpet materials. In the NZ general long survey the list of synthetic carpet and rug materials was longer and included: nylon, polyester, polypropylene, acrylic and synthetic blends. Unfortunately, with only 23 responses this sample is not large enough to be reliable, but indicates that the synthetic blends were rated higher than any of the individual synthetic materials (mean 3.22 vs. 2.95-3.10 for the rest). This implies a contradiction of general trust in synthetics, whilst recognising the shortcomings of individual synthetic materials. Acrylic, a reasonably new use in carpets and rugs, received the lowest ratings with mean 2.95. Furthermore, the overall mean from the NZ short sample was much lower than any of the means in the NZ long (2.91 vs. 2.95-3.22), which could indicate a change in ratings following the change to the list of materials being rated. However, the ratings the NZ long sample gave to the long list of synthetic carpet materials seemed similar to the ratings from the international samples, suggesting there could be another factor influencing these differences, perhaps related to the modest sizes of the separate NZ general samples (N 23 for long, N 37 for short). When comparing these results with all other results, ratings received for all synthetic carpet materials were averaged and rounded.

Table 6.10: Mean, standard deviation and standard error for natural materials such as wool, jute, cotton and synthetics such as nylon, polyester, polypropylene.

	Natural materials such as wool, jute, cotton				Synthetics such as nylon, polyester, polypropylene			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	60	4.44	0.92	0.12	59	2.98	1.06	0.14
NZ architects	65	4.03	0.98	0.12	65	2.75	1.06	0.13
US	59	3.98	1.09	0.16	59	3.49	1.14	0.17
UK	61	3.80	1.09	0.15	62	3.21	0.90	0.12
Total sample	245	4.07	1.04	0.07	245	3.08	1.07	0.07

Chart 6.29: Health ratings for natural materials such as Wool, Jute, Cotton.

Chart 6.30: Health ratings for synthetics such as Nylon, Polyester, Polypropylene.

6.4.2 Carpet underlays and treatments

The questionnaire asked for a health rating for '7+ year old carpet underlay' to represent the old and contrast with the rating of 'new foam carpet underlay' (Table 6.11; Charts 6.31-6.32). Although less polarised than for carpet materials, the two sets of ratings differ as might be expected, with old underlays rated as less healthy. In fact, the mean health rating for old underlay (2.38, standard deviation 1.19) was one of the two lowest means in the survey. Overall old underlay was strongly rated in the neutral to unhealthy range, although with a fairly even distribution across categories 1-3. In the US sample this fairly even distribution continued into healthy range. When rating old carpet underlay, the NZ general sample had the highest proportion of 'neutral 3' ratings at 39% (with 38% in the two unhealthy categories), while the NZ architects and US samples peaked in 'unhealthy 1' (34% and 22% respectively). Indecisiveness was also evaluated, forming 12% of the total sample.

Similarly to the wall-to-wall carpet ratings, the UK sample was closest to the unhealthy rating given by the NZ architects for 7+ year old carpet underlay (means 2.31 and 1.98 for the UK and the NZ architects, compared with 2.31 and 2.60 for the US and NZ general samples respectively).

There was a noticeable pairing of samples in the results. Apart from natural carpet materials, the NZ architects rated carpets in all forms lower than the other three samples. However, for some carpet materials the NZ general and UK samples were closer to the NZ architects ratings. This applied to the higher ratings of natural and lower ratings of synthetic carpet materials and carpet treatments of the NZ general sample, and the low ratings for 'wall-to-wall carpets' and '7+ year old carpet underlay' of the UK sample. This could be relevant given the on-going Asthma Foundation educational programme regarding the health issues associated with wall-to-wall carpets, where old carpet underlays are discussed as particularly dangerous sources of dust mites and similar allergens. Thus, apart from the NZ architects sample, which demonstrated the highest level of awareness of risks throughout the survey, the UK sample indicated a higher understanding of the health disadvantages of wall-to-wall carpets and old carpet underlays than the other two general samples.

However, new carpet underlay received mixed ratings and elevated indecisiveness (15% of total sample), indicating that while the participants perceived old carpet underlays as unhealthy, many found it harder to provide a health rating for new carpet underlays. The overall mean was 3.03, with a standard deviation of 1.20, and all four samples had the highest proportion of responses in the 'neutral 3' (31% overall), accompanied by a fairly even distribution of other ratings. Furthermore, the distribution of ratings for new carpet underlay is similar to that of vinyl and linoleum.

Table 6.11: Mean, standard deviation and standard error for new foam carpet underlay, 7+ year old carpet underlay and stain, dust, moth protection built into carpet.

	New foam carpet underlay				7+ year old carpet underlay				Stain, dust, moth protection built into carpet			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	57	3.22	1.14	0.16	57	2.60	1.12	0.15	57	2.57	0.98	0.14
NZ architects	63	2.21	0.97	0.13	64	1.98	0.93	0.12	65	2.13	1.01	0.13
US	58	3.50	1.17	0.18	57	2.71	1.44	0.21	59	3.11	1.27	0.19
UK	62	3.36	1.09	0.15	62	2.31	1.17	0.16	62	3.24	1.25	0.17
Total sample	240	3.03	1.20	0.08	242	2.38	1.19	0.08	243	2.74	1.21	0.08

Chart 6.31: Health ratings for new foam carpet underlay.

Chart 6.32: Health ratings for 7+ year old carpet underlay.

Chart 6.33: Health ratings for stain, dust, moth protection built into carpet.

‘Stain, dust, moth protection built into carpet’ overall had a low mean of 2.74, with a standard deviation of 1.21. This is one of the materials where the ratings from the NZ architects sample, which peaked at ‘unhealthy 2’ (mean 2.13, SD 1.01), differed from the other samples, which peaked at ‘neutral 3’ (means 2.57, 3.11 and 3.24, and standard deviations 0.98, 1.27 and 1.25 for the NZ general, US and UK samples respectively). It is worth observing that without the NZ architects, the other three general samples had a mean of virtually neutral (2.97). Also worthy of note is that the mean for stain, dust, moth protection built into carpet from the NZ architects sample was one of their lowest ratings.

6.5 Descriptive report on health rating of varnishes and paints

This discussion separates varnishes (polyurethanes and wood oils), and paints. The distribution of health ratings for varnishes and paints exhibited a new pattern; the ratings had a small peak, usually in 'neutral 3,' with the majority either grouped between neutral and healthy or neutral and unhealthy. This means that although ratings differed between samples, generally products were either seen as consistently unhealthy, or healthy.

6.5.1 Varnishes

The ratings of water-based polyurethane, solvent-based polyurethane and wood oils and waxes are important because these products can have very different health impacts. The polarisation in ratings between water-based and solvent-based polyurethanes was very clear (Table 6.12; Charts 6.34-6.39). The former was rated in the neutral to healthy range with an overall mean of 3.42 and standard deviation of 1.00, while the latter was in the neutral to unhealthy range with a mean of 2.38, almost a whole point lower, and standard deviation of 1.16. They both had similar rates of indecisiveness of 11-12%, which although somewhat elevated were not as high as for other materials.

Table 6.12: Mean, standard deviation and standard error for water-based and solvent-based polyurethane, and wood oils and waxes.

	Water-based polyurethane				Solvent-based polyurethane				Wood oils and waxes			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	59	3.38	1.03	0.14	59	2.38	1.12	0.16	59	3.80	0.90	0.12
NZ architects	65	3.02	0.86	0.11	65	1.72	0.88	0.11	65	3.52	0.95	0.12
US	60	3.76	1.02	0.15	60	3.17	1.19	0.17	57	3.49	1.24	0.18
UK	62	3.67	0.96	0.13	60	2.48	1.00	0.14	61	3.40	0.99	0.13
Total sample	246	3.42	1.00	0.07	244	2.38	1.16	0.08	242	3.53	1.02	0.07

There were differences in the distribution of health ratings for this group of varnishes. The ratings by the NZ architects again differ from the other samples and influenced the overall results. For both water-based and solvent-based polyurethane the mean rating from the NZ architects was lower than the mean of the three general samples (3.02 compared to 3.60, and 1.72 compared to 2.68 respectively). Furthermore, while the three general population samples all rated water-based polyurethane in the neutral to healthy range (with 7% of ratings in unhealthy '1' or '2'), the NZ architects almost exclusively rated it neutral, and with more 'unhealthy 1' (5%) than 'healthy 5' (3%) ratings (Chart 6.34,6.37; Table 6.12). Similarly, while the three general samples all rated solvent-based polyurethane in the neutral to unhealthy range (with 13% of ratings in healthy '4' or '5'

range), 86% of the NZ architects rated it unhealthy '1' or '2', with 9% 'neutral 3' and only 5% in healthy '4' and '5' (Chart 6.35,6.38; Table 6.12). The same trend did not occur in health ratings of wood oils and waxes where all four samples were similar with 0.40 maximum difference in means (Chart 6.36,6.39; Table 6.12).

Chart 6.34: Health ratings for water-based polyurethane.

Chart 6.35: Health ratings for solvent-based polyurethane.

Chart 6.36: Health ratings for wood oils and waxes.

Therefore, it is possible to conclude that the NZ architects strongly rated water-based polyurethane as neutral and solvent-based polyurethane as unhealthy. This contrasts with the neutral to healthy rating for the former and neutral to unhealthy for the latter from the three general population samples. This again indicates a stronger polarisation in ratings by the NZ architects, whereas the three general samples tend to assign more neutral and positive ratings for most materials.

Chart 6.37: Health ratings for water-based polyurethane. **Chart 6.38: Health ratings for solvent-based polyurethane.** **Chart 6.39: Health ratings for wood oils and waxes.**

6.5.2 Paints

While the NZ architects somewhat polarised the health ratings of varnishes, for paints they accentuated trends shared by all samples (Charts 6.40-6.45). Of the three different types of paint rated, water-based acrylic interior paint had the highest overall mean of 3.38 and standard deviation of 0.99 (Table 6.13). The ratings were strongly grouped in 'neutral 3' (39% of total), with almost as many ratings in healthy '4' and '5' (38% of total). There were no significant differences in ratings between samples, but the line diagram shows the NZ architects ratings were mostly grouped in the

‘neutral 3’ category, in contrast to the more pronounced neutral to healthy grouping of ratings in all other samples (Charts 6.43-6.45).

One relevant feature was the similarity between the health ratings for water-based polyurethane and water-based acrylic paints, with overall means of 3.42 and 3.38, and standard deviations of 1.00 and 0.99, respectively, and this is reflected in the line diagrams for these products (Charts 6.37,6.43; Tables 6.12-6.13). However, two opposing trends were also observed. For both NZ samples, the mean rating of water-based acrylic paint was higher than that of water-based polyurethane (3.53 and 3.38 for the NZ general sample, and 3.16 and 3.02 for the NZ architects sample, respectively). In both samples there was also an increase in number of ratings in the healthy ‘4’ and ‘5’ categories. In contrast, the US and the UK sample means had the opposite trend (3.46 and 3.76 for the US, and 3.42 and 3.67 for the UK samples, respectively for paint and polyurethane), again reflected in the distribution of mean ratings (Charts 6.37,6.43; Tables 6.12-6.13). These observations imply that water-based paints and varnishes are seen as similar in terms of their health impact, and that there are cross-cultural differences, indicating a higher level of confidence in the healthiness of interior paints in the NZ samples, than in those for the US and UK.

Table 6.13: Mean, standard deviation and standard error for water-based acrylic interior paint, oil-based interior paint, and plant and mineral paints, such as Bio Paints.

	Water-based acrylic interior paint				Oil-based interior paint				Plant and mineral paints, such as Bio Paints			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	57	3.53	1.03	0.14	57	2.71	1.15	0.15	55	4.05	0.95	0.14
NZ architects	64	3.16	0.80	0.10	65	2.15	0.92	0.11	64	3.73	0.94	0.13
US	60	3.46	1.17	0.17	60	3.12	1.20	0.17	60	3.79	0.99	0.14
UK	62	3.42	0.94	0.13	61	2.73	1.04	0.15	60	3.74	1.01	0.14
Total sample	243	3.38	0.99	0.07	243	2.64	1.12	0.08	240	3.82	0.98	0.07

Oil-based interior paint had a much lower overall rating with a mean of 2.64 and standard deviation of 1.12 (Table 6.13; Chart 6.41,6.44). While the majority of ratings were strongly grouped in the neutral to unhealthy range (71% of total), the NZ architects sample rated more in unhealthy ‘1’ and ‘2’ range (72%), and had the lowest mean, being almost one point lower than the highest mean (2.15 compared to 3.12 for the US sample). This could be seen as the NZ architects sample accentuating the general trend captured in the three general samples. The ratings of oil-based paint were lower than those of water-based acrylic paint, but still noticeably higher than the lowest ratings in this group, which were given to solvent-based polyurethane.

The highest health ratings in this group were generally for plant and mineral paints (for NZ samples Bio Paints were given as an example in the questionnaire) with the overall mean being 3.82, and standard deviation 0.98 (Table 6.13; Chart 6.42,6.45). There was little difference between samples with means ranging from 3.73 for the NZ architects to 4.05 for the NZ general sample, and the distributions were also similar.

Chart 6.40: Health ratings for water-based acrylic interior paint.

Chart 6.41: Health ratings for oil-based interior paint.

Chart 6.42: Health ratings for plant and mineral paints, such as Bio Paints.

Chart 6.43: Health ratings for water-based acrylic interior paint.

Chart 6.44: Health ratings for oil-based interior paint.

Chart 6.45: Health ratings for plant and mineral paints, such as Bio Paints.

The tendency for the health ratings of varnishes and paints not to peak, but form strong groups either side of neutral, indicates people find it difficult to form opinions about their healthiness. Throughout this discussion, the NZ architects repeatedly accentuated trends observed in the three general samples. The three general samples on the other hand, tended to rate these substances around neutral, with a general trend for rating more towards the positive than the negative.

Nevertheless, the results indicate that solvent- and oil-based products (normally containing solvents) were perceived as noticeably less healthy than their water-based equivalents. This means all samples could differentiate between solvent and water-based products, thus demonstrating a general understanding that the latter are a healthier option. Furthermore, the health ratings of wood oils and waxes and plant and mineral paints additionally indicate a general understanding that these products are healthier than their more conventional equivalents. Unfortunately, this trend was not strong for wood oils and waxes, potentially acknowledging the great diversity of products of this type available on the market, including many with very high solvent content and some with little or none. The same trend was clear for plant and mineral paints, which were rated higher than water-based acrylic paints. However, plant and mineral paints also attracted a high rate of indecisiveness, 16%, which was the second highest rate of indecisiveness for all materials, with as much as 24% of the NZ general sample rating in this category.

6.6 Descriptive report on health rating of curtains/drapes

There were two rating options in this category: 'thermal or blackout lined curtains/drapes' and 'unlined or with separate lining curtains or drapes' (Table 6.14; Charts 6.46-6.47). The overall health rating of these was similar, with a mean of 3.66 and standard deviation of 1.09 for the former, and a mean of 3.56 and standard deviation of 0.98 for the latter. There were differences between samples, however, but more importantly there were no clear trends across all samples. For example, the UK rated both equally (3.58 and 3.57), while the US and NZ architects samples rated thermal/blackout curtains (3.85 and 3.17 respectively) slightly lower than unlined curtains (3.92 and 3.25 respectively). The greatest change in means was for the NZ general sample with their mean for thermal/blackout curtains being 0.51 points higher than that for unlined curtains (4.09 compared to 3.58 respectively). Furthermore, 45% of the NZ general sample rated thermal /blackout curtains as 'healthy 5,' which was the largest number of 'healthy 5' ratings of any material. This implies that for this sample thermal properties are seen as important in health rating, and probably more important than other properties of thermal/blackout curtains. The ratings from the NZ architects differed from those of the NZ general sample, indicating the former were potentially more aware of the health risks associated with curtain materials.

Chart 6.46: Health ratings for thermal or blackout lined curtains/drapes. **Chart 6.47: Health ratings for unlined or with separate lining curtains/drapes.** **Table 6.14: Mean, standard deviation and standard error for thermal or blackout lined and unlined or with separate lining curtains/drapes.**

	Thermal or blackout lined curtains/drapes				Unlined or with separate lining curtains or drapes			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	58	4.09	1.07	0.14	60	3.58	1.12	0.15
NZ architects	65	3.17	1.07	0.14	65	3.25	0.91	0.12
US	58	3.85	1.01	0.15	59	3.92	0.96	0.14
UK	59	3.58	0.98	0.14	60	3.57	0.81	0.11
Total sample	240	3.66	1.09	0.07	244	3.56	0.98	0.07

6.7 Descriptive report on health rating of insulation materials

Four insulation materials were rated: fibreglass, wool, polyester, and inner wall spray foam. From the start it was assumed health ratings would differ between samples for two reasons: firstly the local popularity of particular insulation products could distort results, and secondly awareness of insulation materials could vary depending on how much input the general population has into insulation choices. Recently in New Zealand, changes to Part H of the building code in relation to insulation and government subsidies for retrofitting insulation to the existing housing stock have contributed to a general awareness of these materials (Chapter 8) and accelerated development of new insulating products, such as wool and polyester batts. In another country where insulation has been required for decades, awareness of insulation products might differ.

The ratings for these materials exhibit a mixture of patterns, with strong grouping in the neutral to healthy (wool) or neutral to unhealthy range (fibreglass), a clear peak in neutral (polyester) and fairly even distribution of ratings with an elevated rate of 'I don't know' (inner wall spray foam).

Of all the materials in this group, wool received the highest health rating with a mean of 3.95, standard deviation 0.95 (Table 6.15; Chart 6.49). Wool was rated higher by the NZ general sample (mean 4.49) than all other samples, with the second highest rating from the NZ architects sample (mean 3.95), while the US and UK samples rated wool lower (means of 3.60 and 3.70 respectively) although still in the neutral to healthy range. Furthermore, the two NZ samples predominantly rated wool healthy '4' and '5', with only 14% of ratings outside this for the NZ general and 18% for the NZ architects samples. In contrast, the US and UK samples rated wool more in the neutral range. This could be related to the tendency of both NZ samples to rate all natural materials higher than the US and UK samples.

At the other extreme the lowest rated insulation material was fibreglass with an overall mean of 2.62 and standard deviation of 1.21 (Table 6.15; Chart 6.48). The two lowest means came from two different samples, the UK sample with 2.23 and the NZ architects sample with 2.25, and both peaked in the unhealthy '2' category. The ratings from the US sample were a little higher at 2.88, while the NZ general sample had higher ratings with a mean of 3.14, but both samples peaked in 'neutral 3,' with the NZ general sample having more ratings in the healthy '4' and '5' range (22%).

Table 6.15: Mean, standard deviation and standard error for wool and fibreglass insulation.

	Wool				Fibreglass			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	58	4.49	0.76	0.10	59	3.14	1.28	0.17
NZ architects	65	3.95	0.87	0.11	65	2.25	0.98	0.12
US	60	3.60	1.01	0.14	59	2.88	1.28	0.18
UK	59	3.70	0.93	0.13	60	2.23	1.04	0.14
Total sample	242	3.95	0.95	0.06	243	2.62	1.21	0.08

Chart 6.48: Health ratings for fibreglass insulation. **Chart 6.49: Health ratings for wool insulation.** **Chart 6.50: Health ratings for polyester insulation.** **Chart 6.51: Health ratings for inner wall spray foam insulation.**

The health rating of polyester provided one of the most normal distributions in this survey, with a mean of 3.27, standard deviation of 1.02, which is close to the average mean of the survey 3.36 (Table 6.16; Chart 6.50). In fact, all four samples peaked in the 'neutral 3' category, with the proportions of ratings either side influencing small variations in means. The NZ architects and UK samples still provided lower ratings, with means of 3.14 and 3.17 respectively, while the NZ general and US samples had higher ratings with means of 3.45 and 3.39 respectively.

Table 6.16: Mean, standard deviation and standard error for polyester and inner wall spray foam insulation.

	Polyester				Inner wall spray foam			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ general	58	3.45	1.12	0.16	58	3.09	1.35	0.20
NZ architects	65	3.14	1.01	0.13	64	1.95	0.87	0.12
US	60	3.39	1.08	0.15	60	3.16	1.17	0.17
UK	60	3.17	0.87	0.12	60	2.75	0.96	0.14
Total sample	243	3.27	1.02	0.07	242	2.69	1.19	0.09

The health rating of inner wall spray foam varied the most between samples, with an overall mean of 2.69 and standard deviation of 1.19 (Table 6.16; Chart 6.51). This should not be a surprise given the wide range of materials that could be sprayed as insulation into wall cavities, including natural wool. Additionally, in some masonry construction types there are no wall cavities unless specifically provided to house insulation (e.g. cavity wall construction in the UK). The wording of the question deliberately pointed to a range of synthetic products used in such applications. In NZ, urea-formaldehyde foam has been used, and although newer products seem to differ in their chemistry rarely are all the ingredients apparent to the end user. Polyurethane and recycled paper coated in fire-retardants have also been used.

The results for this group of materials revealed a general difference between samples. The NZ general sample rated all insulation materials higher than all other samples. Although the ratings varied between different insulation materials, their consistency indicates another factor could be implicated. If considered in relation to the similarly noticeable higher health rating the NZ general sample gave to thermal/blackout curtains and the high frequency of discussing insulation, temperature and comfort in the open ended questions (Section 8.1), this could be a reflection of a heightened interest in thermal comfort in the NZ general sample.

6.8 Discussion of descriptive analysis

One important general conclusion from the results for health rating of materials is that the scale used succeeded in measuring the more healthy materials as being perceived as healthy. However, and unfortunately, it is much harder to argue the same clarity for materials which could be argued to be unhealthy. Materials and substances discussed in part I as hazardous for human health have generally received lower means, higher standard deviations and a higher proportion of indecisive

responses. However, there were no clear peaks in the unhealthy range, but rather strong agglomerations in the 'unhealthy' to 'neutral' range. Potentially, questions about lead and asbestos, as probably the best known health hazards, could have helped measure the lowest ratings the samples might have given. Clearly, when ratings were provided for materials commonly used in current building practices, the results rarely fall below neutral. Although this is consistent with general research which has indicated that survey respondents tend to rate more in the range of neutral to positive (Lam and Stevens 1994), it also seems to indicate that the general population tends to see all products available on the market as generally neutral to healthy.

Throughout the discussion of results, the NZ architects sample frequently differed significantly from the ratings of the other three general samples. Given this sample formed about 25% of the total sample, in some cases it strongly affected the results. A good example of this is vinyl, which was rated almost identically by the three general samples but much lower in the NZ architects sample. Therefore in the subsequent analyses the total sample (including the NZ architects) was often compared to the three general samples (excluding the NZ architects).

Furthermore, differences between samples appeared throughout this analysis. The UK sample generally tended to provide lower ratings, while the US sample generally did the opposite. On average these variations cancelled each other out, possibly leading to a more levelled out result. However, this levelling out could also have cancelled out other trends in the data set, perhaps contributing to the low levels of observable patterns.

6.8.1 Correlations between health ratings of materials

Another important feature of the results is a high prevalence of correlations between health ratings of different materials. When the health ratings of 28 main materials are inter-correlated, they produce 378 pairs of materials with correlated health ratings. The vast majority of these (91%) were significantly correlated at $p < 0.05$ level (84% were significantly correlated at $p < 0.01$ level). All correlations were positive, apart from one not significant correlation (between the health ratings of tiles and old carpet underlays). This indicates that the health ratings are in fact relatively similar for all materials, generally tending towards positive ratings. The small number of exceptions to this trend (34 at $p > 0.05$ level, and 27 at $0.05 > p > 0.01$ level) could potentially reveal some useful tendencies.

Most pairs without correlation included one very highly rated material and one very low rated material. Table 6.17 provides correlations only between the highest and lowest rated materials, capturing 68% (23 out of 34) of relationships that were not significant $p > 0.05$, and 26% (7 out of 27) of correlations at $0.05 > p > 0.1$ level (this is not considered as statistically significant, but is close to that range). Although this explained about half of the relationships, another explanation is still needed.

Table 6.17: Bivariate correlations between ratings of materials that received high and low ratings.

			Materials that received 5 highest ratings				
			Wood (M 4.19)	Metal (M 4.03)	Glass (M 4.50)	Ceramic, porcelain or stone tiles (M 4.25)	Natural carpet materials (M 4.07)
Materials that received 8 lowest ratings	Particleboard and MDF (M 2.68)	P.C. Sig. N			0.022 0.746 216	0.051 0.466 209	0.092 0.179 213
	Low/zero formaldehyde particleboard and MDF (M 2.99)	P.C. Sig. N	0.148 0.066 156		0.078 0.324 161	0.138 0.087 155	0.065 0.422 156
	Stain, dust, moth carpet treatment (M 2.74)	P.C. Sig. N	0.178* 0.011 201		0.012 0.864 207	0.004 0.953 201	0.100 0.153 206
	7+ year old carpet underlay (M 2.38)	P.C. Sig. N	0.157* 0.025 204	0.105 0.212 144	0.097 0.162 208	-0.038 0.596 202	
	Solvent-based polyurethane (M 2.38)	P.C. Sig. N	0.136* 0.049 210	0.207* 0.013 144	0.084 0.223 213	0.108 0.120 207	0.080 0.249 211
	Oil-based paint (M 2.64)	P.C. Sig. N			0.139* 0.042 215		0.112 0.101 215
	Fibreglass insulation (M 2.62)	P.C. Sig. N	0.142* 0.037 217	0.146 0.075 150	0.109 0.109 219	0.106 0.121 216	
	Inner wall spray foam insulation (M 2.69)	P.C. Sig. N	0.098 0.181 189		0.101 0.162 194	0.186* 0.010 189	0.108 0.136 193

P.C. – Pearson correlation. Sig. – Significance (2-tailed). Correlations that were significant at the $p < 0.01$ level (2-tailed), were omitted. * Correlation is significant at the $p < 0.05$ level (2-tailed) (highlighted green). Correlations $0.05 > p > 0.1$ level highlighted in orange.

It was observed that pairs of natural and artificial materials formed another group of non-significant correlations. Although to a degree this could be explained by the high and low ratings, because overall natural materials were rated more highly than more artificial materials, when tested this approach started to explain relationships between materials that overall received mid-range ratings, which are unlikely to happen by chance (Table 6.18). For example, vinyl received mid-range ratings (mean of 3.29, with overall mean of 3.36), although it is an unhealthy and artificial material. Because of its mid-range ratings, and overall high level of correlation between health ratings, it is reasonable to assume that it would correlate with the majority of materials. Despite this, the health ratings of vinyl differed from the ratings of six out of seven natural materials evaluated here, even when some of these natural materials also had mid-range means, such as wood oils and waxes with a mean of 3.53. This analysis of differences in ratings for natural and artificial materials explained just under half of the relationships 40% (14 out of 34) that were not significant $p > 0.05$, and 67% (18 out of 27) of correlations at $0.05 > p > 0.01$ level.

Table 6.18: Bivariate correlations between more natural and more artificial materials.

			More natural materials						
			Wood (M 4.19)	Cork (M 3.70)	Ceramic, porcelain or stone tiles (M 4.25)	Natural carpet materials (M 4.07)	Wood oils and waxes (M 3.53)	Plant and mineral paints (M 3.82)	Wool insulation (M 3.95)
More artificial materials	Vinyl (M 3.29)	P.C. Sig. N		0.202* 0.011 175	0.151* 0.026 219	0.170* 0.011 220	0.173* 0.012 212	0.138 0.055 194	0.146* 0.031 216
	Laminated wood (M 3.51)	P.C. Sig. N				0.104 0.128 216			0.159* 0.020 213
	Synthetic carpet materials (M 3.08)	P.C. Sig. N	0.160* 0.018 218	0.108 0.153 175	0.171* 0.012 217			0.171* 0.016 196	0.094 0.169 217
	Stain, dust, moth carpet treatment (M 2.74)	P.C. Sig. N	0.178* 0.011 201	0.196* 0.11 167	0.004 0.953 201	0.100 0.153 206			0.083 0.244 201
	Solvent-based polyurethane (M 2.38)	P.C. Sig. N	0.136* 0.049 210		0.108 0.120 207	0.080 0.249 211		0.167* 0.020 192	0.126 0.069 209
	Oil-based paint (M 2.64)	P.C. Sig. N				0.112 0.101 215			
	Fibreglass insulation (M 2.62)	P.C. Sig. N	0.142* 0.037 217		0.106 0.121 216			0.176* 0.014 194	
	Polyester insulation (M 3.27)	P.C. Sig. N				0.143* 0.038 210		0.183* 0.011 192	
	Inner wall spray foam insulation (M 2.69)	P.C. Sig. N	0.098 0.181 189		0.186* 0.010 189	0.108 0.136 193			

P.C. – Pearson correlation. Sig. – Significance (2-tailed). Correlations that were significant at the $p < 0.01$ level (2-tailed), were omitted. * Correlation is significant at the $p < 0.05$ level (2-tailed) (highlighted green). Correlations $0.05 > p > 0.1$ level highlighted in orange. Grey highlight for uncontroversially healthy and uncontroversially unhealthy materials.

When these two explanations for exceptions are brought together they explain 82% of relationships with significance at $p > 0.01$ level (Tables 6.17-6.18). Of the remaining relationships more than half relate to glass, either through its high rating or through it being seen as healthy, leaving a very small proportion of outliers. (These explanations do not explain the following pairs of non-correlated health ratings: glass vs. new underlay, vinyl, laminated wood, synthetic carpet materials, thermal curtains; low/zero formaldehyde particleboard and MDF vs. thermal and unlined curtains, wool insulation; tiles vs. new underlay; unlined curtains vs. fibreglass; lino vs. natural carpet materials.)

6.8.2 Combined parameters

This analysis helped identify that some polarisation in ratings could be observed indicating personal preferences or views. Two other pairs were also observed: soft flooring vs. hard flooring, and possibly healthier vs. suspected unhealthy materials. In the subsequent analyses these were called the combined parameters and, together with the uncontroversially healthy and unhealthy materials, were used when evaluating differences and correlations. It was hoped that in the subsequent analyses these combined parameters could help reveal more subtle trends.

The combined parameters were defined as:

- Natural materials (5 items): wood, natural carpet materials, plant and mineral paints, unlined curtains, wool insulation;
- Artificial materials (5 items): particleboard or MDF, synthetic carpet, stain, moth, dust treatment built into carpet, thermal or blackout curtains, inner wall spray foam insulation;
- Soft flooring/worst for asthma triggers (4 items): wall-to-wall carpet, natural carpet materials, synthetic carpet materials, old carpet underlay;
- Hard flooring (4 items): vinyl, linoleum, laminated wood floor, tiles;
- Possibly more healthy, but not well known as such (4 items): wood oils and waxes, plant and mineral paints, unlined curtains, wool insulation; and
- Suspected unhealthy, but not well known as such (4 items): water-based polyurethane, water-based paint, thermal or blackout curtains, polyester insulation.

6.9 Conclusion

This chapter had identified two clear problems with poor recognition of health risks when comparing the ratings received for two pairs of materials: vinyl and linoleum, and ‘normal’ and low/zero formaldehyde particleboard and MDF. In both cases the general samples provided almost identical distributions of ratings, although the majority of participants rated them differently. This strongly indicates that the general samples struggle to articulate relevant differences between these materials, which is significant because as shown in section 3.3 they are both already recognised risks and in process of regulation against their use.

The scale developed for the health rating of materials has shown a reasonable level of consistency. The results clearly differentiate between materials that are more or less healthy and these tendencies generally correspond with the available scientific information. Furthermore, the distributions were strongly indicative of collective clarity in what is healthy or lack of certainty that certain materials are healthy. The latter was not as clear as the former because it seems that the ratings tend to gravitate towards the neutral, and this seems to be more pronounced in low scoring materials. It seems that participants were readier to rate more extremely for materials that they

were more certain are healthy. Another noticeable aspect of this trend is that even materials that received very low ratings also received some scores in the high part of the range. The NZ architects sample when generally providing a fairly low rating for a particular material, still used the whole scale of positive scores, as apart from particleboard or MDF, where their highest score is '4', all others include both '4' and 'healthy 5'. When materials were scored positively, the negative part of the range was generally not used (as for glass), or was less used (as for wood).

Both these trends strongly suggest that many people operate from a position of trust that there is some form of external control of how healthy materials are before they enter their private homes. This could imply trust in the government and legislation, or trust in market forces and their inherent controls (by implication these would normally rely on legislation or regulations). The next chapter evaluates the health ratings of materials through the use of inferential analysis, in an attempt to identify any trends in what influences the health ratings of materials.

Chapter 7

Inferential analysis of health ratings of materials

This chapter provides inferential analysis of the health ratings of materials. This is undertaken in two groups, reflecting the different analytical tools used: differences in health ratings of materials between groups (female/male; younger/older, etc.) generally using one-way between subject ANOVA tests, and Pearson bivariate correlations between health ratings of materials and scores for the five personality traits and environmental concerns. Given the exploratory nature of this study, much was considered as potentially related. It should be emphasised that it is not reasonable to expect the general population to have very strong views about building and furnishing materials, and even for the views that they hold, numerous factors could potentially be influencing these. Therefore, finding any clear patterns should be treated as a discovery. This is especially true because of the lack of similar studies, which prevents building on the research results of others.

The inferential analyses in this chapter explore the possibility that there are demographic characteristics or psychological factors (personality traits and environmental concerns) that relate to observable differences in ratings. Therefore, it is important to note that what follows are analyses of patterns that generally have a low level of intensity but a clear consistency. In the discussion more emphasis is given to consistency than to the strength of various tests. The underlying assumption is that if there are consistent patterns, even if low in intensity, subsequent work could be designed to measure and evaluate the low intensities more clearly, by being specifically designed towards that end. However, because this study is perforce exploratory it was designed to obtain information about many different facets quickly, so that niches for further research could be identified. For this reason, results of the tests in range of $0.05 < p < 0.10$ were often reported as 'almost significant,' in contrast to the more usual $p < 0.05$ significance level. These 'almost significant' relationships also help capture consistencies of patterns, without claiming the significance of these findings.

7.1 Between group differences

In order to evaluate the impact of demographic characteristics on the health rating of materials a series of one-way between subjects ANOVA tests were conducted. The analysis considered the following paired groups:

- gender (female vs. male),
- level of education (high-school or trade qualification vs. bachelor or higher university education),
- age (younger 20-49 years old vs. older 50-75 years old),
- ownership (owning home vs. renting home),
- asthma (present in the household vs. not present in the household), and
- allergies (present in the household vs. not present in the household).

A series of tables for each paired group set out the mean health ratings for the materials and the key one-way between subjects ANOVA test results are provided in the column containing the higher mean value of the two. All significant differences between groups are highlighted in yellow, while those close to being significant are boxed. Of all analysed pairs, ownership did not lead to identifiable trends and therefore is not discussed below.

7.1.1 Gender

Of all the pairs, the strongest pattern of differences was observed for gender for the total sample and the three general samples. When a series of one-way between subjects ANOVA tests were conducted to compare the effect of gender on the health rating of materials, it was observed that males tended to rate materials higher (i.e. healthier) than females (Table 7.1). For the total sample 86% of male means (24 out of 28 materials) were higher than female. These differences were confirmed as significant by the ANOVA tests, at $p < 0.05$ level for ten materials and close to significant for one ($p = 0.055$ for oil-based paint) for the general sample, but for the three general samples there was significance for 68% of materials (19 out of 28).

For the total sample female ratings were higher for only four materials (tiles; natural carpet materials; plant and mineral paints; thermal/blackout curtains), and these differences were not significant. Half of these materials were uncontroversially healthy, and the rest also low rated. In contrast, males often rated low rated materials higher. Of the eleven materials males rated significantly higher (including one that was almost significant), four were the lowest rated materials in the survey (old underlay; solvent-based polyurethane; fibreglass insulation; oil-based paint), four were in the bottom, less healthy 50% of materials ordered by their ratings (wall-to-wall carpet; synthetic carpet; polyester insulation; water-based acrylic paint); two were in the top, healthier, 50% (wood oils and waxes; cork), and one, metal, was in the six highest rated material (the NZ architects sample did not have this question).

These general trends were stronger for the three general samples where for 89% of materials (all but three) male participants provided higher ratings than female participants. As with the total sample, the materials females rated higher were uncontroversially healthy materials (tiles, natural carpet materials, and plant and mineral paints). Because of the strong predominance of higher male ratings, materials where there was no significant difference could also be taken as indicative of higher female ratings, with the majority of these being uncontroversially healthy, and some mid-range (plant and mineral paints, and two curtain materials).

Table 7.1: Means of health ratings of all materials for female and male participants for the total sample and three general samples. Results on significance of one-way between subject ANOVA tests provided for all materials in column with the higher mean.

			Total sample		3 general samples	
			Female	Male	Female	Male
			N 137	N 109	N 117	N 65
1	Wood	Mean sig.	4.12	4.27 .231	4.09	4.24 .334
2	Particleboard and MDF	Mean sig.	2.66	2.74 .587	2.82	3.23 .028*
3	Low/zero formaldehyde particleboard and MDF•	Mean sig.	2.85	3.16 .103	2.89	3.66 .003**
4	Metal•	Mean sig.	3.87	4.29 .007**	3.87	4.29 .007**
5	Glass	Mean sig.	4.50	4.50 .970	4.44	4.48 .747
6	Vinyl	Mean sig.	3.25	3.35 .528	3.45	3.95 .006**
7	Linoleum	Mean sig.	3.45	3.70 .112	3.45	3.87 .021*
8	Cork•	Mean sig.	3.47	3.94 .004**	3.39	4.05 .002**
9	Laminated wood	Mean sig.	3.50	3.53 .843	3.54	3.88 .064
10	Ceramic, porcelain or stone tiles	Mean sig.	4.30 .330	4.18	4.28 .908	4.26
11	Wall-to-wall carpet	Mean sig.	2.82	3.32 .002**	2.90	3.78 .000**
12	Natural carpet materials	Mean sig.	4.10 .596	4.03	4.11 .723	4.05
13	Synthetic carpet materials	Mean sig.	2.90	3.32 .003**	2.99	3.61 .000
14	Stain, dust, moth carpet treatment	Mean sig.	2.71	2.79 .640	2.84	3.25 .049*
15	New foam underlay	Mean sig.	3.01	3.08 .696	3.20	3.63 .025*
16	7+ year old carpet underlay	Mean sig.	2.06	2.75 .000**	2.16	3.18 .000
17	Water-based polyurethane	Mean sig.	3.33	3.52 .159	3.41	3.91 .002**
18	Solvent-based	Mean	2.20	2.60	2.36	3.18

	polyurethane	sig.		.011*		.000**
19	Wood oils and waxes	Mean sig.	3.41	3.71 .027*	3.35	3.94 .001**
20	Water-based acrylic paint	Mean sig.	3.25	3.52 .047*	3.27	3.82 .001**
21	Oil-based paint	Mean sig.	2.51	2.80 .055	2.63	3.21 .002**
22	Plant and mineral paints	Mean sig.	3.90 .118	3.69	3.87 .760	3.81
23	Thermal/ blackout curtains	Mean sig.	3.73 .289	3.53	3.79	3.95 .379
24	Unlined/ separate lining curtains	Mean sig.	3.53	3.59 .669	3.59	3.83 .146
25	Fibreglass	Mean sig.	2.46	2.78 .040*	2.51	3.21 .001**
26	Wool	Mean sig.	3.90	4.00 .442	3.87	4.09 .187
27	Polyester	Mean sig.	3.11	3.46 .012*	3.08	3.76 .000**
28	Inner wall spray foam	Mean sig.	2.59	2.81 .196	2.67	3.55 .000**

For all: Maximum number of participants specified at the top; • marks materials that were not rated in all surveys, thus fewer participants; ** p is significant at $p<0.01$ level (highlighted yellow); * p is significant at $p<0.05$ level (highlighted yellow); p is almost significant at $0.05< p<0.10$ (boxed), closer to $p=0.05$ values are closer to significant.

This pattern was evaluated over all samples because the proportion of female/male participants varied between them, when two general tendencies in ratings emerged (Charts 7.1-7.2). For almost half of the materials (12 out of 28) distribution of mean ratings between sample groups and gender took the form of two lines of similar shape, with male being noticeably higher than female (Chart 7.1). Many of the remaining materials had distributions which indicate that male ratings tended to have higher variance, while female ratings tended to vary less (Chart 7.2).

Charts 7.1 and 7.2: Differences between female and male means across four sample groups for solvent-based polyurethane and tiles.

The group that varied their responses the most were male participants in the NZ architects sample. Four times they had the lowest mean of all gender/sample groups (laminated wood; water-based paint; thermal/blackout curtains; inner wall spray foam insulation). However, of these four, only one had a total male rating lower than the female rating (thermal/blackout curtains), indicating that high male ratings from the general sample influenced the overall high male ratings. In fact, for 43% of materials (12 out of 28), the male and female NZ architects either had very similar ratings (8 times) or male ratings were lower (4 times). In contrast, the US male group tended to rate materials higher than all other groups, being true for 75% of materials (21 out of 28). This contradiction between male ratings of different sample groups did not challenge the general trend of higher male ratings, given that even the male NZ architects tended to rate the majority of materials higher than their female colleagues.

When the differences in ratings of combined parameters were evaluated for the total sample two were significant (uncontroversially unhealthy and soft flooring), while for the three general samples an additional two were significant (artificial materials, and suspected unhealthy) and two more almost significant (hard flooring and more healthy) (Table 7.2). These results from the three general samples confirm the male tendency to rate all materials higher, regardless of whether they are healthy or not, while female ratings tended to be higher for more healthy and natural materials. Clearly, additional knowledge acts as a mediator for ratings from male NZ architects.

Table 7.2: Means for combined parameters for female and male participants for the total sample and three general samples. Results on significance of one-way between subject ANOVA tests provided for all materials in column with the higher mean.

			Total sample		3 general samples	
			Female	Male	Female	Male
			N 137	N 109	N 117	N 65
	Uncontroversially healthy	Mean sig.	4.15	4.21 .500	4.12	4.24 .256
	Uncontroversially unhealthy	Mean sig.	2.43	2.77 .004**	2.53	3.24 .000**
	Natural	Mean sig.	3.93	3.95 .835	3.93	4.04 .360
	Artificial	Mean sig.	2.98	3.09 .380	3.09	3.51 .002**
	Soft flooring	Mean sig.	3.02	3.36 .002**	3.09	3.65 .000**
	Hard flooring	Mean sig.	3.64	3.69 .667	3.70	3.95 .053
	More healthy	Mean sig.	3.71	3.76 .666	3.71	3.92 .093
	Suspected unhealthy	Mean sig.	3.39	3.50 .265	3.42	3.82 .003**

For all: Maximum number of participants specified at the top; ** p is significant at $p < 0.01$ level (highlighted yellow); * p is significant at $p < 0.05$ level (highlighted yellow); p is almost significant at $0.05 < p < 0.10$ (boxed), closer to $p = 0.05$ values are closer to significant.

In summary, males gave materials higher health ratings more frequently than females and this was very strong for the three general samples, and strong for the total sample. This trend was consistent regardless of how healthy materials were, and in contrast to female ratings which were higher or closer to male ratings for healthier and more natural materials. One observed difference was not expected: for both the total sample and the three general samples males tended to rate soft flooring materials higher than females.

7.1.2 Age

A series of one-way between subjects ANOVA tests were conducted to compare the effect of participant age on the health rating of materials. The sample was divided into two age groups, younger (20-49 years old) and older (50-75 years old), 56%/44% for the total sample. In the total sample, the younger participants rated 13 materials higher and for 5 of these the difference was significant (Table 7.3). Three were uncontroversially unhealthy (old carpet underlay, fibreglass, particleboard or MDF), and two were from the bottom ten rated materials (low/zero formaldehyde particleboard or MDF and new carpet underlay). When the three general samples were similarly evaluated, all relationships became more significant, apart from a modest change for low/zero formaldehyde particleboard and MDF and a change from a significant to almost significant difference for particleboard and MDF (Table 7.3). The other uncontroversially unhealthy materials (solvent-based polyurethane, oil-based paint and inner wall spray foam insulation) also received higher ratings from the younger participants in the total sample and for solvent-based polyurethane this was almost significant for the three general samples. This trend of younger participants rating less healthy materials higher was also confirmed for the total sample and was more significant for the three general samples.

On the other hand, older participants in the total sample rated 15 materials higher, and of these all uncontroversially healthy materials were rated higher, as were many other highly rated materials. However, these differences were not significant for the combined parameter of uncontroversially healthy, and only one individual difference in higher ratings of the older participants was significant (unlined curtains), with another two being almost significant (tiles and water-based paint) (Table 7.3). For the three general samples, only 10 materials were rated higher by the older participants, and apart from unlined curtains, where a close to significant difference was observed, generally these differences were neither nominally big nor tested as significant.

Given these results, it is possible to observe a reasonable trend that more unhealthy materials were rated higher by younger participants, and less strongly that the more healthy materials were rated higher by the older participants. However, these differences were neither very strong nor numerous. Nevertheless, the finding was unexpected, given that the age groups were defined in a way that made the 'young group' reasonably old, and could, therefore, be due to generational difference in personal experiences with materials, rather than due to achieved maturity and wisdom.

Table 7.3: Summary of key findings: means for health rating of materials and combined parameters for younger and older participants for the total sample and three general samples. Results on significance of one-way between subject ANOVA tests provided for all materials in column with the higher mean.

			Total sample		3 general samples	
			Younger 20-49 years	Older 50-75 years	Younger 20-49 years	Older 50-75 years
			N 129	N 101	N 97	N 68
2	Particleboard and MDF	Mean sig.	2.79 .007**	2.44	3.14 .062	2.76
3	Low/zero formaldehyde particleboard and MDF•	Mean sig.	3.27 .001**	2.62	3.43 .004**	2.69
10	Ceramic, porcelain or stone tiles	Mean sig.	4.14	4.36 .079	4.16	4.39 .135
15	New foam carpet underlay	Mean sig.	3.21 .011*	2.76	3.58 .008**	3.05
16	7+ year old carpet underlay	Mean sig.	2.54 .015*	2.12	2.77 .003**	2.13
18	Solvent-based polyurethane	Mean sig.	2.48 .127	2.23	2.81 .098	2.47
20	Water-based paints	Mean sig.	3.25	3.49 .082	3.37	3.57 .244
24	Unlined curtains	Mean sig.	3.43	3.73 .031*	3.58	3.85 .091
25	Fibreglass insulation	Mean sig.	2.73 .022*	2.35	2.94 .006**	2.36
	Uncontroversially unhealthy	Mean sig.	2.66 .041*	2.41	2.91 .025*	2.56

For all: Maximum number of participants specified at the top; • marks materials that were not rated in all surveys, thus fewer participants; ** p is significant at $p < 0.01$ level (highlighted yellow); * p is significant at $p < 0.05$ level (highlighted yellow); p is almost significant at $0.05 < p < 0.10$ (boxed), closer to $p = 0.05$ values are closer to significant.

7.1.3 Level of education

Differences in health ratings of materials based on level of education were not as clear as for age and gender. For the total sample, a series of one-way between subjects ANOVA tests were conducted to compare the effect of level of education on the health rating of materials. High-school or trade qualifications were defined as the lower, and bachelor or higher university education as the higher level of education. For eight materials the one-way between subjects ANOVA tests were significant at $p < 0.05$ level, and for another five materials they were almost significant at $0.05 < p < 0.1$ level, which means that for almost half (46%) of the materials there were significant differences between participants in different education level groups (Table 7.4). However, these trends became less strong and for many materials the direction of the relationship changed for the three general samples. When the same series of one-way between subjects ANOVA tests were conducted on the latter four rather than eight significant differences in ratings were observed, indicating that the NZ architects ratings had a noticeable effect on the total results (Table 7.4). This should not be a

surprise given that the NZ architects differed in ratings from the three general samples and almost all its participants were in the more educated group. Therefore, the more informed ratings from the NZ architects sample would tend to increase the level of rating accuracy of the more educated participants.

Generally, participants with higher education rated materials higher and this was a much stronger trend for the three general samples. Of these, some of the uncontroversially healthy materials (wood, glass, and natural carpet materials) were rated more highly by the more educated general participants. This trend was stronger for the total sample (significant differences were observed for three materials: wood, glass, and wool insulation), and the level of significance of these differences generally decreased when only the three general samples were examined, but was still significant for wood and wool insulation at $p < 0.05$ level (Table 7.4). Furthermore, when the combined parameters were tested using one-way between subjects ANOVA tests to compare the effect of level of education on the health rating, the results indicated that the uncontroversially healthy, natural and potentially more healthy materials were rated more highly by the more educated participants of the three general samples, and this difference was significant or almost significant. This trend supported the overall observation that the more educated participants tended to vary their ratings more, especially in the positive range. The differences observed for the uncontroversially unhealthy were not significant, but were consistent. The more educated participants as a group also rated these materials higher with only one exception (oil-based paint), while for another two this was significant (fibreglass and inner wall spray foam) or almost significant (old carpet underlay) (Table 7.4).

The only contradiction to this trend were the ratings for vinyl and laminated wood which in the total sample were rated higher by the less educated participants, and this was a significant difference. In the three general samples this difference was still close to significant ($p = 0.057$ and $p = 0.059$ respectively, at $p < 0.05$ as significant level) (Table 7.4). This implies that although in three general samples it was generally the more educated participants who provided higher ratings, some materials seem to have been perceived by this group as potential hazards and consequently rated lower.

Additionally, it was observed that all four insulation materials and thermal/blackout curtains were rated higher by the more educated participants and this was stronger for the three general samples than the total sample, although some differences were significant for both samples (Table 7.4). This was consistent regardless of the actual healthiness of insulating materials, and indicated a strong preference for warmth regardless of how it was achieved, and the fact warmth was being equated with healthiness.

Table 7.4: Summary of key findings: means for health rating of materials and combined parameters for lower and higher educated participants for the total sample and three general samples. Results on significance of one-way between subject ANOVA tests provided for all materials in column with the higher mean.

			Total sample		3 general samples	
			Lower education	Higher education	Lower education	Higher education
			N 92	N 154	N 90	N 91
1	Wood	Mean sig.	4.00	4.31 .019*	4.00	4.30 .046
3	Particleboard and MDF	Mean sig.	2.89 .062	2.59	2.92	3.02 .620
5	Glass	Mean sig.	4.35	4.59 .021*	4.35	4.57 .064
6	Vinyl	Mean sig.	3.75 .000**	3.05	3.79 .057	3.46
8	Cork•	Mean sig.	3.52	3.81 .085	3.50	3.80 .151
9	Laminated wood	Mean sig.	3.80 .004**	3.35	3.83 .059	3.51
12	Natural carpet materials	Mean sig.	3.96	4.15 .200	3.94	4.25 .055
14	Stain, moth, dust treatment built into carpet	Mean sig.	2.93 .083	2.63	2.99	3.00 .946
15	New carpet underlay	Mean sig.	3.30 .023*	2.89	3.35	3.38 .858
16	7+ years old carpet underlay	Mean sig.	2.35	2.40 .738	2.36	2.72 .076
18	Solvent-based polyurethane	Mean sig.	2.57 .091	2.29	2.61	2.71 .604
20	Water-based paint	Mean sig.	3.54 .095	3.31	3.57 .320	3.40
21	Oil-based paints	Mean sig.	2.87 .031*	2.52	2.88 .773	2.83
22	Plant and mineral paints	Mean sig.	3.73	3.88 .288	3.71	4.01 .061
23	Thermal/blackout curtains	Mean sig.	3.68 .907	3.66	3.67	4.02 .032*
25	Fibreglass insulation	Mean sig.	2.45	2.70 .156	2.47	3.02 .005**
26	Wool insulation	Mean sig.	3.71	4.08 .006**	3.71	4.18 .002**
28	Inner wall spray foam insulation	Mean sig.	2.99 .010**	2.52	2.98	3.00 .940
	Uncontroversially healthy	Mean sig.	4.08	4.24 .068	4.07	4.26 .062
	Natural	Mean sig.	3.88	3.99 .231	3.87	4.09 .044*
	Artificial	Mean sig.	3.19 .030*	2.93	3.21	3.28 .630
	Hard flooring	Mean sig.	3.89 .002**	3.54	3.90 .097	3.69

	More healthy	Mean sig.	3.66	3.79 .180	3.51	3.62 .017*
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For all: Maximum number of participants specified at the top; • marks materials that were not rated in all surveys, thus fewer participants; ** p is significant at $p < 0.01$ level (highlighted yellow); * p is significant at $p < 0.05$ level (highlighted yellow); p is almost significant at $0.05 < p < 0.10$ (boxed), closer to $p = 0.05$ values are closer to significant.

In summary, analysis of differences in health ratings of materials between the groups of more and less educated participants identified many inconsistencies when comparing the total sample and the three general samples. These inconsistencies suggest the ratings from the NZ architects strongly impacted on the total sample for this analysis, and the rating for vinyl was especially impacted in this way. When evaluating just the ratings from the three general samples, it was hard to make any clear conclusions, apart from the general observation that for the total sample the more educated group participants tended to provide lower ratings, whereas they tended to higher ratings for the three general samples.

One possible explanation of such opposing trends could relate to the sample characteristics (Section 5.4), where it was noted that the more educated participants tended to belong to the younger group. This was largely due to the high demarcation age of 49/50 between the younger and older groups, meaning older participants in the younger groups would already hold their terminal qualification. Charts 7.3 and 7.4 compare means per sample group for level of education and age for the uncontroversially unhealthy parameter, indicating that the patterns observed for the level of education were less clear than those for age. Therefore, it is possible to conclude that age was a stronger predictor of the health rating of materials than level of education.

Charts 7.3 and 7.4: Comparisons of means of health ratings for the uncontroversially unhealthy parameter per sample group for level of education and age.

7.1.4 Asthma and allergies

A series of one-way between subject ANOVA tests were performed to assess differences in health ratings of materials between groups of participants who reported asthma and allergies and those who did not (Tables 7.5-7.6). Generally, materials received higher ratings from the participants who did not report asthma or allergies.

For the total sample only six materials were rated higher by the participants who reported asthma than those who did not. These were glass, laminated wood, tiles, old carpet underlay, thermal/blackout curtains and wool insulation, and none of these differences between groups were significant. The only significant difference was observed for cork, which was rated higher by the non-asthma group (Table 7.5). When assessed for the three general samples, a higher number of differences occurred, but still with the same general trend of participants who did not report asthma rating materials higher. This was significant for cork and low/zero formaldehyde particleboard or MDF, and almost significant for wood, particleboard or MDF, wall-to-wall carpet and wood oils and waxes (Table 7.5).

Table 7.5: Summary of key findings: means for health rating of materials and combined parameters for participants who reported asthma and those who did not for the total sample and three general samples. Results on significance of one-way between subject ANOVA tests provided for all materials in column with the higher mean.

			Total sample		3 general samples	
			Yes, asthma	No, asthma	Yes, asthma	No, asthma
			N 66	N 172	N 56	N 124
1	Wood	Mean sig.	4.05	4.25 .168	3.99	4.24 .099
2	Particleboard and MDF	Mean sig.	2.58	2.79 .242	2.74	3.09 .079
3	Low/zero formaldehyde particleboard and MDF•	Mean sig.	2.70	3.11 .059	2.82	3.35 .044*
8	Cork•	Mean sig.	3.37	3.77 .035*	3.28	3.77 .030*
11	Wall-to-wall carpet	Mean sig.	2.97	3.08 .556	2.96	3.34 .066
19	Wood oils and waxes	Mean sig.	3.41	3.58 .270	3.35	3.66 .091
	Natural	Mean sig.	3.87	3.96 .372	3.84	4.04 .092

For all: Maximum number of participants specified at the top; • marks materials that were not rated in all surveys, thus fewer participants;

** p is significant at $p < 0.01$ level (highlighted yellow); * p is significant at $p < 0.05$ level (highlighted yellow); p is almost significant at $0.05 < p < 0.10$ (boxed), closer to $p = 0.05$ values are closer to significant.

Similarly, in the total sample participants who reported allergies only rated three materials higher: particleboard or MDF (nominal difference between means only 0.04), laminated wood, and unlined curtains, and none of these differences between groups were significant. Three significant differences were observed for the health rating of old carpet underlay, polyester insulation and inner wall spray foam insulation, which were all rated higher by the non-allergy group of the total sample (Table 7.6). However, for the three general samples, there was a larger number of differences in the same trend of the non-allergy group rating materials higher, and this was significant for wood, low/zero formaldehyde particleboard or MDF, wood oils and waxes, inner wall spray foam insulation and almost significant for solvent-based polyurethane, oil-based paints and wool insulation (Table 7.6).

Table 7.6: Summary of key findings: means for health rating of materials and combined parameters for participants who reported allergies and those who did not for the total sample and three general samples. Results on significance of one-way between subject ANOVA tests provided for all materials in column with the higher mean.

			Total sample		3 general samples	
			Yes, allergies	No, allergies	Yes, allergies	No, allergies
			N 102	N 137	N 105	N 76
1	Wood	Mean sig.	4.11	4.22 .372	3.95	4.28 .027*
3	Low/zero formaldehyde particleboard and MDF•	Mean sig.	2.81	3.13 .103	2.89	3.38 .048*
16	7+ year old carpet underlay	Mean sig.	2.18	2.54 .034*	2.37	2.65 .171
18	Solvent-based polyurethane	Mean sig.	2.29	2.49 .219	2.47	2.80 .082
19	Wood oils and waxes	Mean sig.	3.43	3.62 .182	3.35	3.72 .035*
21	Oil-based paints	Mean sig.	2.50	2.77 .085	2.66	2.98 .086
26	Wool insulation	Mean sig.	3.82	4.00 .162	3.78	4.07 .067
27	Polyester insulation	Mean sig.	3.10	3.41 .035*	3.18	3.43 .153
28	Inner wall spray foam insulation	Mean sig.	2.46	2.86 .020*	2.75	3.15 .050*
	Uncontroversially healthy	Mean sig.	4.09	4.22 .133	4.02	4.27 .015*
	Uncontroversially unhealthy	Mean sig.	2.46	2.69 .054	2.61	2.92 .035*
	Natural	Mean sig.	3.87	3.97 .278	3.84	4.06 .048*

For all: Maximum number of participants specified at the top; • marks materials that were not rated in all surveys, thus fewer participants;

** p is significant at $p < 0.01$ level (highlighted yellow); * p is significant at $p < 0.05$ level (highlighted yellow); p is almost significant at $0.05 < p < 0.10$ (boxed), closer to $p = 0.05$ values are closer to significant.

When the differences were tested in relation to combined parameters (Tables 7.5-7.6), a significant difference was observed for the high ratings the non-allergy group had for uncontroversially healthy and uncontroversially unhealthy. This implies that the participants who reported allergies rated both more healthy and more unhealthy materials lower, again consistent with the overall tendency of lower health ratings from the participants reporting allergies. However, more interesting was the significant difference in ratings of the combined parameter for natural materials, which was rated higher by the non-allergy group (Table 7.6). The same trend was observed for the asthma group, where the combined parameter for natural materials approached the significance range (Table 7.5). This could reflect concerns that natural materials might trigger either asthma or allergies and the on-going series of recommendations from organisations such as the Asthma Foundation endorsing the highly engineered new, inherently synthetic products (Asthma Foundation 2013).

One important result of these comparative tests was it was possible to observe that tendencies related to asthma and allergies were more apparent when the three general samples were analysed on their own rather than as part of the total sample. This implies that although there might be many factors that influence the health rating of materials from the professionals, for the general population familiarity with the health conditions of asthma or allergies seem to relate with more knowledge about materials. The increase of observable differences was as high as two and three fold.

7.2 Summary of between group differences

From the inferential analysis of between-group differences the following conclusions emerged. Of all the analysed differences, the greatest level of impact and significance was observed for gender. As a general trend, male participants tended to rate all materials higher, regardless of whether these were healthy or not, and this was significant for many individual materials in many sample groups and for many of the evaluated combined parameters. Women, on the other hand tended to be more moderate in their ratings, had lower variation, and tended to rate higher the more healthy and more natural materials. However, there were also significant areas where lack of knowledge can be observed in female participants, given that, for example, for the three general samples their ratings produced the same mean rating (3.45) for vinyl and linoleum (Table 2.5.1), while the male ratings were not only higher than female for both, but also higher for vinyl than for linoleum (3.95 and 3.87 respectively).

A much weaker but also clear trend was observed for differences in age, whereby younger (under 49 years old) participants tended to rate many materials higher. This difference was especially clear for the less healthy materials, including being significant for the combined parameter uncontroversially unhealthy. Differences between more educated and less educated participants were less clear, possibly because in the sample the more educated participants contained a higher proportion of younger participants. More sophisticated data would be required for a clearer interpretation of these findings. Results as they stand indicate these might be influenced by a generational change in

life-style and the general acceptance of newer, more artificial materials by the participants who were born since 1963. Given that many highly toxic materials received prolific use during the 1970s, this could equally be capturing a more general tendency of younger people to be more open to seeing newer materials as good, or it could be that a childhood during the period of high contamination has influenced views within one particular generation that have become more accepting of health risks.

Finally, amongst the general participants, reports of experience with asthma and allergies were generally related with lower ratings of materials with a mild trend of recognising higher risk materials more accurately. Although the trend in the available data was not strong, it implies that experiences with asthma, and even more with allergies, in the general population operate as predictors for a moderate increase in level of knowledge about the health risks associated with building and furnishing materials.

7.3 Discussion for gender

Other scholarly works have observed similar gender differences in ratings. The study of Lai and Tao (2003) measured perception of environmental hazards in Hong Kong Chinese and found that females tended to rate hazards consistently higher on the risk scale, with only two exceptions out of 25 hazards. Similarly, Stenberg and Wall (1995) evaluated reasons for the observed pattern of 12% of females reporting Sick Building Syndrome, compared to 4% of males. They analysed a wide range of environmental, physical and psychological characteristics that could have influenced this trend, concluding that the observed differences in symptom occurrence among women and men were real and due to factors outside the work environment, and suggesting they could be due to biological factors or the totality of encountered risks, including psychosocial conditions (Stenberg and Wall 1995). Finally, when evaluating gender differences in relation to pro-environmental behaviour, Stern, Dietz and Kalof (1993) observed that compared to men, women tended to see environmental quality changes as more likely to have consequences for personal well-being, social welfare, and the health of the biosphere (Stern, Dietz and Kalof 1993; 338). Furthermore, they concluded that their findings were:

'consistent with the argument in feminist theory that women tend to see a world of inherent interconnections, whereas men tend to see a world of clearly separate subjects and objects, with events abstracted from their contexts. That argument suggests that men might be less attentive than women to links between the environment and things they value, even if men and women hold the same values' (Stern, Dietz and Kalof 1993; 340).

This study contributes to this body of knowledge by providing another example of where men clearly rated building and furnishing materials higher than women regardless of how healthy the materials are, and which could be seen as males underrating risks. The relevance of the observed consistency of higher health ratings from male than from female participants should also be considered in

relation to traditional ideas of architecture as a male dominated profession. In the last three or four decades, the gender balance within the architectural profession has evolved. In New Zealand there has been a noticeable increase in the proportion of female students of architecture since the mid 1970s (Matthewson 2004). Between 1990 and 2002 proportion of women graduates in New Zealand has increased from 27% to 38% (Haarhoff 2010, 6). This mirrors similar trends in the US where the proportion of female graduates rose from 5% to 43% between 1950 and 2003 (Haarhoff 2010, 6). However, despite the increase in enrolments many female graduates seem not to continue into professional practice as in 2004 women held only 13.4% of NZIA registrations (Matthewson 2004). By 2009, this had risen to 17% (Haarhoff 2010, 10). Similar trends have been recorded elsewhere at the start of the 21st century: women held 11.5% of registrations in Canada, 13% in the UK, 8.9% in the US, and 9.5% in Australia (Haarhoff 2010, 7). Thus, the traditional stereotype of architecture as a male dominated profession is being challenged, but is still an issue.

As discussed in section 5.1.1 the NZ architects sample was male dominated (69%/31%). The biggest subgroup group of participants in this sample responded to invitation through the NZIA, making half of the NZ architects sample (49%), and was strongly male dominated (81%/19%).

If, as seen, males tend to rate materials higher, make lower ratings of risks (Lai and Tao 2003), and complain less about sick building syndrome (Stenberg and Wall 1995), then this prominent male presence in the architectural profession could be related to fairly poor recognition of health issues related to building and furnishing materials at present. If Stern, Dietz and Kalof (1993) are correct in their evaluation that women tend to recognise the consequences and consider the interconnectedness of activities more than men, then the male dominated architectural profession is likely to struggle with recognising the healthiness of building and furnishing materials as interrelated with the concept of sustainability. This could explain why although architecture has made significant progress in incorporating sustainability in its practices, recognition that the healthiness of materials is part of this process has not always followed. This can be seen as another example of 'single object' male type focus.

7.4 Correlations between health rating of materials and the personality traits

A series of Pearson bivariate correlations were performed for the health ratings of materials and the five personality traits (extraversion, agreeableness, emotional stability, conscientiousness, and openness), to evaluate whether the latter can predict the health ratings of materials. When for the total sample 28 materials were correlated with the five personality traits (140 bivariate pairs) a relatively low number of significant correlations were observed, 30 (21%), at $p < 0.05$ level (Appendix 3). However, this level indicates that there is a much higher tendency for significant correlations than 5%, which is considered to be found by chance. Additionally, when the significant correlations were grouped in relation to subsets of personality traits, personality traits of agreeableness and

openness had the highest level of correlation with the health rating of materials (12 and 10 respectively), while conscientiousness and extraversion had none or just one, respectively.

Furthermore, correlations differed between samples, and therefore the patterns of these were considered throughout. The sample with the highest number of correlations was the total sample, which was therefore considered as the basis for all the following discussion. As a general feature, the number of correlations dropped from 30 to 20, when comparing the total sample and the three general samples combined. A further drop was observed when evaluating each individual sample, with five correlations in the US sample, 12 in the UK sample, 14 in the NZ general and 16 in the NZ architects sample. This could be because of the variability in general rating tendencies observed (the UK sample tended to rate all lower, while the US sample tended to rate all higher (Section 5.4). Research on correlations has recognised that correlations are clearer if there is more variability amongst observations (Goodwin and Leech 2006). Thus, due to variations in ratings, the more the samples of this study were combined, the greater was the variation in the combined samples and thus more correlation was observed.

Another feature worth remembering is the gender differences already discussed. In the total sample female participants tended to score higher in agreeableness, while the male participants scored higher in emotional stability and both differences were significant (Section 5.3.1). However, in the three general samples combined (without the NZ architects), female participants tended to score higher on agreeableness and openness (both significant, though the difference for openness was stronger), while male participants tended to score higher on conscientiousness (again a significant difference). The difference between male and female scores on emotional stability was not significant for the three general samples, although it was still fairly strong.

7.4.1 Openness

For the total sample, the most significant pattern for the personality trait of openness was that it correlated with the health ratings of materials in a way that was reflective of the real healthiness of materials (Appendix 3). All of the 10 observed significant correlations support this. Scoring on openness three times positively correlated with the health rating of materials, these being glass, tiles and natural carpet materials (all uncontroversially healthy), and seven times negatively correlated with the health rating of materials, for particleboard and MDF, low/zero formaldehyde particleboard and MDF, vinyl, stain, dust, moth protection built into carpet, new foam underlay, solvent-based polyurethane, and oil-based paint (four of these being uncontroversially unhealthy, and the fifth, vinyl, should ideally be so categorised) (Appendix 3). Even when the correlations were not significant their positive or negative direction corresponded with which materials were factually healthy or not. In addition to three significant positive correlations, there were another eight positive correlations that were not significant, for wood, metal, cork, wood oils, plant and mineral paints, unlined curtains, and wool and polyester insulation.

Therefore, it is possible that for the total sample a clear and consistent, although statistically not significant, pattern existed in correlations between high scores on openness and accurate health rating of materials.

However, given that the NZ architects sample scored highest of the four samples on openness (Section 5.3.1) and often exhibited a higher level of knowledge of the healthiness of materials (Chapter 6), these findings were re-examined for the three general samples. For the three general samples combined this trend was milder but generally consistent in direction (Appendix 4). The number of significant correlations dropped to five, half those of the total sample. Of the remaining significant correlations, for two (glass and natural carpet materials) no significant change was observed, for one (tiles) there was an increase in the level of correlation (from Pearson correlation coefficient $r=0.134$, $p=0.047$, to $r=0.202$, $p=0.009$), and for two (particleboard and MDF and low/zero formaldehyde particleboard and MDF) there was a decrease in the level of correlation (from Pearson correlation coefficient $r=-0.277$, $p=0.000$ and $r=-0.308$, $p=0.000$, to $r=-0.171$, $p=0.034$ and $r=-0.231$, $p=0.021$, respectively). Of the five correlations no longer significant, two (stain, dust, moth carpet treatment, and oil-based paint) remained close to being significant, and the remaining three (vinyl, new foam underlay, and solvent-based polyurethane) had a very low correlation coefficient, but maintained the same direction of relationship. Correlations changed direction for four materials: cork (from + to -), water-based polyurethane and thermal/blackout lined curtains (from - to +), and for fibreglass (from neutral to -). It should be noted that for all of these materials Pearson correlation was quite low, being close to neutral.

Therefore, it was possible that although the strength of correlations between the ratings of the personality trait openness and health ratings of materials decreased in strength and statistical significance between the total sample and the three combined general samples, there was still the same feature of reasonable consistency in direction. More open participants tended to rate less healthy materials lower and more healthy materials higher.

Two features were significant. Firstly, both samples maintained the significant negative correlation between openness and ratings of particleboard and MDF and low/zero formaldehyde particleboard and MDF. Secondly, the significance of negative correlation between openness and ratings of vinyl relied on the NZ architects sample, which rated vinyl much lower than all other samples (Section 6.3.1). Therefore, in the three general samples combined, negative correlation between openness and rating of vinyl drops to a level approaching neutral (Pearson correlation coefficient $r=-0.085$, $p=0.287$).

7.4.2 Agreeableness

For the total sample, 12 significant correlations were observed between the personality trait of agreeableness and health ratings of materials (Appendix 4). All of these were positively correlated,

regardless of whether the materials were healthy or not. Positive correlations were significant for glass, vinyl, linoleum, laminated wood, tiles, natural carpet materials, synthetic carpet materials, water-based polyurethane, plant and mineral paints, thermal/blackout curtains, unlined curtains, wool insulation. Particularly telling were the pairs of similar materials with different health impact (vinyl and linoleum, or natural and synthetic carpet materials) which all had ratings positively significantly correlated with agreeableness. Furthermore, agreeableness positively correlated with all health ratings of materials, apart from one (low/zero formaldehyde particleboard and MDF), and this was not significant, but very close to neutral.

Therefore, for the total sample it was possible to conclude that the more agreeable participants tended to give higher ratings for all materials regardless of whether they were healthy or not.

When comparing correlations between agreeableness and the health ratings of materials for the total and the three general samples, there was a drop from 12 to 8 significant correlations, with no change in direction of these (Appendix 4). However, there was an increase in negative correlations between agreeableness and the health ratings of materials for the three general samples (8 rather than 1 in the total sample). These included five uncontroversially unhealthy materials (old carpet underlay, solvent-based polyurethane, oil-based paint, fibreglass and inner wall spray foam insulation), two close to being in that group (low/zero particleboard and MDF, and stain, dust, moth caret treatment), and cork, as a mid-range rated material. This indicates that although agreeableness still generally positively correlated with the health ratings of all materials, in the three general samples, this was more accurately related to how healthy materials are.

7.4.3 Emotional stability

Emotional stability was similar to agreeableness, although a milder pattern was observed (Appendix 4). For the total sample, emotional stability positively correlated to all health ratings of materials apart from three (vinyl, stain, dust, moth protection built into carpet, and water-based paint), and these correlations were not significant, but very close to neutral. However, all seven significant positive correlations were for the healthy materials (metal, glass, cork, tiles, wood oils, plant and mineral paint, and wool insulation, and six of these were uncontroversially healthy). Therefore, it is possible to conclude that for the total sample, the participants who scored higher on emotional stability generally tended to give higher ratings for most materials, but more so for the more healthy and less so for the less healthy materials.

The same conclusion arose when analysing the three general samples (Appendix 4). Only one new negative non-significant correlation appeared for one of the uncontroversially unhealthy materials, oil-based paint. Although there were fewer significant correlations (5 rather than 7), the direction of relationships was consistent. Therefore, it was possible to conclude that the same pattern was observed for emotional stability for the total sample and the three general samples.

7.4.4 Extraversion and conscientiousness

The other two personality traits, extraversion and conscientiousness, rarely had significant correlations with health ratings of materials for the total sample, but some patterns were nevertheless observable (Appendices 3-4). For the total sample, extraversion ratings significantly correlated only once with a healthy rating of inner wall spray foam insulation, and this was a positive correlation, indicating high ratings of an unhealthy material. This is unexpected given that high ratings on extraversion were predominantly negatively related to ratings of materials (negative 60% of materials, including a mixture of healthy and unhealthy materials). This indicates that participants who highly rated on extraversion generally tended to give lower ratings for materials, and for most of these Pearson correlation was quite low, close to neutral. Conscientiousness exhibited a very similar, but milder trend with no significant correlations and fewer negative relationships. Therefore it is possible to conclude that the personality traits of extraversion and conscientiousness are unrelated to the health rating of materials. These trends were true for the total and the three general samples.

7.4.5 Correlations with the combined parameters

These general patterns were consistent when evaluated for the combined parameters (Tables 7.7-7.8). For the total sample, agreeableness positively correlated for almost all of the combined parameters, with the exception of the uncontroversially unhealthy, where it was also close to correlating. This was much milder for the three general samples, where there were no correlations for soft flooring, artificial materials and suspected unhealthy materials, and even more importantly no correlation for the uncontroversially unhealthy, with the numbers being close to neutral.

Table 7.7: Bivariate correlation for total sample between the five personality traits and the combined parameters.

	For Total sample		Extraversion	Agreeableness	Conscientiousness	Emotional stability	Openness
	Uncontroversially healthy	P.C. Sig.	-.015 .823	.264** .000	.105 .109	.203** .002	.184** .005
	Uncontroversially unhealthy	P.C. Sig.	.048 .466	.111 .092	-.030 .649	.071 .284	-.189** .004
	Hard flooring	P.C. Sig.	-.099 .136	.256** .000	.011 .872	.087 .187	-.058 .383
	Soft flooring	P.C. Sig.	-.044 .508	.185** .005	.000 .997	.116 .079	-.053 .420
	Natural	P.C. Sig.	-.022 .736	.298** .000	.069 .294	.173** .008	.094 .151
	Artificial	P.C. Sig.	-.016 .805	.177** .007	.003 .966	.036 .590	-.203** .002
	More healthy	P.C. Sig.	.005 .937	.246** .000	.014 .834	.159* .017	.042 .532
	Suspected unhealthy	P.C. Sig.	-.041 .542	.210** .001	.071 .287	.030 .654	-.025 .710

P.C. – Pearson correlation. Sig. – Significance (2-tailed). * Correlation is significant at the $p < 0.05$ level (2-tailed). ** Correlations is significant at the $p < 0.01$ level (2-tailed).

Table 7.8: Bivariate correlation for three general samples combined between the five personality traits and the combined parameters.

	For 3 general samples		Extraversion	Agreeableness	Conscientiousness	Emotional stability	Openness
	Uncontroversially healthy	P.C. Sig.	.012 .871	.264** .000	.133 .079	.195* .009	.219** .003
	Uncontroversially unhealthy	P.C. Sig.	.092 .226	.009 .904	-.072 .341	.089 .243	-.078 .303
	Hard flooring	P.C. Sig.	-.130 .090	.198** .009	-.044 .567	.071 .354	.003 .972
	Soft flooring	P.C. Sig.	-.004 .956	.129 .088	-.019 .799	.109 .150	.024 .752
	Natural	P.C. Sig.	.033 .659	.267** .000	.067 .378	.173* .022	.140 .063
	Artificial	P.C. Sig.	-.020 .789	.052 .495	-.052 .492	.057 .455	-.113 .137
	More healthy	P.C. Sig.	.047 .546	.196* .010	-.040 .606	.169* .027	.084 .277
	Suspected unhealthy	P.C. Sig.	-.057 .457	.123 .109	-.010 .899	.039 .614	.030 .695

P.C. – Pearson correlation. Sig. – Significance (2-tailed). * Correlation is significant at the $p < 0.05$ level (2-tailed). ** Correlations is significant at the $p < 0.01$ level (2-tailed).

On the other hand, for the total sample openness positively correlated with the health ratings for uncontroversially healthy, and negatively correlated with the health ratings for uncontroversially unhealthy and artificial materials (Table 7.7). All other correlations were not significant and were positive in their direction for natural and healthier materials, and negative for the rest. This trend was weaker but still present for the three general samples (Table 7.8), where there was only one significant (positive) correlation, with the ratings for uncontroversially healthy materials. Uncontroversially unhealthy and artificial materials were only negative in direction with no significance.

Similarly, for emotional stability there were similar trends of general positive correlation with health ratings and all the relationships were positive. Of these, there were three significant correlations for uncontroversially healthy, natural and more healthy materials, confirming the previous observation that the participants who scored higher on emotional stability rated materials higher but more so for more healthy materials. These trends were identical for the total sample and for the three general samples.

There were no observable trends for extraversion and conscientiousness.

7.4.6 Other issues

When correlations between personality traits and the health ratings of materials were examined for each of the four samples separately there were variations (Table 7.9). For example, there were significantly more negative correlations in the US and the UK samples than in the two NZ samples. This could imply a similarity between these groups of participants in the way they rated the personality traits (higher/lower). Similarly some sub-themes were observable, such as the NZ general sample six times having significant positive correlations between different personality traits and wood and wood oils, which was not observed in any of the other samples.

Table 7.9: List of significant bivariate correlations between the five personality traits and the health rating of materials for the four samples.

	Extraversion	Agreeableness	Conscientiousness	Emotional stability	Openness
NZ general	Wood + Wood oils +	Wood + Wood oils + Plant/min. paint + Wool insul. +	Water-b. PU +	Wood oils + Plant/min. paint + Thermal curt. –	Glass + Tiles + Natural carpet + Wood oils +
NZ architects	Unlined curtains – Inner wall spray +	Laminated wood + Synthetic carpet + Water-b. paint + Plant/min. paint + Wool insul. + Polyester insul. +	Water-b. paint + Polyester insul. +	Cork + Water-b. PU + Oil-b. paint +	Low/zero FA – Laminated wood + Thermal curtains +
US				Linoleum + Laminated wood + Water-based PU + Thermal curtains +	Unlined curtains +
UK	Vinyl – Linoleum –	Metal + Vinyl + Lamin. Wood + Thermal curt. +		Tiles +	Particleb. MDF – Linoleum – Stain..treatm. – Solvent-b PU – Oil-b paint –

N=44-62, listed for p significant at $p < 0.05$ level.

However, further research would be required for any conclusive evaluation of these differences. The problem is that when the significant differences between samples are taken into consideration (Chapter 5), the samples cannot be asserted as mutually comparable, which unfortunately makes any study of the cross-cultural features impossible.

Furthermore, when evaluating the relatively low level of correlations between health ratings of materials and the personality traits, several lines of re-evaluation and redesign of the questionnaire become apparent:

- Re-evaluating the impact of scale for the health ratings and the wording of anchors on the results, both of which can influence the distribution of frequencies (Lam and Stevens 1994).

Potentially a longer scale, 7 rather than 5 points, could have influenced the distribution of frequencies in a way that makes correlations more effective.

- Developing the questionnaire, by adding one or more explanatory questions for health ratings, asking for rating of health characteristics (such as possible impact on indoor air, impact on touch/feel, impact on natural environment) for each material, rather than simply rating it (Lai and Tao 2003). Potentially this could better refine the responses.
- The short, 10 item personality traits test has some tested reliability, but a longer test could be more robust for the culturally diverse samples.

7.5 Correlations between health ratings of materials and the environmental motives

A series of Pearson bivariate correlations were performed to assess the hypothesis that the three environmental motives (biospheric, egocentric and altruistic) could correlate with higher or lower health ratings of some materials. When for the total sample 28 materials were correlated with the three environmental motives (84 bivariate pairs) there was a relatively low number of significant correlations, 5 (6%), at $p < 0.05$ level (Appendix 5). This was even lower for the three general samples combined, with only two significant correlations (2%), at $p < 0.05$ level (Appendix 5). Therefore, the frequency of correlations is not high enough to justify many conclusions.

The clearest correlation for both the total and three general samples was significant positive correlation between health ratings for natural carpet materials and biospheric and altruistic motives (Appendix 5). Even these correlations were weak, but not surprising, indicating that natural carpet materials were seen as healthy by people who rate nature and other humans as important. In addition, the biospheric motive correlated negatively with vinyl and old carpet underlay (Appendix 5), but these correlations were not significant when evaluated for the three general samples, indicating that this was probably influenced by the difference in ratings from the NZ architects, who also had the highest mean for biospheric concern (Section 5.3.1). The egocentric concern positively correlated with the ratings of particleboard and MDF (Appendix 5), but only for the total sample, which was probably reflective of the very strong positive correlation between these variables in only one sample (UK). Finally, in addition to the natural carpet materials, for the total sample the altruistic motive positively correlated with the health ratings of plant and mineral based paints, being almost significant for the three general samples.

Given the low number of correlations and their weak value, it seems that very little can be observed in terms of correlations between the environmental motives and the health ratings of materials. There are three reasons for the low levels of correlation between the health ratings of materials and the environmental motives. Firstly, environmental motives have been tested less than the five personality traits, and so have not been proven to perform well either on a conceptual level or as testing instruments. Section 4.2.2 shows that relatively standard psychological tests regularly undergo both conceptual and instrumental development. Secondly, most participants tended to rate

environmental concerns reasonably highly (Section 5.3.2). This could have created a distorted distribution that matched less well with the distributions for other material health ratings, in turn decreasing the level of correlation (Lam and Stevens 1994). While these two are issues related to testing tools, the final suspicion is that this could be indicating a lack of relationship between environmental concerns and people's views on materials. Although this is possible, the results from the follow-up trial suggest the reverse in that high scores on environmental concerns could operate as predictors of readiness to learn about healthier options (Chapter 9).

Table 7.10: Bivariate correlation for three general samples combined between the three environmental concerns and the combined parameters.

			Biospheric Total sample	Biospheric 3 general samples	Egocentric Total sample	Egocentric 3 general samples	Altruistic Total sample	Altruistic 3 general samples
	Uncontroversially healthy	P.C. Sig.	.078 .237	.123 .103	.087 .186	.070 .353	.140* .034	.151* .045
	Uncontroversially unhealthy	P.C. Sig.	-.092 .163	-.064 .399	.039 .560	.002 .975	-.073 .272	-.069 .366
	Hard flooring	P.C. Sig.	-.086 .194	-.036 .640	.118 .075	.108 .160	.052 .430	.106 .166
	Soft flooring	P.C. Sig.	-.049 .462	.030 .691	.039 .552	-.009 .906	.056 .395	.077 .313
	Natural	P.C. Sig.	.076 .248	.144 .056	.042 .525	.010 .900	.147* .025	.162* .032
	Artificial	P.C. Sig.	-.043 .511	-.009 .906	.132* .044	.093 .219	.041 .535	.077 .309
	More healthy	P.C. Sig.	.071 .285	.108 .161	.006 .931	-.030 .696	.123 .066	.112 .145
	Suspected unhealthy	P.C. Sig.	.067 .317	.099 .199	.061 .358	.020 .795	.085 .201	.089 .249

P.C. – Pearson correlation. Sig. – Significance (2-tailed). * Correlation is significant at the $p < 0.05$ level (2-tailed). ** Correlations is significant at the $p < 0.01$ level (2-tailed).

Table 7.11: List of significant bivariate correlations between the three environmental motives and the health rating of materials for four individual samples.

	Biospheric	Egocentric	Altruistic
NZ general		Old carpet underlay – Unlined curtains –	Solvent-based PU – Inner wall spray insulation –
NZ architects	Old carpet underlay – Inner wall spray insulation +	Plant/mineral paints +	Water-based paint +
US	Natural carpets + Unlined curtains +	Natural carpets +	
UK	Natural carpets + Plant/mineral paints +	Particleboard/MDF + Low/zero FA particleb/MDF + Vinyl + Tiles + Synthetic carpets + Stain, dust, moth carpet treat. + Water-based paint + Polyester insulation + Inner wall spray insulation +	Vinyl + Laminated wood + Synthetic carpets + Stain, dust, moth carpet treat. + New carpet underlay + Water-based PU + Plant/mineral paints + Polyester insulation + Inner wall spray insulation +

N=44-62, listed for p significant at $p < 0.05$ level.

7.6 Conclusion

The primary aim of this chapter was to evaluate the possibility of identifying trends for predicting the health ratings of materials, and the results do suggest some possible predictors. For this data set, gender was the strongest predictor, since female participants have generally rated materials more accurately and lower. This was an unexpected finding, but the subsequent literature review showed this is unlikely to be a chance finding. In addition, for the general population familiarity with asthma or allergies was also a predictor, although not strong, of more knowledge about the healthiness of materials, while age and level of education produced some non-consistent results, only indicating a possibility of generational differences in views about materials. In terms of correlations, no clear relationships were found between the health rating of materials and the environmental concerns. However, some of the personality traits potentially can be used as predictors. Openness generally correlated to suggest the more open participants were more aware of risks, while agreeableness indicated a general tendency to rate higher. Neither of the patterns were strong nor clear enough to be conclusive.

Additional research is needed to confirm all conclusions outlined above. This is even true for gender, where the difference was strong, consistent, and supported by other literature. There is a chance that this research and other work on risk could be recording a male tendency of always giving higher ratings to everything. To disprove this, either a survey capable of measuring such trends is needed or a complementary research method used. In this thesis, the follow-up trial offers one such complementary, mixed-method source to provide additional insights, which concur with the observations here (Chapter 9).

Chapter 8

Additional analyses

This chapter provides results, analysis, and discussion of answers to all the core survey questions not covered in chapters 5-7, such as house health rating, attitudes and current views. While the health rating of materials did prove a successful tool for evaluating people's views about the materials and potential predictors of these (Chapters 6 and 7), other parts of the questionnaire varied in how useful they were for answering the research questions, and hence their level of analysis and discussion varies. To a large extent this was expected, because the primary focus was the health rating of the materials and exploration of predictors of those ratings, while the questions covered here either support that main effort or are part of the casting of a wider net for possibly capturing additional relevant factors. This explains why much of the data presented here is in a more summarised fashion.

8.1 House health rating and its explanations

One of the most important questions in the core survey was the house health rating and explanations for it. The question on this was structured in a similar way to the health rating of materials, but used a 6 point, rather than a 5 point Likert scale. This difference in length of scale reflects the character of the questions. While it seemed reasonable to assume that some participants might not have strong views about materials, this seemed unlikely when it came to their own homes. Therefore the scale used for house health ratings did not allow for indecisiveness or neutral ratings. In addition, this rating was followed by two open ended questions which allowed participants to explain the main reasons for their assessment, and suggest the main improvement they perceive their house to need. These questions offer more qualitative insights into what people think is healthy in their homes, and were coded and analysed as such.

8.1.1 House health rating

Generally, most participants rated their houses as reasonably good, in the mid to high range, with extremes not used much (Chart 8.1). The mean ratings were highest for the NZ general (4.33) and US (4.31), followed by the UK (3.87) and NZ architects (3.78). The latter is interesting as despite the sample being 84% homeownership, the NZ architects provided both the lowest overall house health rating and much higher proportions of 'very poor' and 'poor' ratings (7% and 12% respectively), than the three general samples (2% and 5% respectively). This is probably due to the architects' better understanding of hidden problems with housing, and their higher expectations of architecture, as seen in the next two sections.

Because of these lower house health ratings from the NZ architects sample, evaluations for any predictors of house health ratings were only performed for the three general samples. Generally there were no surprising discoveries. Unlike the NZ architects, participants who owned their homes provided higher mean house health ratings and when a one-way between subjects ANOVA was performed this difference was significant $F(1,185)=21.13$, at $p<0.000$ level. Also, Pearson bi-variant correlations showed that participants who indicated that for them finance was an obstacle to making changes to their home (see Section 8.2), provided lower house health ratings, and vice-versa, higher house health ratings correlated to having the means to make changes (Pearson correlation coefficient $r=-0.294$, at $p<0.000$ level). Although these trends were observed, they were not analysed further as not being related to the main questions of this thesis.

Chart 8.1: House health rating.

8.1.2 Explanations of the house health ratings

In all samples some participants did not provide explanations for the house health ratings they provided, which led to reductions in the available sample for further analysis: NZ general (N 58), NZ architects (N 55), US (N 53), and UK (N 56), totalling 222 responses. Because many participants replied with a list of factors, these were coded as individual categories, thus the same response could refer to more than one category, and percentages below are based on total responses for the whole category.

When asked to specify what influences the health rating of their house, 95% of the NZ general sample provided responses which referenced insulation, warmth or ventilation. Predominant were the categories of insulation 37 (64%), heating 20 (34%), double glazing 15 (26%), warmth/coldness 14 (24%), dampness /dryness 13 (22%), availability of sun 8 (14%), ventilation 7 (12%), HRV 6 (10%), and condensation 5 (9%). Other categories identified the quality of construction 9 (16%), that their house was new (recently renovated or extended) 8 (14%), that the house was well built or structurally sound 4 (7%), or specifically that it complied with the 2004 Building Act (1 response), or was better than the current building standard (1 response). In addition, 4 (7%) participants mentioned general maintenance. Mentioned once each were the quality of paint work, the re-roofing of the house, and that asbestos cladding had been encapsulated. The level of cleanness of the house fell into the two general categories of dust/regularity of cleaning 5 (9%), and presence or absence of mould 5 (9%). A small proportion of participants 4 (7%) spoke about the spaciousness of their house, quality of layout and access. Finally, 5 (9%) of participants saw the health rating of their house as linked to their own health, through frequency of doctor's visits or appearance/disappearance of certain medical conditions such as bronchitis and asthma.

The trend of a high proportion of references to warmth was also observed in the NZ architects sample (89% of participants). Of these 23 (42%) explicitly mentioned insulation, 15 (27%) ventilation (this includes one mention of HRV), 12 (22%) warmth/coldness, 11 (20%) dry/dampness, 11 (20%) mould and mildew, 9 (16%) heating, 8 (15%) double/single glazing, and 8 (15%) availability of sun. One clear feature of this sample was the greater diversity of responses, which makes separate grouping more difficult, and perhaps accounts for a decrease in consideration of general maintenance 2 (4%), structural integrity/earthquake proneness 1 (2%), and cleanness 7 (13%). The expectations from houses seem higher, with features such as passive and active solar gain design mentioned, along with rain water storage tanks, and underfloor heating. One respondent had a mudbrick house and one a strawbale house, which had influenced their ratings. However, there was a group of 7 (13%) responses more directly related to indoor air quality and these formed further groups of participants who mentioned issues such as natural/non-hazardous materials (2 reports), low VOC materials (2 reports), no present or exposed particleboard and MDF (3 reports), and indoor air quality and emissions (2 reports). Two participants mentioned having no lead-based paint or the fact it had been removed from the house, while 4 (7%) mentioned using water-based acrylic paint as a healthier choice. 29% of participants in this sample in some way referenced the view that hard floors are superior to carpeted floors.

The US and UK samples differed considerably from both NZ samples in the way they responded to this question. One strong feature was a high frequency of explaining house health rating in relation to personal health. The preliminary sample for the Qualtrics data collection had indicated this and a clarification was then included: 'This is rating of how healthy your home is, is not the health of those living in it,' but this did not really solve the problem. In the final US results 12 (23%) participants rated their house in relation to their personal health, while 7 (13%) did the same in the UK sample. In the NZ general sample only 3 (5%) people made comments about their personal health, with none in the NZ architects sample. In addition to this, 14 (26%) in the US sample and 5 (9%) in the UK sample answered this question in very general terms, such as 'good house/no problems,' which did not provide useful data for analysis. Taken together these two trends decreased the proportion of relevant data for analysis, especially in the US sample where 50% of responses fell into one of these two categories, leaving only 27 responses for analysis. For the UK these trends reduced the sample to 44 (79%) responses.

The two categories that featured most strongly in the US sample were general maintenance 7 (13%) and structural stability 6 (11%). There were also a series of more specific concerns related to weatherproofing improvements, with issues with mould mentioned by 7 (13%), protection from leaks and/or floods mentioned by 4 (8%), an additional 2 reports each of plumbing problems and draughtiness. Cleaning and dust were only mentioned 4 (8%) times. There were a very small proportions of other responses, reflections on recent renovations (2 reports), poor materials used when the house was built (1 report), little carpeting (1 report), smoking indoors (1 report) and cost (1 report). Additionally, insulation was mentioned once in the US sample, and ventilation not at all.

The UK sample related the house health rating to a long list of thermal comfort issues, such as dampness/dryness of the house 9 (16%), warmth/coldness 7 (13%), insulation 6 (11%), single/double/triple glazing 5 (9%), mould 5 (9%), heating 3 (5%), draughts 3 (5%), water tightness 2 (4%), ventilation 2 (4%), and also condensation and access to sunlight (1 report each). This thermal comfort group attracted 18 (32%) of reports, reflecting the type of issues mentioned by the NZ samples. In addition the UK sample had a strong group of reports of general maintenance 14 (25%), and structural stability 7 (13%). Absence of asbestos was also mentioned by 2 (4%).

8.1.3 The most important health improvement in homes

Following the explanation of the house health ratings, participants were also asked to identify what they perceived to be the most important health improvement in their homes, in the hope of having a more qualitative insight into what participants see as healthy in their homes. The response rate to this question was lower than for the previous question totalling in 207 responses: NZ general (N 56), NZ architects (N 53), US (N 51), and UK (N 58). As with the explanations, the replies often came in list form and each category was coded and grouped for analysis. (This question did not appear in the same place of the survey in the NZ general long survey, but there were no indications that this impacted the comparability.)

When answering this question all samples exhibited very similar trends to the answers to the question on what influenced their home health rating. The main difference is that almost one fifth of participants (40 (19%)) reported felt their homes did not need any health improvements. Although this perhaps reflects the positive value people give their own homes it contrasts with the much lower proportion rating their house as excellent (20 (8%) excellent, 70 (29%) very good), potentially indicating reluctance to make changes to a home, even if it is perceived as less than perfect. This trend was strongest for the NZ general sample (14 (25%)) and weakest for the NZ architects sample (6 (11%)).

The most frequently mentioned need in the NZ general sample was additional insulation 14 (25%), and this was often accompanied by a similar set of issues dealing with warmth, such as double glazing 10 (18%), ventilation (including HRV) 8 (14%), heating 6 (11%), dryness 3 (5%), draught stops around windows and doors 3 (5%). Other things mentioned were a heat transfer system, retention of heat, and better access to sunlight. In total more than half the participants mentioned some items from this group. Compared to these, only 6 (11%) of participants specifying issues to do with maintenance, but of those, two stand out, one proposing a total rebuild, and one mentioning asbestos roof replacement. Redecorating jobs such as repainting and new carpets also appear in a small proportion of responses 3 (5%), as do strategies of replacing materials, such as installing natural wood walls and reducing dust.

The NZ architects sample reflected the majority of themes of the previous question by dealing with needed improvements to insulation 15 (28%), double glazing 9 (17%), ventilation 9 (17%), and different ways need to increase warmth in the house, through access to sun, and decreasing the inflow of unwanted cold air 9 (17%), and generally improvements of energy efficiency (1 report). Small numbers of the remaining responses deal with a great variety of different priorities. Some mention issues of maintenance, which range from small window repairs to earthquake strengthening. Some note the need to make changes to the functioning of the house due to changed needs. Redecorating and changes to layout and use of space are also mentioned. Two responses suggest demolition as the best improvement strategy, indicating a high level of disappointment with the house and the inability to improve it.

In the US sample the most frequent theme was maintenance 10 (20%), of those specifically ventilation, air filters and maintenance of ducting 5 (10%) and mould 5 (10%). Insulation was mentioned by 2, heating by 1 and improvements to windows by 3, but no-one specifically mentioned double glazing. Of the other themes, 6 (12%) participants were not sure what was needed, and another 5 (10%) suggested changes in lifestyle, one of which was no smoking indoors. A small group of five participants made some prudent but not very specific comments here such as 'cleaner air,' 'energy efficiency,' 'allergens,' better germ containment,' and 'air does not seem very clean.'

The UK sample recorded the need for additional insulation, double glazing, more warmth, and energy efficiency 8 (14%), improved ventilation (2 responses), draught stopping (1 responses), changing air filter (1 response), and replacement of windows (2 responses). A topic that did not appear in the other samples was damp proofing, with 4 (7%) participants noting need for change in this area. There was also one mention of asbestos removal. In addition, there was mention of need for decorating, and adjusting the house to new needs.

8.1.4 Discussion and conclusions for house health rating and its explanations

Different samples appear to have different priorities in what they think makes their houses healthy. The strongest finding is that both NZ samples see thermal comfort, including insulation, and ventilation as the most significant factor in how healthy the house is. The same theme is reiterated when suggesting their improvements. This theme significantly overweighs both the importance of structural solidity and maintenance and what building and furnishing materials should be included in the house. This theme was also the strongest group in the UK sample, where it received almost equal attention to issues of maintenance and structural stability. Interestingly, insulation and warmth were not mentioned by the US sample, where weatherproofing and issues with mould are more important and where maintenance and structure get greater emphasis.

Only the NZ architects sample made comments related to indoor air quality (13%) and health issues related to position that uncarpeted floors are healthier option than wall-to-wall carpets (29%). Only three participants of this sample mentioned avoidance of particleboard or MDF in their homes (or having these sealed), and only one mentioned avoidance of vinyl.

These results suggest that if a grounded theory approach had been undertaken for this sample allowing the sample itself to delegate issues that they see as important for house health rating, similar factors probably would have been identified. Based on the results obtained in this way the following categories are clear: insulation, warmth and ventilation, issues of maintenance and structural stability, weatherproofing and mould. The same are likely to appear at the top of any list identified through a grounded theory approach. Furthermore, as suggested in Section 4.1.2, a grounded theory approach could fail to identify adequately issues that are not well known by the population studied. Effectively, indoor air quality issues were not mentioned by any of the three general samples, but only by the NZ architects sample. This suggests that a grounded theory approach might not have been very successful for this study. Especially relevant for this conclusion is that issues with particleboard and MDF, and vinyl were only mentioned four times, and might not, therefore, have emerged as significant in such an approach.

A possibly significant limitation should be noted when discussing the strong emphasis both NZ samples have placed on insulation, warmth and ventilation, because this could be a temporary trend. Data collection for the core survey took place in 2012, three years after July 2009 when the NZ Government started its Energywise: Warm Up New Zealand: Heat Smart programme committing \$347 million to it (EECA 2013). This programme was still being run in 2013 by the Energy Efficiency

and Conservation Authority (EECA 2013) with the aim of retrofitting insulation to 230,000 NZ homes. One important feature of the programme is it offers a subsidy of up to \$1,300 (or 33%) towards the cost and installation of ceiling and under floor insulation to houses built before 2000, for all NZ homeowners regardless of income, and including landlords. The programme also offers other, smaller programmes, such as a subsidy for clean heating. One part of this programme was TV advertising which focused on educating on importance of insulation, warmth and ventilation.

When the programme started in 2009/10, EECA estimated that around 900,000 homes in NZ had substandard insulation, and current figures show more than 150,000 homes have already been insulated through the programme (EECA 2013). Studies monitoring indoor temperature have found that even with adequate heaters (heat pumps), many NZ houses are below the 18-24°C recommended by the World Health Organisation (Boulic et al. 2004). Therefore, perhaps the most important feature of the programme is that it has established a new expectation that NZ homes should be insulated and warmer. This can be related to more than half the NZ general responses pointing to the fairly recent insulation of their homes, and an additional 25% intending to undertake such improvements. Therefore, although the need for more warmth in NZ houses is real, the general awareness of the advantages of insulation post construction is probably at its peak in NZ, and consequently this survey might have recorded this peak.

8.2 Attitude

In section 4.2.5 seven items used to measure participants' attitudes were grouped into 'internal' and 'external' items. Of these, three 'internal' items only deserve a quick mention here. The item 'Living in a healthy home is important to me' received very high scores with almost all responses 'agree' and 'strongly agree.' There were no 'strongly disagree', only one 'disagree', and 11 neutral responses, jointly representing 5% of participants. Therefore, it seems fair to conclude that most participants agreed with this item. However, a wider distribution of responses was received to 'I would appreciate learning more about what are the healthier options,' indicating that for one fifth of participants (20% rated other than 'agree' and 'strongly agree') living in a healthy home did not correspond to interest in learning what makes it healthy. It is worth noting that the NZ architects sample had the highest interest in learning more about healthier options.

Item that asked participants to indicate the level to which they see finance as the major obstacle to make substantial changes to their homes (Chart 8.2) showed that this was least important in the NZ general short sample (mean 3.5; this question was not included in the NZ general long sample), while being the greatest issue for the US sample (mean 4.18). This question could have captured information on the financial standing of participants without asking about their income (Section 8.1.1). Further testing would be required to evaluate this fully, but this is outside the scope of this thesis.

Chart 8.2: Finance is the major obstacle for me to make substantial changes to my home.

The results for 'external' items which consist of three statements on the level of trust participants held for different bodies that could be monitoring health related to building and furnishing materials, and belief that sustainable materials are good as the fourth, are summarised in table 8.1 and charts 8.3-8.6. Charts 8.3-8.4 make the cross-cultural contrast between the samples very clear: the US and UK samples trust their market and government significantly more than the two NZ samples, with the NZ architects being the least trusting. The results in relation to trust in architects or builders were more even between samples, but still there was a higher level of trust for the US and UK samples than the two NZ samples (Chart 8.5). (Note: 13% of the NZ architects sample selected 'not applicable' for this question.)

Table 8.1: Comparison of means for four 'external' attitude items by sample.

	Number of participants *	Trust market means	Trust government means	Trust architect/ builder means	Trust sustainable materials means
NZ general	58-60	2.60	2.62	3.36	3.96
NZ architects	57	1.88	1.84	3.00	3.79
US	59-60	3.59	3.41	3.63	4.29
UK	62	3.66	3.38	3.70	4.00
Total		2.95	2.82	3.44	4.01

*Actual number of responses varied between these four questions.

Chart 8.3: I feel reassured that if a product was not healthy for me and my family it would not be on the market.

Chart 8.4: I trust that the government and/or other bodies are controlling how healthy the products that are on the market are.

Chart 8.5: I trust that my architect/builder has used healthy materials when working on my home.

Chart 8.6: I believe that sustainable materials are good for my health and health of my family.

Finally, all samples expressed a fairly high level of belief that the sustainable materials are also healthy, with almost all ratings in the neutral to positive range, and only 0.5 difference between extreme means in sample groups (Table 8.1). Despite this, some clear differences can be observed in chart 8.4, which again reiterates the pattern of the US and UK samples expressing a noticeably

higher level of trust than the two NZ samples, with the NZ architects again providing the lowest ratings.

The observed patterns in ratings of the different sample groups were not anticipated in the survey design, but rather greater variation between individuals within the same sample was anticipated which could have been a way of predicting other ratings. However, the cultural groupings are very strong in the data, which prevents further analysis of these questions as possible predictors, because most of what has already been discussed around the different patterns between samples would apply.

The core survey data is unable to explain the difference in trust between the samples. However, two explanations are possible. Theoretically the level of trust in the government and market could be a cultural construct, or it could be reflective of experience. As chapter 3 establishes, in recent years greater changes in legislation around the healthiness of building and furnishing materials have been observed in the US and UK than in NZ, thus potentially this survey could justifiably be recording a greater level of trust in these countries, and greatest mistrust in NZ where the changes have been very modest. More research is required to provide more complete interpretation of the observed differences, but again this is outside the scope of this thesis.

8.3 Current Views

A series of five questions asked participants to provide answers on their current practices in a format of 'select as many options as they apply to you.' These were diverse questions in terms of themes and although they attracted an excellent response rate, they vary in their relevance for the core study.

8.3.1 Level of knowledge

Probably the most important question in this series asked participants to evaluate their own level of knowledge about the health risks at home (Chart 8.7). The largest group of responses was the 59% of participants who stated that they knew about the same as others, but because not many NZ architects selected this option, this was 71% for the three general samples. The NZ architects strongly rated themselves as knowing more than most others (70% of responses), a possible answer selected by only 15% of the three general samples (the NZ general sample selected this more often than the US and UK samples). The option of knowing less than most others was only selected twice in the total sample, while the option of knowing more about risks in some areas and less in others attracted 15% of responses, with the largest group in the NZ general sample (23%).

Chart 8.7: I feel that I know about health risks at home...

When evaluated for how this related to real reports of knowledge, the NZ architects sample has to be considered separately from the three general samples. As the majority of this sample selected they knew more than others, and given that their ratings were generally more accurate, this can be seen as accurate self-assessment. However, when the reports of knowing more than others were compared with actual health ratings of materials no clear patterns indicating greater knowledge could be observed. The same was true when testing for other answer options in the three general samples. Therefore, this type of question did not perform as a predictor of actual knowledge, as had been hoped.

8.3.2 Sources of information

The subsequent two questions are analysed together, because rather than being designed as possible predictors or indicators of knowledge they were designed to provide more detailed insights into possibly influential sources of information about health risks associated with building and furnishing materials.

When asked which sources participants would approach to find more information about specific products the samples had fairly similar distributions of replies (Chart 8.8). The majority 84% selected they would research the products through the internet and books (the highest option for the NZ architects 95%). 40% would ask people working in the shop, and this was highest for the NZ general (55%), and lowest for the UK samples 25%. 27% selected they would ask their friends and family (38% for the US sample), and only 3% that they would not try to find out more. While these results suggest readiness to find out more, it is concerning that as many as 40% of the total sample would ask for information from sales assistants who clearly have an interest in selling the product, or who

may have limited technical knowledge. This figure is especially elevated for the NZ general sample, reflecting the similar tendencies reported by this sample on trust.

Chart 8.8: When making a purchasing decision, if I am unclear which product is healthier, I would...

The next question asked participants to select the types of source that they would consider would inform them about health problems of this nature (Chart 8.9). Possibly due to the poor wording of the question ('I trust that I would know if there was a real problem because...') a proportion of participants did not answer this question, especially in the NZ architects sample with 19 responses fewer than for the previous question. Overall samples indicated a similar level of expectation (around 30%) that the government would be making changes, but this was a bit higher in the UK sample (38%). 78% and 80% of participants from the US and UK samples expected that there would be more information on the news, while in the two NZ samples less than half of participants selected this option. However, the two NZ samples had higher expectations that word of mouth ensured that all knew about the problem, which was especially strong for the NZ architects sample (84%), which suggests that architects often talk to other architects. Only 20% of the US and UK samples selected this reply.

Chart 8.9: I trust that I would know if there was a real problem because...

8.3.3 Readiness to make changes

The final two questions dealt with financial and organisational readiness to make changes. When asked how much extra cost would they be ready to pay for the healthiest option, a majority 46% selected their readiness would depend on what it is for (Chart 8.10). 11% stated they would not be able to pay any difference, while 17% would select the healthiest option regardless of the price difference. The next two sub-questions were especially useful in helping to understand how far people would go for that extra 'health'. Only 16% selected that they would go up to 30% more, while 26% would pay up to 10% more, suggesting that finance is still a limiting factor.

The next question asked about the readiness to make changes, if these were needed to improve health (Chart 8.11). Only two people stated they would not make changes. Four selected that they would do it only if everyone else was doing it. The majority (57%) would do it only if it was fairly affordable, 40% would be ready to make changes, and 27% selected would make them only if the process was fairly simple. This again indicates that finances are seen as the main obstacle in creating a healthier home, but that a group of people are ready and willing to make changes.

Chart 8.10: If the healthiest option was more expensive I would be... **Chart 8.11: If I knew we had to make some changes to our home to improve health...**

8.4 Conclusion

This chapter has provided some additional analysis to support the discussion in the previous chapters. Although the level of detail of analysis varied in this chapter some additional patterns have emerged.

The results of the health rating of materials and their explanations suggested the key themes participants consider when evaluating the healthiness of their own homes. The strength of some of the observed themes suggests that using open ended questions to qualify answers provided important qualitative insights. One unavoidable conclusion suggests the NZ general population is focused on improving thermal properties and ventilation as the main way of improving the healthiness of their homes. As a result, this might obscure other issues, including issues with emissions from building and furnishing materials.

When discussing trust attitudes, the difference between the two NZ samples, with their lack of trust in government, and the US and UK samples was obvious, and was supported by the results from the question about who would know about such problems. Although the possibility of cultural and national differences is unavoidable, the samples also greatly differed in their demographic characteristics (Section 5.4), it is possible that these are reflected in the differences in attitudes and who would know if the problem was real. It seems possible that the older, more educated, and higher homeownership rates of the NZ sample could have influenced these trends. Further research would be required to explain this more clearly.

Part III: Follow-up trial intervention

Chapter 9**Follow-up trial intervention****9.1 Introduction**

Chapter 9 deals with the follow-up trial intervention. It explains the reasons for it, its aims and objectives, and how these translated into the design, results, analysis and discussion. As explained in the Introduction, the main objective of the follow-up trial intervention was to start evaluating the effectiveness of an educational intervention and identifying frameworks which could be relevant for a more detailed educational intervention in this area. On a general level, the follow-up trial is primarily addressing the third research question of this thesis (Section 1.2). In addition, the follow-up trial also created an opportunity for more qualitative insights into participants' views on the healthiness of materials, and possible predictors of those, thus linking back to the main questions of this thesis. These conceptually separate investigations are approached through a differentiation between the educational intervention and the focus groups, which were the two inseparable parts of the follow-up session and the follow-up trial.

Two aspects of the follow-up trial limit the possible findings and affect the organisation of material in this part. Firstly, the sample was small (N 12) which limits the analysis and possible conclusions. Therefore, all results in this chapter can only be an indication of possible statistically significant results. Secondly, this study was an exploratory trial study, and its different parts were more or less successful. Therefore, the data obtained varies in quality. These limitations meant it was appropriate to have a relatively brief discussion of this follow-up trial in one chapter. Furthermore, rather than discussing the design of individual questions separately from the results, discussion of individual questions, or groups of questions, are provided together, giving a brief introduction to design intention, results and, if relevant, their analysis and discussion. This organisation means the less successful parts can be short, while giving adequate attention to the more successful. For the same reason the order in which questions are discussed reflects the order of their significance in

answering the relevant research questions, rather than following the order of the questionnaires (Appendices 6-7).

This chapter starts with a review of other sources that discuss the use of educational intervention. It continues with the design development of the follow-up session, the participant recruitment process, execution of the event and discussion of the sample characteristics. The chapter evaluates the level of change after the follow-up session on two different levels: the first based on participants' reports of changes made to their homes and the second based on changes in their repeat health ratings of materials, followed by discussion of reported knowledge on alternative treatments and remedies, experience of the follow-up session, house health rating, and other potentially influential factors.

9.2 Review of similar works

Part II suggests knowledge about the health risks associated with building and furnishing materials is limited and education could be a possible way of addressing this. For example, a cluster of studies deals with education about the hazard of lead-based paint in existing, normally older housing (Ferguson et al. 2012; Jordan et al. 2007; Brown et al. 2006; Jordan et al. 2004; Jordan et al. 2003; Hilts et al. 1998). Again lead seems an ideal example here, because as explained in Section 3.2, it has been recognised as a health hazard and regulated against in many Western countries for a long time, but is an environmentally persistent substance and therefore, despite these efforts, has persisted as a problem. It can also be measured in blood relatively easily. Finally the interest in developing a solution to the lead problem is high. For example, in the US, it has been estimated that 25% of the population are at risk from high lead exposure (Jordan et al. 2003), and lead poisoning in children costs the nation \$43.4 billion a year, compared to \$2.0 billion for childhood asthma (Ferguson et al. 2012).

Early studies on the effectiveness of educational interventions related to lead were in highly polluted areas. For example, during the 1990s, Trail in Canada has been actively monitored because of the active lead/zinc smelter in the area, and because many children had blood lead levels at the individual intervention level, set then at 15µg/dl (Hilts et al. 1998). The actions on site included indoor dust control trials, ongoing soil treatment experiments, close monitoring of community blood lead levels, and included community education (Hilts et al. 1998). Even when controlled for other factors, the researchers concluded that community education was making a measurable difference in children's blood lead levels, especially when comparing outcomes of years with and without such programmes (Hilts et al. 1998).

When comprehensive peer studies of educational interventions on children's blood lead levels were conducted, findings were mixed with many pointing to measurable reductions (Hilts et al. 1998; Jordan et al. 2003; Ferguson et al. 2012), and others not observing such a clear difference (Brown et al. 2006). For example, when children's blood and household lead dust levels were comprehensively monitored and compared in paired groups either receiving the standard level of education or a more intense 20 visit intervention, the latter reduced the risk of blood lead levels over 10µg/dl by approximately 34% (Jordan et al. 2003). Others have observed no such difference between the intervention and non-intervention groups and concluded that once the blood lead level is elevated, it is hard for educational interventions to help reduce it (Brown et al. 2006).

Research on the outcomes of educational interventions has identified a wide range of factors that influence possible outcomes, decreasing causal clarity. For example, the participants of the non-intervention group generally also receive additional information about their lead exposures, either through measured blood lead levels, or through measured lead content in household dust, or both (Jordan et al. 2003; Brown et al. 2006), and some participants have reported this information as inspiring positive change (Jordan et al. 2003; Jordan et al. 2004). Additionally, it is hard to evaluate all possible influential factors, which are as diverse as the level of rainfall in the months leading to the study, which influences the lead in outdoor dust (Hilts et al. 1998), or the type of floor cleaner used for floors painted with lead paint, which can influence greater or lesser release of lead (Jordan et al. 2004).

Some educational interventions monitored neither blood lead level nor household dust, but self-reported change. For example, a broad scale educational intervention on lead exposure in Arkansas with surveys immediately after the educational intervention and 36 months later showed 45% of participants reported some changes to prevent exposing a child to lead, while 53% reported planning to change something (Ferguson et al. 2012). Such programmes have been recognised as increasing the level of lead awareness through education by empowering individuals with knowledge that can aid in reducing blood-lead levels in at-risk children (Ferguson et al. 2012). Such programmes are also cost effective (Ferguson et al. 2012).

As seen in part I, more materials and substances are still in the process of evaluation rather than having achieved research and legislative consensus that they should be eliminated. Additionally, lead could be the best possible hazard for evaluating the success of educational interventions as it is possible to measure blood lead level and record change, and thus evaluate how change correlates with other actions. Therefore, it is possible to conclude that even for lead, one of the most recognised and easily measurable health risks associated with housing, conclusive evidence for the success of educational interventions is not yet available. This suggests a need for further development of strategies used in educational interventions.

Within the frameworks used in this thesis (Chapter 4), a wide range of demographic and individual psychological factors are expected to influence the process of assimilation of an educational intervention. Although all the studies discussed included demographic information about participants, none evaluated their results in relation to individual psychological factors. Studies that were focus-group based (Jordan et al. 2004) reported on a number of factors, which jointly indicate that the assumption that more information directly translates into behaviour change is too simplified. Therefore, even for lead, as the most studied health hazard in homes, there is much to explore around possible mediators that impact assimilation of new information.

Developing from such observations, the follow-up trial was established to explore an area that has not received much research attention on two levels. Firstly, no studies were found exploring the impact of an educational intervention on a wide range of materials that might be associated with health issues. Secondly, this follow-up trial explores the role of the five personality traits, environmental concerns and values as possible mediators in the reception of educational material.

9.3 Follow-up trial design

Like the core study, the follow-up trial is exploratory. The main question investigated is how participants react to an educational intervention on the health risks associated with building and furnishing materials. To help answer this, the following sub-questions were outlined:

- Did participants make changes to their homes once they learned that change is needed?
- Did participants change the way they rate materials and their own homes in terms of health?
- Can any predictors of either of the above changes be identified from the demographic or individual psychological parameters?
- What learning did the participants report as being most significant for them?

In terms of methodology, the follow-up trial is a longitudinal study with an intervention. It developed from the core survey because the consent form for this asked the participants to consider being part of the follow-up. The follow-up trial consisted of one group session and two additional sets of questionnaires, one immediately after the session and the other four to five months later. The group session comprised focus group discussions and an educational intervention, with more focus on the latter. There were also core survey responses for this set of participants, providing a three stage data set, and the focus group results. This method of data collection allows changes in views, ratings, and actions of individual participants to be observed.

9.3.1 Recruitment

Of 61 participants in the NZ general core survey, 29 volunteered to be approached for the follow-up trial (12 from the NZ long, 11 from the NZ short, and 6 from the Mainly Music group; Table 9.1). These volunteers were approached using a combination of phone calls and emails. Generally, phone calls were the first point of contact, but where a home phone number was not provided or there was no answer to the phone call, emails were sent. All participants were offered the same two pre-booked times for the follow-up session: a Tuesday evening 7.30pm start in a suburban location (after dinner, easy parking), and subsequent Tuesday late afternoon 5.30 start in an urban location (close to workplaces, just after work). Some participants, predominantly women, explained that neither time suited them although they were interested in the follow-up. Therefore, a third time was organised for a Saturday morning in an urban location. Even with this additional time, there were still some interested participants not able to come at these times. Efforts to identify a fourth time failed, mainly because of proximity to Christmas. Interestingly, the group that expressed greatest difficulty in finding time for the follow-up session were generally mothers with young children, recruited either through the general surveys or the Mainly Music parenting group. For those who could come, text message or email reminders were sent close to the agreed follow-up session.

Table 9.1: Distribution volunteers and attendees for the follow-up session per sample.

	Completed survey	Volunteered to be approached for follow-up session	Actually attending follow-up session
NZ long	24	12	5
NZ short	23	11	5
Parenting group	14	6	3
Total	61	29	13

Of the 29 potential volunteers, 13 attended (5 from the NZ long, 5 from the NZ short, and 3 from the Mainly Music group; Table 9.1). Participants from any of these NZ general samples were invited for any of the sessions, and sessions had attendees from different samples and 3-5 participants (Table 9.2). A higher attendance was hoped for, but having only three participants for the third session made it clear additional sessions could be too small to act as a focus group. A reasonable number of potential participants who completed the NZ long survey four and a half months earlier said that they have forgotten about it, and were no longer interested. However, in fact the rates of attendance for the NZ long and NZ short samples were almost identical (42% and 45% respectively, Table 9.1). One volunteer was only interested in an assessment at their own home. As this was not available, although it was considered early on, they dropped out.

At the end of the session, participants were asked to complete the follow-up session questionnaire, which all did. At the time, they were told they would receive a final follow-up questionnaire, to be posted four months after the last session, and all but one participant completed this. Therefore, 12

complete and 1 partial follow-up data sets were available, with the partial not included in the follow-up trial analysis.

The three follow-up sessions took place between 13th November and 1st December 2012. The final follow-up questionnaire was mailed early in April 2013, and responses received until mid June 2013.

Table 9.2: Comparison of follow-up session numbers.

Follow-up session	Number of participants who attended
Session 1	5
Session 2	5
Session 3	3

9.4 Follow-up sessions

Each follow-up session was designed in three parts: the initial 10-15 minutes operated as a focus group, the subsequent 60-70 minutes was the educational intervention, and the session finished with a group discussion of simple and practical solutions to problems identified during the session. In order to maintain comparability between sessions, a detailed outline of the whole follow-up session was submitted for human ethics approval and generally adhered to. However, in all sessions individual participants asked questions and introduced topics of interest to them, which impacted on the overall order. Generally the same key points were delivered, although the atmosphere and group dynamic varied between sessions, and thus some had a more informal and conversational style while others were more structured. It seemed the group that gathered straight after work had the least relaxed atmosphere, and was possibly the least successful. All sessions were audio recorded for easier recollection and summarising of the discussions.

9.4.1 Focus groups

The objective of the focus group was to provide an opportunity for less structured group discussion on three key topics:

- How knowledgeable participants feel they and the general population are about health risks associated with materials. (This question was part of the core survey, but the hope was a group discussion could reveal new information.)
- The main reasons for the participants attending the follow-up session.
- A brief description of participants' homes.

Generally, participants did not discuss their own knowledge as much as their reasons for being there, although these often overlapped. A significant majority of participants (many expressing more than one reason) stated supporting research was why they attended the follow-up session. The second almost equally popular reason was to learn more about health risks associated with building materials. Of these, a small number related this to the core survey questionnaire which they found difficult, thus inspiring an interest to learn more. Another set of reasons was in relation to past, current or future renovation projects. One participant stated they were aware of hazardous substances in the work place, but were interested to learn what these would be in the home environment. However, overall it seemed most participants attended more in a gesture of support for research, than with a clear idea of what learning to expect, which is reasonable given that limited information about the educational intervention was provided prior to the sessions.

The conversation about the participants' homes was very useful for establishing the needs of each group. The groups varied greatly, one group had predominantly old houses, while in another all participants had recently either completed significant changes to their home or moved to a new house. The subsequent material was correspondingly adjusted, so that nobody ended the session regretting past decisions too strongly.

9.4.2 Educational intervention

Two risks were anticipated in the design of the educational intervention part of the follow-up session, and solutions to both built in:

1. Given that what is factually and legislatively considered a health risk is rapidly evolving, it was determined to use an external authority on what is unhealthy in homes. The Smarter Homes website jointly run by the Department of Building and Housing, Ministry for the Environment, Beacon, and BRANZ (www.smarterhomes.org.nz) was therefore used. Although the organisation of the material, the wording and some of the examples varied from points expressed in this website, all key risks discussed were also covered there.
2. Some participants could feel overwhelmed if they discovered high health risks in their homes. To counter this, information from the discussion about participants' homes was used to adjust the tone of the educational intervention. Also, to provide a safe environment for such considerations, the educational intervention generally opened with the presenter's personal story of being in the same position. The synopsis for this part reads:

'As a mother of a five month old baby and a three and half year old child who shared a bedroom, I read a book which made me discover that my children were sleeping in a highly dangerous bedroom environment, which I had lovingly redecorated and furnished just months before. While scared and initially overwhelmed with the information I had learnt, I decided to take a deep breath, not panic and start by making an assessment of cheapest and most effective changes, such as first increasing the airing time of the bedroom.'

In terms of content the educational intervention provided:

- An introduction to the precautionary principle, its importance and the limitations to current knowledge on many substances discussed, thus establishing the importance of everyone being better informed when choosing from what the market offers.
- Discussion of issues with formaldehyde and its replacements, vinyl/PVC, other VOCs, and fire retardants.
- Explanation that current sustainable and environmental choice ticks do not generally include evaluation of impact of these products on the indoor air environment, but rather focus on the natural environment.
- Recommended general avoidance of artificial and synthetic materials (especially formaldehyde, vinyl and other products containing VOCs), in preference of natural materials (such as wood, ceramics, inert metal and glass materials, linoleum, wool, cotton, natural paints and oils).
- Two hand-outs were distributed. One listed plastics commonly used in kitchens, their impact on health and the natural environment. The other recommended four additional sources of information in this area (Thompson, Athena. (2004). *Homes that Heal: and those that don't*. Gabriola Island: New Society Publishers; Smarter Homes. www.smarterhomes.org.nz; REGREEN residential remodelling guidelines. (2008). American Society of Interior Designers (ASID) and US Green Building Council (USGBC). Washington: ASID; Washington: USGBC; The Asthma Foundation. asthmafoundation.org.nz). In addition, verbal reference to the Building Biology Institute website was made.
- Recommendation of simple and inexpensive changes, including sealing off MDF or particleboard with four coats of acrylic paint or aluminium tape, using sense of smell as an indication of possible strong chemical content, avoiding wall-to-wall carpets; selecting rugs of natural materials, even if second hand; using wood oils rather than polyurethane on wooden floors; avoiding thermal and blackout lined curtains, and washing these if they exist.

Although the outline was used, it performed poorly when delivered and adjustments had to be made. At the start in the first session, a participant mentioned asbestos which engendered conversation not part of the outline. An attempt was made to avoid discussion of lead and asbestos at the start of the second follow-up session, but again the group were reluctant to start and discussion of these substances helped the conversation. Observing this, lead and asbestos were used intentionally and successfully to start discussion in the final session. This experience had a subsequent impact on chapter 3 of this thesis, through establishing lead and asbestos as two critical examples to explain the problems with hazards in building materials.

The following are some issues brought up by participants during the follow-up sessions:

- In two groups participants felt people are expected to know about too many different areas, such as investment (session 2) and healthy food and issues with chemicals in foods (session

- 1). In both groups there was a sense of bewilderment about this coupled with the lack of time for learning in modern life.
- A tradesperson felt protection gear is often sufficiently uncomfortable to make it impossible to do the job using it. However, another participant mentioned ten years ago no protection gear was seen on sites, suggesting progress in this area.
- The same tradesperson commented that recommending water-based glues is easy, but that they are not as good as solvent-based glues and installers have to work hard to make them work.
- A participant mentioned current information on the importance of increasing air tightness does not deal with the risks from this, in terms of poorer elimination of indoor air pollution.

The general impression from all three sessions was participants felt that they learnt something new during the sessions, and that given the problem of having too much to deal with, the follow-up session provided shortcuts for learning in this particular area. Therefore, the follow-up sessions were successful as an educational intervention, as well as providing useful data through their associated questionnaires.

9.5 Sample characteristics

Due to the small size of the follow-up trial sample, all discussion of results is based on the total sample, rather than smaller subgroups. To evaluate how representative the follow-up trial sample is of the NZ general core survey (and NZ population), this section compares the participants of both studies.

Although there were slightly more female participants in the NZ general sample (54%), the follow-up trial was more male (58%). This could be because all four participants who were interested in the follow-up but could not make any of the proposed times were women.

The participants were strongly grouped in the 50-64 year group (58% or 7 participants), with a smaller proportion of younger (25% or 3 participants in the 35-49 year group), and an even smaller proportion of older participants (17% or 2 participants in the 65-75 year group). However, in the NZ general sample 53% of participants were 35-49 years of age, indicating older participants attended the follow-up session. It should be noted that all three participants in the 35-49 year group were women, which is to be expected given that only one man in this age group took part in the NZ general survey.

A related sample feature is household size. Only 5 (42%) participants had households with more than 2 people, indicating family with children, another participant was at the stage before children, while the remaining 6 (50%) either had no children or the children had left home. This is a lower proportion of households with three or more members than the NZ general sample (56%). Of the five follow-up trial participants with families, two were male, and three female. These observations are worth noting, because they influence the interpretation of other results of the follow-up trial, because women in this sample are not only younger, but also live with their families. (The four female participants who could not make the available times were all women under 50 living with their families.)

All 12 follow-up participants were New Zealand European, the category that strongly dominated the NZ general sample (Section 5.1.4). In terms of education, 9 (75%) had university or higher education, and 3 (25%) had high-school or trade. Although this is a higher prevalence of university or higher education than the national average, it is almost the same as in the NZ general sample (Section 5.1.3). Two participants were in construction industry trade occupations.

Asthma and allergies were present in the same number of households (4, 33%), while in 5 households (42%) at least one condition was present. This is slightly lower than for the NZ general sample (48% for both), with the decrease due to less asthma in the follow-up than in the NZ general sample (33% vs. 69%), although the prevalence of allergies was similar (33% vs. 31%, respectively) (Section 5.1.5).

In terms of five personality traits and environmental concerns, the follow-up trial was similar to the NZ general sample (Chart 9.1). For the five personality traits differences were insignificant and generally in expected directions based on other literature (Section 4.2.2), given that the NZ general sample was predominantly younger female and the follow-up sample predominantly older male. There were bigger differences for the environmental concerns with the biggest for biospheric where the follow-up sample scored half a point less than the NZ general. Nevertheless, these differences are small and can be explained by the gender/age differences between samples. However, the follow-up sample did score lower for biospheric and altruism concerns, and higher on egocentric concerns than the NZ general sample. This implies the follow-up sample had a lesser proenvironmental attitude.

In summary, although the follow-up trial sample was generally similar to the NZ general for many characteristics, it was older, with stronger male representation and with participants predominantly living in smaller households, probably without children, and scoring a bit lower on environmental concerns. This suggests the follow-up trial sample is neither a good representation of the NZ general sample, nor of the NZ population. This should be considered in relation to the characteristics that were self-reported during the follow-up session, such as high prevalence of desire to support research and high prevalence of experience with renovations and DIY projects.

Chart 9.1: Comparison of means for five personality traits and environmental concerns for NZ general and follow-up samples

9.6 Reports of real changes

- One of the most important research sub-questions for the follow-up trial was whether the sessions inspired real changes in participants' homes. The final follow-up questionnaire was designed to capture these through the question 'Since the follow-up session, I have made the following changes in my living environment.' Unfortunately, no significant changes were reported. Three participants did not respond to this question, but from their other responses it seems they were settled with their living arrangements and did not recognise any real need to make changes, therefore these non-replies can be interpreted as no change. Four other participants explicitly reported no changes, some explaining this was due to extended travel, or being busy with other things during the study period. Of the remaining five participants, one reported having insulation installed in the roof and under floor, which could be unrelated to the follow-up session, and the other four (33% of follow-up trial sample) made changes that were more about using their home than changing the house itself, although each change reflected application of learning from the follow-up session. Changes reported were: Changed position of bed, and regular airing of house;
- Removed rug with chemical/formaldehyde smell. Checked other soft furnishings for odour and investigated kitchen cabinets for off gassing.
- Moved all the children's shoes out of their bedrooms. Washed all of our new curtains to remove the 'smell.' Did not make purchases I would ordinarily have made as I was wary of

their contents (chemicals etc.). I try to purchase second hand so that the chemical content is lower. I wash all of our children's brand new clothes before I put them on the children;

- Removed mobile phone from night table when sleeping.

When asked to provide other comments that best describe their experience, three participants did not answer, but of the nine replies renovations were a strong theme. Three participants commented they had recently completed renovations or purchased fairly new houses, so were generally reluctant to make any changes, although one expressed regret these renovations involved standard MDF kitchen cabinetry. One participant was currently undertaking renovations and intended to use knowledge from the follow-up session when making future decisions. A further participant had evaluated their whole house for impact on health, and will use the knowledge when undertaking future renovations. Thus, five participants explained their behaviour in relation to renovations. The only other theme related to babies, as one participant explained they would have made more significant changes if they had a baby in the house. All remaining comments generally reiterated lack of significant changes, and/or perceived lack need for change.

From the combined responses to these two questions two groupings of how participants have discussed changes emerge. The first relates to change in the use of space or living habits, such as the four who had made changes, while the second relates to more significant changes which were generally discussed as part of (future or past) renovations. This grouping of possible actions seems significant because although both types could have a beneficial impact on the healthiness of living spaces, they vary in how this is achieved. The first group of changes is in complete, direct control of the individuals and has minimal cost, while the second takes longer, requires financial investment, and often involves negotiating with the market or the work of other people (such as various trades people).

In this sample of 12, only changes of the first kind were reported, and even then only by one third of the group. Apart from retrofitted insulation, there were no other renovation activities although about half of participants said they intended to use the new knowledge in future renovations. Given that these more extensive changes often take longer, it is possible posting the final questionnaire 4-4.5 months after the follow-up session did not leave enough time to capture such changes. Nevertheless, these results suggest people are open to acting faster on changes that are easier to undertake and cost nothing or very little. Therefore, better health outcomes might occur through specifically focusing on this group of changes.

For demographic characteristics, it is relevant that 3 out of the 5 participants reporting changes were women aged 35-49. Because there were no men in this age group in the follow-up trial, it is impossible to evaluate whether gender or age was the more significant feature. Similarly, based on this small sample it seems possible older participants were less likely to accept need for change, but these trends are not clear. More research and a larger sample would be needed to establish either

trend. although on a very general level, this study indicates that younger women are more likely, and older men less likely, to make changes.

When the individual psychological factors of the five participants who made changes were analysed with the seven who did not, the former scored higher on personality traits of extraversion and agreeableness, somewhat higher on conscientiousness and somewhat lower on emotional stability and openness. However, these participants also scored higher on all three environmental concerns, especially the biospheric and altruistic concerns (1.7 and 1.0 point differences respectively), but less for egocentric (0.36 point difference). Interestingly no real difference was observed between participants who made changes and those who did not in the health ratings of the uncontroversially healthy (0.03 point difference) and uncontroversially unhealthy materials (0.67 point difference). When a series of one-way between subjects ANOVAs were performed to evaluate the statistical relevance of differences in these means, none were significant at $p < 0.05$ level (although the biospheric concern difference was close to significant $F(1, 10) = 4.530$, $p = 0.059$).

This suggests the follow-up session did inspire some, generally less complicated, changes in 33% of participants. The small size of the sample reduced opportunities to identify significant patterns in predicting changes, but it seems possible that gender, age, and previous experience with significant renovations were all related to these outcomes (female, younger participants with experience of significant renovations made changes more often).

9.7 Comparison of health ratings of materials before and after

9.7.1 General features of change

In contrast to the very modest reporting of physical changes, there were noticeable changes in the health ratings of materials before and after the follow-up session. Table 9.3 shows the changes in mean ratings for individual materials. To analyse these differences the following tests were considered: one-way repeated-measure ANOVA; paired-samples t-tests; and non-parametric tests, such as Wilcoxon. Each test is suited to aspects of this analysis, reflecting the small sample size and frequent non-normal distribution of ratings. Technically the most appropriate test is the one-way repeated-measure ANOVA, because it is designed to evaluate change in participants' scores over time or after an intervention (Green and Salkind 2011: 232). However, t-tests are generally considered to be the most robust when dealing with small samples, while non-parametric tests are designed to deal with non-normal distributions (Green and Salkind 2011: 395). For simplicity and robustness, paired-samples t-tests were performed for all before and after health ratings of materials by the follow-up trial sample (final column of table 9.3).

Table 9.3: Before and after mean health ratings of materials, with change to means and paired samples t-test results, compared to means from the total, the NZ architects, and the BBE samples. The order is from greatest decrease in ratings to greatest increase in ratings.

Material	Change	Before mean (standard deviation)	After mean (standard deviation)	Total sample mean (SD)	Mean NZ arch sample	Means from BBE sample	Paired sample t-test results significant at $p < 0.05$ level (N 12)
Thermal or blackout lined curtains	-2.22	3.92 (1.24)	1.70 (1.16)	3.66 (1.09)	3.17	3.13	$t = 5.13^*$ $p = 0.001$
Polyester insulation	-1.30	3.63 (1.41)	2.33 (1.30)	3.27 (1.02)	3.15	2.25	$t = 1.82$ $p = 0.111$
Wall-to-wall carpet	-1.02	3.75 (1.49)	2.73 (1.27)	3.03 (1.22)	2.54	2.17	$t = 3.63^*$ $p = 0.005$
Synthetics carpet materials	-0.92	3.00 (1.48)	2.08 (0.90)	3.08 (1.07)	2.75	1.50	$t = 2.04$ $p = 0.068$
Particleboard or MDF	-0.90	2.40 (1.32)	1.50 (0.67)	2.68 (1.14)	2.03	1.50	$t = 3.50^*$ $p = 0.006$
Inner wall spray foam insulation	-0.83	2.75 (1.75)	1.92 (1.31)	2.69 (1.19)	1.98	2.86	$t = 2.38^{**}$ $p = 0.049$
Oil-based interior paint	-0.78	2.45 (1.37)	1.67 (0.50)	2.64 (1.12)	2.15	1.88	$t = 1.89$ $p = 0.095$
Vinyl	-0.76	3.09 (1.22)	2.33 (1.16)	3.29 (1.24)	2.48	1.50	$t = 2.04$ $p = 0.068$
New foam carpet underlay	-0.67	3.00 (1.23)	2.33 (1.50)	3.03 (1.20)	2.21	1.17	$t = 1.32$ $p = 0.225$
Solvent-based polyurethane	-0.54	2.36 (1.63)	1.82 (0.75)	2.38 (1.16)	1.72	1.00	$t = 1.33$ $p = 0.217$
Laminated wood	-0.47	2.89 (1.05)	2.42 (1.38)	3.51 (1.12)	3.11	2.25	$t = 0.69$ $p = 0.512$
Fibreglass insulation	-0.42	2.50 (1.27)	2.08 (0.90)	2.62 (1.21)	2.25	1.63	$t = 0.51$ $p = 0.619$
Stain, dust, moth protection built into carpet	-0.37	2.20 (1.03)	1.83 (0.90)	2.74 (1.21)	2.13	1.00	$t = 0.80$ $p = 0.443$
Water-based acrylic interior paint	-0.27	3.36 (1.21)	3.09 (1.30)	3.38 (0.99)	3.16	2.75	$t = 0.56$ $p = 0.591$
Artex	-0.23	2.33 (1.32)	2.10 (1.60)	N/A	N/A	N/A	$t = 0.20$ $p = 0.849$
Plant and mineral paints	-0.11	3.78 (1.20)	3.67 (1.32)	3.82 (0.98)	3.73	3.88	$t = 0.29$ $p = 0.782$
7+ year old carpet underlay	-0.09	2.00 (.943)	1.91 (1.04)	2.38 (1.19)	1.98	1.63	$t = 0.00$ $p = 1.000$
Wood oils and waxes	-0.04	3.86 (1.00)	3.82 (1.25)	3.53 (1.02)	3.52	3.38	$t = 0.16$ $p = 0.879$
Natural carpet materials	+0.17	4.25 (1.14)	4.42 (1.00)	4.07 (1.04)	4.03	4.38	$t = -1.00$ $p = 0.339$
Water-based polyurethane	+0.18	3.09 (1.30)	3.27 (1.35)	3.42 (1.00)	3.02	2.38	$t = -0.26$ $p = 0.798$

Glass	+0.22	4.45 (0.93)	4.67 (0.78)	4.50 (0.78)	4.50	4.63	t = -1.00 p = 0.341
Wood	+0.29	4.38 (0.77)	4.67 (0.65)	4.19 (0.96)	4.31	4.14	t = -1.63 p = 0.131
Wool insulation	+0.34	4.33 (0.99)	4.67 (0.65)	3.95 (0.95)	3.95	3.88	t = -1.30 p = 0.220
Metal	+0.41	4.09 (0.94)	4.50 (0.80)	4.03 (0.97)	N/A	N/A	t = -1.49 p = 0.167
Linoleum	+0.50	3.33 (1.16)	3.83 (0.94)	3.57 (1.18)	3.49	3.00	t = -1.20 p = 0.256
Unlined/with separate lining curtains	+0.57	3.33 (1.30)	3.90 (1.52)	3.56 (0.98)	3.25	3.38	t = -2.06 p = 0.070
Ceramic, porcelain or stone tiles	+0.67	4.00 (1.05)	4.67 (0.65)	4.25 (0.91)	4.19	4.50	t = -2.69** p = 0.025

** p is significant at p<0.01 level (highlighted yellow); * p is significant at p<0.05 level (highlighted yellow).

Generally, ratings decreased for more synthetic materials, and increased for more natural materials. The greatest drops were for thermal or blackout curtains (-2.22), polyester insulation (-1.30), wall-to-wall carpet (-1.02), synthetic carpet materials (-0.92), particleboard or MDF (-0.90), and inner wall spray foam insulation (-0.78). The greatest increases were for tiles (+0.67, significant difference), unlined curtains (+0.57), linoleum (+0.50), metal (+0.41), wool insulation (+0.34), wood (+0.29), and glass (+0.22). Of all materials, paired-samples t-tests were significant for thermal and blackout curtains, wall-to-wall carpet, particleboard or MDF, inner wall spray foam insulation, and tiles, thus generally the change was significant for materials that had the largest nominal changes (Table 9.3). Many of the largest and most significant changes were for mid-range rated materials.

What is clear is that materials discussed during the follow-up session that were a surprise for the participants seem to have influenced the subsequent ratings most strongly. For example, although the follow-up session discussed issues with vinyl due to plasticisers and composite wood (particleboard and MDF) due to formaldehyde content (and limited knowledge about the healthiness of formaldehyde replacements), many participants were more surprised that formaldehyde and similar chemicals are used in fabric treatments of curtain and upholstery materials, carpets and especially carpet backing. At the time, it seemed participants had some awareness that composite wood contained or could contain unhealthy chemicals, but not that this also applied to soft furnishings. This might indicate a tendency for a more dramatic change of views when there is an element of surprise or even shock.

When the ratings for uncontroversially healthy and uncontroversially unhealthy materials were evaluated they generally changed, with ratings for healthy materials increasing from mean 4.25 to 4.60, and ratings for unhealthy materials decreasing from mean 2.41 to 1.82. Charts 9.2-9.3 show the changes in combined distribution of ratings for the uncontroversially healthy and uncontroversially unhealthy groups. In this small sample the means for uncontroversially healthy

were higher than the means from the total sample (4.17) and the NZ architects sample (4.22) even before the follow-up session, so little can be concluded. However, the change in means for uncontroversially unhealthy materials is more telling. Before the follow-up the session the sample mean rating for uncontroversially unhealthy materials was a bit lower than the total sample mean (2.41 vs. 2.57), while after the session the mean dropped to 1.82. This new mean after the follow-up, was not only lower than that of the NZ architects (2.01), but also very close to the mean of 1.75 from the BBE sample, the group within the NZ architects sample which seemed most aware of risks (Section 6.1.3, Table 6.3). These results suggest that the follow-up session was successful in increasing participants' knowledge about health risks.

Two more features of the change should be evaluated regarding prevalence of 'I don't know' and 'unhealthy 1.' As discussed in section 6.1.4, the three general samples in the core survey generally tended to rate materials higher than 'unhealthy 1' and seemed to use 'I don't know' instead of giving very low ratings, while the NZ architects had very low use of 'I don't know' and more frequent use of the full range for ratings. Comparing before and after ratings for the follow-up session, the use of 'I don't know' decreased from 12% of all responses before to 6% after, and 'unhealthy 1' scores increased from 13% before to 21% after (38 and 18 instances of the former, and 43 and 68 of the latter, out of 324 individual ratings for 27 materials by 12 participants). Jointly these indicate participants were less unsure about rating materials and more likely to use the lowest ratings after the follow-up sessions, and this change can be seen as an increase in knowledge after the educational intervention.

However, when evaluating these changes for the impact of gender, the most significant factor for differences in ratings for the core survey (Section 7.1.1) relevant differences were observed. The male participants continued to give either 'I don't know' or 'unhealthy 1' rating at about the same 6% to 7% level before and after the follow-up trial (12 to 13 for the former, and 14 instances each for the latter, for 27 materials by 7 male participants). In contrast, for female participants the prevalence of 'I don't know' dropped from 19% to 4%, while the prevalence of 'unhealthy 1' ratings almost doubled from 21% to 40% (26 to 5 individual instances for the former, and 29 and 54 individual instances for the latter, for 27 materials by 5 female participants). So in this small sample, female participants showed a significantly stronger tendency for 'correcting' their views after the follow-up sessions: they were more confident both in rating and using the lowest extremes. Table 9.4 compares before and after ratings from the female and male participants. Especially worth mentioning are the health ratings female participants gave particleboard and MDF, and Artex after the follow-up session, which were unanimously 'unhealthy 1' for the former and all but for the latter (one participant opted for 'I don't').

Unfortunately, the small sample size makes it hard to evaluate the impact of age and especially age in relation to gender. With three female participants also being the only younger participants (35-49 years), some of the trends observed could be due to either age or gender. The indication from this sample is that gender could be a stronger predictor than age, because the ratings received from the older and younger female participants were very comparable. More study in this area would be needed to evaluate this further.

9.7.2 Gender as predictor of change

Changes in mean ratings were also evaluated for the impact of gender. Table 9.4 compares before and after means for female and male participants, grouping materials for patterns of drops or increases. For the first group of five materials (thermal or blackout curtains, new carpet underlay, wall-to-wall carpet, Artex, and vinyl) the health ratings dropped more for female than male participants. The most striking example in this group are thermal or blackout curtains with a drop of 3.20 in female ratings (from 4.20 to 1.00), compared to drop of 1.31 in male ratings (from 3.71 to 2.40). Also, the female mean ratings for thermal or blackout curtains after the intervention was lower than the male ratings, although before they were higher (Table 9.4). For three other materials (inner wall spray foam insulation, oil-based paint, and laminated wood) female ratings did not change but male ratings dropped, but in these cases female ratings were already low. For inner wall spray insulation the female mean rating was 1, which was the lowest possible score, and remained at 1. For five other materials (polyester insulation, synthetic carpet materials, particleboard or MDF, solvent-based polyurethane, and protection built into carpet), male ratings dropped more than female, although both for this and the previous group, female means remained consistently lower than male means. Therefore, it is possible to consider these changes as male ratings becoming more like female ratings, and given that half of the materials in these two groups are uncontroversially unhealthy, this can be seen as male ratings being 'corrected' after the follow-up session.

Table 9.4: Before and after follow-up session changes in health ratings of materials based on gender.

Material	Change	Before mean (standard deviation)	Before female	Before male	After mean (standard deviation)	After female	After male	Female change	Male change
Female mean dropped more than male									
Thermal or blackout lined curtains	-2.22	3.92 (1.24)	4.20 (1.10)	3.71 (1.38)	1.70 (1.16)	1.00 (0.00)	2.40 (1.34)	-3.20	-1.31
New foam carpet underlay	-0.67	3.00 (1.23)	2.50 (0.71)	3.14 (1.34)	2.33 (1.50)	1.40 (0.89)	3.00 (1.53)	-1.10	-0.14
Wall-to-wall carpet	-1.02	3.75 (1.49)	3.60 (1.67)	3.86 (1.46)	2.73 (1.27)	2.50 (1.29)	2.86 (1.35)	-1.10	-1.00
Artex	-0.23	2.33 (1.32)	2.00 (1.00)	2.50 (1.52)	2.10 (1.60)	1.00 (0.00)	2.83 (1.72)	-1.00	+0.33
Vinyl	-0.76	3.09 (1.22)	3.20 (1.10)	3.00 (1.41)	2.33 (1.16)	2.40 (1.67)	2.29 (0.76)	-0.80	-0.71
Male mean only dropped (F mean still below M mean)									
Inner wall spray foam insulation	-0.83	2.75 (1.75)	1.00 (0.00)	3.80 (1.30)	1.92 (1.31)	1.00 (0.00)	2.57 (1.40)	0	-1.23
Oil-based interior paint	-0.78	2.45 (1.37)	1.25 (0.50)	3.14 (1.22)	1.67 (0.50)	1.25 (0.50)	2.00 (0.00)	0	-1.14
Laminated wood	-0.47	2.89 (1.05)	2.00 (1.00)	3.33 (0.82)	2.42 (1.38)	2.00 (1.73)	2.71 (1.11)	0	-0.62
Male mean dropped more than F (F mean still below M mean)									
Polyester insulation	-1.30	3.63 (1.41)	2.00 (1.41)	4.17 (0.98)	2.33 (1.30)	1.40 (0.55)	3.00 (1.29)	-0.60	-0.83
Synthetics carpet materials	-0.92	3.00 (1.48)	2.00 (1.15)	3.57 (1.40)	2.08 (0.90)	1.80 (1.10)	2.29 (0.76)	-0.20	-1.28
Particleboard or MDF	-0.90	2.40 (1.32)	1.50 (1.00)	2.91 (1.25)	1.50 (0.67)	1.00 (0.00)	1.86 (0.69)	-0.50	-1.05
Solvent-based polyurethane	-0.54	2.36 (1.63)	1.00 (0.00)	3.14 (1.57)	1.82 (0.75)	1.40 (0.89)	2.17 (0.41)	-0.40	-0.97
Stain, dust, moth protection built into carpet	-0.37	2.20 (1.03)	1.33 (0.58)	2.57 (0.98)	1.83 (0.90)	1.20 (0.45)	2.29 (0.95)	-0.13	-0.28
Female mean increased, male mean dropped									
Fibreglass insulation	-0.42	2.50 (1.27)	1.00 (0.00)	3.14 (0.90)	2.08 (0.90)	1.60 (0.89)	2.43 (0.79)	+0.60	-0.71
Water-based acrylic interior paint	-0.27	3.36 (1.21)	2.25 (0.96)	4.00 (0.82)	3.09 (1.30)	2.60 (1.14)	3.50 (1.38)	+0.35	-0.50
Plant and mineral paints	-0.11	3.78 (1.20)	4.00 (1.41)	3.60 (1.14)	3.67 (1.32)	4.50 (1.00)	3.00 (1.23)	+0.50	-0.60

7+ year old carpet underlay	-0.09	2.00 (.943)	1.33 (0.58)	2.29 (0.95)	1.91 (1.04)	1.80 (1.10)	2.00 (1.10)	+0.47	-0.29
Male mean increased, female mean dropped									
Wood oils and waxes	-0.04	3.86 (1.00)	3.75 (1.26)	3.93 (0.93)	3.82 (1.25)	3.40 (1.14)	4.17 (1.33)	-0.35	+0.24
Male mean increased more than female mean									
Water-based polyurethane	+0.18	3.09 (1.30)	2.25 (1.50)	3.57 (0.98)	3.27 (1.35)	2.40 (0.89)	4.00 (1.27)	+0.15	+0.43
Glass	+0.22	4.45 (0.93)	4.40 (0.55)	4.50 (1.23)	4.67 (0.78)	4.60 (0.89)	4.71 (0.76)	+0.20	+0.21
Wood	+0.29	4.38 (0.77)	4.20 (0.84)	4.50 (0.76)	4.67 (0.65)	4.40 (0.89)	4.86 (0.38)	+0.20	+0.36
Female mean increased more than male mean									
Natural carpet materials	+0.17	4.25 (1.14)	4.60 (0.55)	4.00 (1.41)	4.42 (1.00)	4.80 (0.45)	4.14 (1.22)	+0.20	+0.14
Wool insulation	+0.34	4.33 (0.99)	4.40 (1.34)	4.29 (0.76)	4.67 (0.65)	5.00 (0.00)	4.43 (0.79)	+0.60	+0.14
Metal	+0.41	4.09 (0.94)	3.80 (0.84)	4.33 (1.03)	4.50 (0.80)	4.20 (0.84)	4.71 (0.76)	+0.40	+0.38
Linoleum	+0.50	3.33 (1.16)	3.20 (1.10)	3.43 (1.27)	3.83 (0.94)	4.00 (1.00)	3.71 (0.95)	+0.80	+0.28
Unlined/with separate lining curtains	+0.57	3.33 (1.30)	3.20 (1.10)	3.43 (1.51)	3.90 (1.52)	4.25 (1.50)	3.67 (1.63)	+1.05	+0.24
Ceramic, porcelain or stone tiles	+0.67	4.00 (1.05)	3.80 (0.84)	4.20 (1.30)	4.67 (0.65)	4.80 (0.45)	4.57 (0.79)	+1.00	+0.37

At the other end of the scale, there was a general increase in means for healthier materials after the follow-up session for both females and males, with trends similar to those of the core study. Perhaps some preferences rather than views on healthiness influenced why males kept their highest ratings for the same three materials before and after (wood, glass and metal), while for women the top two were wool insulation and natural carpet materials.

For the several materials with mixed changes in ratings only two groups are worth discussing. Firstly, two uncontroversially unhealthy materials, fibreglass and old carpet underlay, had an increase in means from female participants and a decrease from males (Table 9.4). The reasons for this are not clear, because the original mean ratings of these materials by women were very low (1.00 for fibreglass and 1.33 for old underlay) and did not increase much (1.60 for fibreglass and 1.80 for old underlay). However, the latter were still significantly lower than male ratings for the same materials even after the follow-up session (2.43 for fibreglass and 2.00 for old underlay). Perhaps, the change in rating of old carpet underlay reflects discussion of the dual risks associated with different carpet materials (dust mites vs. VOCs). Unfortunately, in the current market the choice is often between the two risks, rather than having many options that avoid both. This could explain why the health ratings of old carpet underlay increased after the follow-up session, recognising it was no longer chemically off-gassing, although possibly containing many dust mites. In contrast, wall-to-wall carpet

received a steep drop in ratings with the recognition that all such carpets tend to exacerbate this dual problem.

Secondly, there were unexpected changes in mean ratings in the paints and varnishes group. Both before and after, the female order of ratings for different paint types had the highest rating for plant and mineral paint (4.00 before; 4.50 after), followed by water-based paint (2.25 before; 2.60 after), and oil-based paint (1.25 before and after), while the male order of ratings had the highest rating for water-based paint (4.00 before; 3.50 after), followed by plant and mineral paint (3.60 before; 3.00 after), and oil-based paint (3.14 before; 2.00 after). Interestingly, after the follow-up session the female mean rating for plant and mineral paints increased, while the male decreased, creating a gender divide in ratings (4.50 female mean, 3.00 male mean). Therefore although there is agreement between the sexes that oil-based paint is the least healthy, females trust plant and mineral paints more, while males trust water-based paint, with an increase in mean ratings of the latter of +0.43. However, there was original agreement between female and male participants that wood oils are the healthiest varnish type, followed by water-based polyurethane, with solvent-based polyurethane the least healthy, and this pattern did not change after the follow-up session.

Therefore, it seems that as with the core survey, female participants have generally rated healthier materials higher and less healthy materials lower, and when provided with more information this polarisation was even stronger for the female participants. In addition female participants decreasing use of 'I don't know,' and increasing use of 'unhealthy 1,' further indicates that female participants in the follow-up session 'corrected' their views more than male participants. If this is considered in relation to the reported changes, where female participants also reported more, it seems the follow-up trial has had more influence on the female participants. However, due to the small sample size this could be an accidental finding.

9.7.3 Asthma and allergies as predictors of change

Reported allergies, asthma or other chronic respiratory problems were evaluated for possible impact on before and after health ratings of materials. Due to the small number of participants, and very high chance of possible distortions, only the most basic comparisons of means were undertaken for the six uncontroversially unhealthy materials and Artex and vinyl (Table 9.5). For the majority of these materials a greater drop in ratings was observed for participants reporting allergies or asthma, often with a very noticeable difference. For example, for particleboard or MDF, the ratings of participants who reported asthma dropped more than one whole point compared to those who did not (Table 9.5). Generally, a greater drop was observed in ratings from participants reporting asthma than those reporting allergies, across all these materials except vinyl and Artex, where the drop was comparable. Only for vinyl and fibreglass was there a greater drop in ratings from the participants reporting neither allergies nor asthma.

Therefore, although further research is needed to substantiate these observations, the results from this small sample echo those of the core study that experience with allergies or asthma could be leading to faster adoption of new information in the general population. Together with observations in Section 7.1.4, this implies that experience with allergies or asthma helps with the uptake of new information about health risks associated with materials. However, for the core survey allergies were more strongly predictive of more 'accurate' health ratings of materials, while in the follow-up survey asthma was a predictor of greater changes. Further research would be needed to explain this fully.

Table 9.5: Drop in means of before and after health ratings of materials in relation to allergies and asthma or other chronic respiratory problems (– indicates an increase).

	Total drop in mean	Combined asthma and allergies	Allergies	Asthma
Particleboard or MDF	0.90	0.54 neither 1.28 either	0.56 no 1.45 yes	0.46 no 1.60 yes
Inner wall spray foam insulation	0.83	0.80 neither 0.87 either	0.79 no 1.00 yes	0.62 no 1.50 yes
Oil-based paint	0.78	0.40 neither 1.25 either	0.47 no 1.33 yes	0.33 no 1.58 yes
Vinyl	0.76	1.00 neither 0.50 either	1.00 no 0.42 yes	1.00 no 0.42 yes
Solvent-based polyurethane	0.54	0.33 neither 0.80 either	0.43 no 0.75 yes	0.29 no 1.00 yes
Fibreglass	0.42	0.81 neither – 0.15 either	0.69 no 0.17 yes	0.43 no 0.42 yes
Artex	0.23	0 neither 0.50 either	0 no 0.67 yes	– 0.03 no 0.66 yes
7+ years old carpet underlay	0.09	– 0.07 neither 0.25 either	0.14 no 0.17 yes	– 0.25 no 0.42 yes

9.8 Health rating of materials in relation to personal psychological parameters

9.8.1 Five personality traits

Health ratings of materials were evaluated for relationships with the personal psychological parameters. A series of Pearson bivariate correlations were computed for all 27 rated materials for 5 personality traits. Of 135 possible pairs, 9 correlations were observed for ratings before the follow-up session, and 8 for ratings after. These translate into 6.7% and 5.9%, respectively, which is very close to the range of 5% per chance find. No clear trends were observed and therefore no further analyses were undertaken. Generally, larger samples give stronger correlations so this was not unexpected (Lam and Stevens 1994).

9.8.2 Environmental concerns

A higher level of correlation was observed for the environmental concerns, especially for the health ratings of materials after the follow-up session (Table 9.6). A series of Pearson bivariate correlations were computed for 27 materials for the 3 environmental concerns. Of 81 possible pairs, 4 correlations were observed for ratings before the follow-up session, and 9 for afterwards. These translate into 4.9% and 11%, respectively, indicating that the number of correlations after the follow-up session was higher than a chance find. Some clear patterns were observed. The lowest number (two significant correlations) was observed for biospheric concerns (one before the intervention, one after, and both negative for materials that were generally rated in the mid-range). The highest number of six significant correlations was observed for altruistic concerns (two before, four after, negative apart from before and after positive correlations with natural carpet materials). Finally, for egocentric concerns five significant correlations were observed (one before, four after, all negative).

Therefore, it seems high ratings on environmental concerns generally correlated negatively with health ratings of materials. Of all the materials where significant correlations were observed, only natural carpet materials can be seen as healthy materials, and these are the only positive correlations observed. All other materials were either in the uncontroversially unhealthy group (carpet treatments, old carpet underlay, fibreglass and inner wall spray foam insulation, and Artex) or close to that group (laminated wood, wood oils, polyester insulation and thermal lined curtains) and their ratings negatively correlated with the environmental concerns. This indicates that people who score higher on environmental concerns rate materials more accurately.

Furthermore, the number of significant correlations more than doubled after the follow-up session, indicating that the educational intervention correlated with high ratings for environmental concerns, being equally strong for the altruistic and egocentric concerns, which both had four significant correlations after the follow-up sessions. This finding is significant despite the small sample size, and could indicate a useful area for further study. While the core survey found very little correlation between the health rating of materials and environmental concerns, the follow-up trial indicates this could be because environmental concerns operate as predictors of readiness to learn. These findings are consistent with the norm-activation model (Schultz et al. 2005; Chapter 2.1). It seems that the educational intervention 'activated' an increase in knowledge in those individuals that were predisposed for such activation, by already having high proenvironmental views. Therefore, based on the results of the follow-up trial it seems likely that exposing a large sample to a similar educational intervention could cause a greater shift in ratings that correlate with the environmental concerns. This has significant implications on two levels:

- Environmental concerns could be used as an important predictor of individual readiness to learn about how healthy building and furnishing materials are; and
- If individuals who score highly on environmental concerns are open to learning about the healthiness of building and furnishing materials, absence of such correlations in the core study could be due to lack of such prior learning.

The last point is especially important, because it is one indirect but very strong indication that the core study was recording lack of knowledge about the healthiness (or not) of building and furnishing materials. Therefore, it adds an additional strength to the argument that the core study sample had insufficient knowledge.

Table 9.6: Summary of significant Pearson bivariate correlations between the three environmental concerns and health rating of materials. Significant at $p < 0.05$ level.

Materials		Biospheric		Altruistic		Egocentric	
		Before	After	Before	After	Before	After
Artex	P.C. Sig. N				– 0.759 0.011* 10	– 0.767 0.016* 9	
Laminated wood	P.C. Sig. N	– 0.698 0.037* 9					
Natural carpet	P.C. Sig. N			+0.844 0.001** 12	+0.752 0.005** 12		
Carpet treatments	P.C. Sig. N						– 0.769 0.003** 12
Old carpet underlay	P.C. Sig. N						– 0.739 0.009** 11
Wood oils	P.C. Sig. N		– 0.771 0.005** 11				
Thermal curtains	P.C. Sig. N						– 0.646 0.044* 10
Fibreglass insulation	P.C. Sig. N						– 0.667 0.018* 12
Polyester insulation	P.C. Sig. N				– 0.612 0.034* 12		
Inner wall spray foam insulation	P.C. Sig. N			– 0.751 0.032* 8	– 0.825 0.001** 12		

P.C. – Pearson correlation. Sig. – Significance (2-tailed). N – number of participants. * Correlation is significant at the $p < 0.05$ level (2-tailed). ** Correlations is significant at the $p < 0.01$ level (2-tailed).

9.8.3 Values

Although the sample was small, it was hoped that when evaluated for impact of values some relevant observations would be possible. As explained in Section 4.2.2, values are social constructs that help individuals negotiate between personal innate tendencies (such as personality traits) and

actual attitudes and actions, such as environmental concerns and knowledge, or change in knowledge. Unfortunately, a detailed analysis failed to identify any relevant patterns.

Chart 9.4 summarises the results obtained for values from the follow-up trial sample and the NZ long sample (four participants appear in both samples), and compares these with the results from a large European sample which used the same scale (Davidov, Schmidt and Schwartz 2008). Noticeable differences between the two NZ and the European samples were expected, given that different cultures tend to provide different scores on values (Davidov, Schmidt and Schwartz 2008). (Means and standard deviations from the European Social Survey (ESS) were double-barrelled, and represent results from 20 European countries from 2002-3 (Davidov, Schmidt and Schwartz 2008).) However, more telling are the great differences in the means obtained from the two NZ samples, which clearly indicate that the samples were not large enough to provide robust data.

Chart 9.4: Comparison of scores for values

Despite this limitation, analyses were conducted in the hope that clear patterns could be observed. (It should be noted that the scales for values and the health rating of materials were in opposite directions, for comparability with all other analyses in this thesis, these are discussed as their opposites, with positive correlation indicating high ratings on a particular value correlating with high rating of the particular material.) The series of Pearson bivariate correlations were computed for the 10 basic values and health ratings for 27 materials. For the follow-up sample this was two sets of 270 bivariate correlational pairs. 27 (10%) significant correlations were observed for the health rating of materials before the follow up session, compared to only 14 (5.2%) after the session, indicating a possible mild trend, even though the prevalence of significant correlations after the follow-up session was not high enough for analysis.

For the health ratings before the follow up session, the strongest groupings of significant correlations were for values of self-direction (9 significant for: metal, linoleum, tiles, water-based polyurethane, solvent-based polyurethane, water-based paint, oil-based paint, fibreglass, and inner wall foam spray), and stimulation (6 significant for: wood, metal, linoleum, tiles, wood oil, and wool insulation). The direction of all these correlations was the same: the higher scores on self-direction or stimulation correlated with higher scores on all materials listed, suggesting that these two values have a high tendency of correlating with higher ratings of materials. Interestingly, for self-direction high ratings of many unhealthy (and some healthy) materials correlated with high scores for this value, while for stimulation high ratings of generally healthy materials correlated with higher scores for this value. What is particularly interesting with these correlations is that both values of self-direction and stimulation are generally seen as part of the same broader value of openness to change (Section 4.2.2). Theoretically, it is possible that openness to change could be reflected in the change in health ratings of materials after the follow-up session. Other values correlated with ratings for up to two materials, and no clear patterns were observed.

For the health ratings after the follow up session, correlations between 10 basic values and the health rating of materials were generally more often positive for the healthier materials and negative for the less healthy materials, but the groupings were much smaller, the overall level of correlation is close to the level of chance finding, and it was hard to identify any clear patterns. While before the follow-up session ratings of either uncontroversially healthy or uncontroversially unhealthy materials correlated with values, for the ratings after the session generally ratings of the mid-range rated materials correlated with values, making any conclusions less clear. On a general level, it is worth observing that the high level of incorrect correlations between self-direction and high ratings of unhealthy materials significantly decreased (from 9 significant pairs before to only 3 after; Artex, oil-based paint, inner wall foam spray insulation). A similarly noticeable decrease in level of correlations with the value of stimulation was observed (from 6 significant pairs to only 1 significant pair, with high stimulation correlating with high rating of inner wall foam spray insulation).

Other groups of correlations appeared. Significant correlations were found with values of security (with 4 materials), universalism (with 2 materials), achievement (with 2 materials), conformity (with 1 material), and power (with 1 material), and generally these were positive for healthier materials and negative for the less healthy materials. It was impossible to make any clear conclusions from this data.

When Pearson bivariate correlations between the 10 basic values and the uncontroversially healthy and uncontroversially unhealthy materials were computed, the relationship was strongest between self-direction and high ratings for uncontroversially unhealthy materials both before and after the follow-up session ($r(12) = -0.796$, $p=0.003$ and $r(8) = -0.925$, $p=0.001$, respectively, significant at level

$p < 0.01$). Additionally, for the results after, values of power and achievement were also found to correlate with high ratings of uncontroversially unhealthy materials ($r(8) = -0.848$, $p = 0.008$; $r(8) = -0.913$, $p = 0.002$, respectively, significant at level $p < 0.01$). However, it is essential to point out that due to missing data, the after sample for all uncontroversially unhealthy ratings was only 8 participants. Distortions are highly possible with such small samples. Because correlations are stronger if there is more variability in the data, even one or two participants who provided extreme ratings more often could easily influence these calculations. Evaluation of these findings for a larger sample is necessary before any conclusions can be made. Pearson bivariate correlations between health ratings of materials and values were also computed for the NZ long sample, but the level of observed correlations was low and no significant patterns emerged.

9.9 Other questions

9.9.1 Knowledge on available treatments and remedies

The final follow-up questionnaire asked participants to list five (or more) materials or substances commonly found in homes that are possibly unhealthy and note actions they could take to decrease or eliminate the adverse impact these could pose. The question tried to evaluate the level of knowledge of possible options to decrease risks after the follow-up session.

Out of 60 materials requested, paired responses of 46 specific materials – strategy for decreasing/eliminating the problem were received. Female participants responded more to this question: 5 female participants provided 22 responses (4.4 per female participant), while 7 male participants provided 24 responses (3.4 per male participant). One male participant did not complete this section. Tables 9.8-9.9 summarise the responses. Generally the responses indicate that participants have a good understanding of what are risks in their homes and what strategies could be used to reduce or eliminate these.

It is especially worth mentioning that particleboard or MDF were most often included in comments (8 times), and that the proposed strategies were generally sound, although some could be expensive, such as removal, depending on the extent and particular use of the materials. However, although frequently mentioned, there was more diversity in the way carpets and paints and varnishes were discussed, possibly indicating a lower level of clarity. In relation to carpets generally two broad groups emerged: in the first removal or avoidance of wall-to-wall carpet was recommended, while the second group dealt with the materials and treatments these participants saw as the most dangerous, such as spray protections in carpets, treated foam underlay and synthetic carpets generally.

Table 9.7: Summary of key groups of hazardous materials as reported by the follow-up trial participants and strategies for decreasing/eliminating the problem. Note: Some responses included more than one strategy so subtotals do not always add up.

Material or substance	Total number of references, % of 12, and gender	Specific use	Total number of references and % of 12, and gender	Strategies for decreasing/eliminating the problem	Number of references and % of 12 if over 1
Particleboard or MDF	8 67% 4M, 4F	In furniture	6 50% 4F, 2M	Paint or tape/cover to seal	4
				Remove	2
				Use alternative materials, e.g. wood	1
Carpet	7 58% 4F, 3M	In floors	2 17% 2M	Seal with polyurethane (1 did not specify type, 1 specified water-based polyurethane)	2
		Carpet generally	3 25% 1F, 2M	Remove; or remove from bedrooms	2
				Use carpet mats that can easily be removed for regular cleaning underneath and cleaned outside the home	1
		Spray protections in carpet	2 17% 1F, 1M	Use alternative floor covering (no carpet – wood)	1
		Treated foam undelay	1	Avoid	1
Solvent-based products	4 33% 2F, 2M	Synthetic carpets	1	Use better quality underlay or recycled woollen carpet	1
				Fire hazard	1
				Avoid	1
				Store and use carefully	1
				Use oil or wax	1
Other paints	4 33% 2F, 2M	Solvent-based products generally	2	Use wood oil	1
				Use alternative, e.g. Bio Paints	1
				Oil-based paints	1
				Use other, bio/plant paints	1
				Choose carefully when painting	1
Asbestos	2 25% 2M	Some paints	1	Use alternatives	1
				Remove	1
				Use bio friendly paint	1
				Remove	1
Thermal of blackout curtains		Lead-based paint	1	Do not break up or sand	1
				Remove with protection and dispose	1
				Use cotton lining	4
				Use untreated fabric	2
Vinyl flooring		Synthetic paint	1	Remove	1
				Use track curtain	1
				Use linoleum	2
Fibreglass		Asbestos cement	1	Keep floor as wood	1
				Use wool insulation	2
Foam inside upholstered furniture		Asbestos coating	1	Use paper insulation	1
				Risk of formaldehyde and other organic gasses as the foam breaks down, replace	1
				Buy second hand so chemicals have already off gassed	1

Comments provided on paints and varnishes indicate a high level of understanding that care should be taken when choosing new products, and that lead-based and solvent-based products are the most dangerous. However, the proposed strategies were not very clear, and that comments also include 'store and use carefully' for solvent-based products, indicating that some participants still used these.

Other hazardous materials mentioned were: asbestos (reported by two participants), vinyl (reported by three participants), and fibreglass (reported by two participants) (Table 9.7). In addition, the high level of change of views on thermal or blackout curtains, discussed in the previous section, was also observed, with six participants (50%) noting these were risks to be avoided. Two participants also commented on issues related to foam upholstered furniture.

In addition, seven other risks were listed by one participant each (Table 9.8). Many were not explicitly discussed or only discussed in passing during the follow-up session, and in ways not really related to this study. However, there were two important exceptions: glues in flooring and old wallpaper. Although the proposed strategies were not very detailed it was good to see that some participants recognised these as risks.

Table 9.8: Hazardous materials and strategies for decreasing/eliminating the problem reported by only one participant.

Material or substance	Strategies for decreasing/eliminating the problem	Number of references
Glues in flooring	Check with the supplier before use	1
Old wallpaper	Remove	1
New purchases that 'smell'	Store them for a long period away from living/people spaces, e.g. shed	1
Inside electrical meter box	Make sure no person is sleeping/playing regularly beside the meter box	1
Shoes containing glues/chemicals	Store all shoes out of living areas, e.g. well ventilated porch	1
Spray for insects	Don't use	1
Plastics for eating, drinking or storing food	Avoid	1

As with the health rating of materials, there were general differences between female and male comments. Generally male comments were briefer and less numerous, and also more likely to reference structural items or well-known risks such as asbestos, while female participants were more likely to list softer items more intimately related to the experience of living at home, such as where shoes go and what is used in the microwave. Occupations and everyday activities seem to

have influenced what different participants reported. Building and flooring contractors reported on specific materials that they use in their work, and the fire service worker on fire risks. This indicates that participants interpreted the learning from the follow-up session in relation to their personal life situations, relating recognition of risks to their own areas of experience. Therefore, it is possible to see prior experience operating as a mediator of learning, and as such, this experience-enhanced learning could help explain some of the processes in assimilation of information. The recognition of the role experience-enhanced learning plays could help with design and development of future educational efforts.

9.9.2 Experience of follow-up session

The questionnaire also asked participants to specify the area of greatest learning for them. Of the 12 participants, 10 mentioned formaldehyde in a variety of forms: specifically as formaldehyde (5 participants), MDF (3 participants), composite wood (1 participant), particleboard (1 participant); curtains (1 participant), and chemicals in curtains and soft furnishings (1 participant). Another group or responses dealt with plastics (3 participants).

Participants were asked whether at any stage during the follow-up session they thought 'If only I knew this before I/we did...' and 8 participants agreed with this statement. Their explanations are summarised below (these are coded and a reply from the same participant can appear more than once):

- They would have made choices differently when installing a new kitchen – 4 participants;
- They would not have built furniture out of particleboard in the 1970s, – 1 participant;
- They would have avoided installing new vinyl – 2 participants;
- They would have chosen healthy paint and wood oils – 1 participant; and
- They would have requested more environmental choices from their builders – 1 participant.

These results indicate that for most follow-up session participants the greatest learning was related to recognised health risks, such as products containing formaldehyde and vinyl, and it seems information about these is not yet known by the general population.

In the informal discussions at the end of the follow-up session, a high proportion of participants indicated that what helped them understand risks was the fact the author (presenter) pointed out pieces of furniture to show participants how to look for unsealed MDF surfaces under tables and kitchen benches. One participant who had accurately rated materials in the core survey was asked for their personal experience of learning during the session. They explained that although they had a good idea of how healthy certain materials are it was only the demonstration during the follow-up session that showed them how to recognise these risks in their home.

These observations indicate that when dealing with information about building and furnishing materials the general population may face difficulties which are hard to envision for architectural or similar professionals. The key problem seems to be the general population sees objects as they are, without much understanding of how they have been made and what materials were used in the process. Most seemed to have little idea of how the undersides or backs of furniture look, and that off gassing of those areas impacts the quality of indoor air as much as the visible parts. If taken further, it could be assumed the same people could struggle to envision and understand the construction of subfloors, if these are covered by wall-to-wall carpet or vinyl.

Interestingly, studies on educational interventions on lead reporting participants' descriptions of their learning 'a-ha' moments, were very similar, with examples such as demonstrations of particular daily activities or explaining when the problem behaviour/action is happening (Jordan et al. 2004). This similarity is especially relevant given that other possible predictors are very different: educational interventions for lead almost always deal with poorer social groups often of cultural minorities (Jordan et al. 2004), while the follow-up trial had a reasonably well-off, more educated sample, representative of the dominant cultural group. Therefore, the observed similarities, despite the demographic differences, could reflect inherent characteristics of the learning process. Further research in this area is needed, and possible educational intervention should include more hands-on teaching of where and how to look for risks, rather than only discussing these in abstract.

9.9.3 House health rating

Participants of the follow-up trial originally provided house health ratings as part of the core survey. At the end of the follow-up session they were asked to rate their house again, considering what they had learnt. The rating scales were identical: (1) very poor; (2) poor; (3) fair; (4) good; (5) very good; and (6) excellent (Appendices 1,2,7). The received means for before and after house health ratings showed a clear half point drop (4.09 before, to 3.59 after). When paired-samples t-tests were performed for before and after house health ratings a significant difference in ratings was revealed $t(1, 10)=2.472$, $p=0.033$, significant at $p<0.05$ level.

The house health rating means dropped more significantly for female than male participants, for younger than older participants, and for more educated than less educated participants (Table 9.9). The greatest difference was observed for gender, with almost a whole point drop in female ratings (Table 9.9).

Table 9.9: Change in house health ratings before and after the follow-up session based on gender, age and education.

		Drop from before to after	House health rating mean (standard deviation)	
			Before	After
Gender	Female	1.27	4.40 (0.89)	3.13 (0.25)
	Male	0.28	4.14 (0.90)	3.86 (0.38)
Age	20-49 years old	0.83	4.00 (0.00)	3.17 (0.29)
	50-75 years old	0.58	4.33 (1.00)	3.75 (0.46)
Education	High-school or trade	0.33	4.00 (1.00)	3.67 (0.58)
	Bachelor or higher education	0.77	4.33 (0.87)	3.56 (0.50)

In both questionnaires the participants were asked to explain the reasons for their rating. These generally changed to include more specific mention of materials discussed during the follow-up session. Similarly what they consider to be the most needed change in the house was different after the follow-up session. Generally, focus in the core survey was on thermal comfort, insulation and ventilation, and this was replaced by specific actions in relation to materials and fixtures at home, such as pieces of particleboard or MDF, or thermal lined curtains.

9.9.4 Other possible influential factors

When designing the follow-up trial other unrelated factors were recognised as potential influences for who makes and does not make changes, in three categories:

- Tendency to undertake home improvement;
- Availability of finance; and
- Availability of time for changes.

Table 9.10 summarises the received responses to questions that deal with these three aspects.

In this sample, past experience with renovations seem to be predictive of participants taking part in the follow-up session, with 75% in this category and 25% participants in the minor to moderate renovations category, and nobody reporting no renovations (Table 9.11). All participants would be able to make some financial investment to improve their home, and most would be able to invest their own time.

Table 9.10: Answers to questions about tendency to undertake home improvement, and availability of finance and time for changes.

House renovation by participants' families in the last ten years:	
<ul style="list-style-type: none"> - 9 participants (75%) reported serious renovations (such as building an extension, changing house room layout, renewing a kitchen or bathroom); - 1 participant (8%) reported moderate renovations (such as re-doing floor coverings and redecorating most of the house, partial renewal of kitchen or bathroom); - 2 people (17%) reported minor renovations (such as painting a couple of rooms, and tiling a room); and - Nobody reported their house needed no change. 	
How participants see their family placed in relation to finance for investing in the house:	How participants see their family in relation to available time to invest in the house:
<ul style="list-style-type: none"> - 4 participants (33%) reported moderate financial means; - 8 participants (67%) reported they would be able to invest into the house; - Nobody reported having very limited finance available 	<ul style="list-style-type: none"> - 2 participants (17%) reported very limited time; - 4 participants (33%) reported moderate time; - 6 participants (50%) reported having time to invest in the house.

Table 9.11: Participants who have/have not made changes after the follow-up session in relation to their tendency to undertake home improvement, and availability of finance and time for changes.

		Reported change after follow-up session	
		No	Yes
Prior tendency to undertake home improvement	Serious renovations	5	4
	Moderate renovations	1	0
	Minor renovations	1	1
Availability of finance for changes	Moderate means to invest	1	3
	Able to invest	6	2
Availability of time for changes	Very limited	0	2
	Moderate	3	1
	Able to invest	4	2

When evaluating these factors for their relationship with the reported change, it was hard to make any statistically robust conclusions due to the very low numbers. However, there were some indications. The reports of changes were distributed reasonably evenly across different categories for finance and time constraints, indicating that these might not be related, while there was a strong grouping of participants who reported changes in the subgroup of those with prior experience with serious renovations, suggesting the latter could be a stronger predictor of change rather than either availability of finance or time. This needs to be evaluated further with a larger sample.

9.9.5 Attitude and knowledge self-assessment questions

The two questionnaires after the follow-up session included two sets of statements aimed to record participants' attitudes towards a wider range of topics, including their experience of the follow-up session, expectations that they would make changes, and whether their own views would match those of their partners (Appendices 6-7). Some of these questions were included on the assumption the majority of participants would have made significant changes to their houses after the follow-up session. Given that this was not the case, many participants did not answer all these questions and the responses received tended to be in the neutral range, and so are not reported here. The results from the remaining questions are summarised in Table 9.12. Participants were asked to rate the statements on a five point Likert scale (strongly disagree (1); disagree (2); neutral (3); agree (4); strongly disagree (5), with the option 'not applicable', (which nobody used).

Generally participants rated the course content as valuable for them, felt that they had a better understanding of health risks at home after the session, and were surprised to learn some of the materials in their home could be dangerous (statements 1-3, Table 9.12). However, when rating their surprise about how little they knew, participants provided a wider range of ratings and lower mean (statement 4, Table 9.12), indicating that generally they did not see great limitations in their own knowledge.

Results to statements dealing with intentions to make change (statements 5-10; Table 9.12) indicate that as a group participants considered their homes did not need much change (statement 5, mean of 3.30) (Table 9.12). Nobody strongly agreed with statement 6 (neutral mean 3.33) expecting they would make changes (Table 9.12). However, the similar statement 10, which aimed to record excitement about making changes at home, received a higher mean of 3.50, with one participant in strong agreement. Participants did not generally expect much difference in views with their partners and did not feel overwhelmed by the new information (statements 7-9; Table 9.12).

Table 9.12: Key results to attitude questions.

	Statement	Lowest rating	Highest rating	Mean	Standard deviation
1	Content of this course was of value to me.	Agree 4	Strongly agree 5	4.75	0.45
2	I feel that now I have a much better understanding of health risks in our home.	Neutral 3	Strongly agree 5	4.33	0.65
3	I was surprised to learn that some of the materials in our home could potentially be dangerous to our health.	Agree 4	Strongly agree 5	4.33	0.49
4	I have been surprised to learn how little I actually knew about the materials used in our house.	Strongly disagree 1	Strongly agree 5	3.83	1.19
5	I am pleased to find out that our home is healthy just the way it is.	Disagree 2	Strongly agree 5	3.00	1.04
6	I expect that me and my family will make some changes based on this new knowledge.	Strongly disagree 1	Agree 4	3.33	0.99
7	I expect that my partner's and my views will be similar on how important a healthy home is for our family.	Disagree 2	Strongly agree 5	3.75	1.06
8	I expect that my partner's and my views will be similar on readiness to make needed changes to our house.	Disagree 2	Strongly agree 5	3.50	1.00
9	I feel overwhelmed by all the information and how much change I should make.	Strongly disagree 1	Agree 4	2.33	0.89
10	I feel eager to start making changes at home.	Disagree 4	Strongly agree 5	3.50	0.91
FU 1	Since the end of the session my enthusiasm for the topic was generally about the same.	Disagree 2	Strongly agree 5	3.75	0.97
FU 2	My partner's views have positively influenced my enthusiasm.	Disagree 2	Strongly agree 5	3.09	1.04

Of all the attitude questions from the final follow-up questionnaire only two are relevant to discuss here (statements FU 1-2; Table 9.12). The first dealt with participants' evaluations of the role their partner would play in perceptions of learning from the course. It was anticipated that partners might increase or decrease enthusiasm and affect whether actions were taken. The comparison between before and after evaluations indicates the role of partners was evaluated somewhat more favourably immediately after the session than several months later (Table 9.12; Chart 9.5). However,

further research is needed to clarify the role of educational interventions with those taking part and those left at home. Although similarly hard to compare, the statements relating to enthusiasm seem to indicate an increase in enthusiasm (Table 9.12; Chart 9.5), although further research is needed to clarify this.

Chart 9.5: Comparison of ratings received for three statements that deal with the role of a partner.

Chart 9.6: Comparison of ratings received for two statements that deal with enthusiasm.

9.10 Discussion and conclusion

Due to the small sample in the follow-up trial, and the experimental, trial character of the work, more research is needed to confirm any of the observations made in this chapter. Additionally, many of the attitude questions did not provide much useful data, because they operated as pilot questions that require more development. Nevertheless, even with these low numbers and with some questions not being very effective, the follow-up trial does suggest some conclusions.

One of the most significant findings is that the before and after health ratings of materials and house health ratings changed, indicating that many participants learned from the follow-up session. This suggests not only that this could be an effective approach to increasing level of knowledge, but also that the ratings received for the core survey were not the most educated views of these participants.

Unfortunately, none of the participants reported significant changes to their homes in the four to six months after the follow-up session, possibly because the final follow-up questionnaire was sent too early to capture such changes. Many participants indicated the intention to use learning from the follow-up session in subsequent renovation projects. Another possible explanation is that previous renovation seems to have influenced an interest in the follow-up trial, and for those participants the new information arrived at a time when no other changes were needed. It should also be noted that studies on educational interventions for lead found the greatest change generally occurring in the first three to six months after the educational intervention (Ferguson et al. 2012), and with responses arriving well into June 2013, the follow-up sample had a comparable period of time available.

However, the small, practical changes which did happen indicate that this area, rather than renovation, might be where it is easier for people to make changes, and this scale of change is more like the changes made in the lead research. The indication that younger female participants made more significant changes indicates that where funds are limited this might be the group to target. However, a high proportion of participants in this particular subgroup struggled to attend the follow-up session due to family commitments. This further suggests that if targeting this particular group any future educational efforts should consider providing childcare for the duration of sessions. This was a common strategy in community-based educational interventions on lead (Ferguson et al. 2012; Jordan et al. 2007; Jordan et al. 2004).

Previous experience with renovation activities was strongly related with attendance at the follow-up session. It could be that such activities help people identify a need to learn more. If so, future educational efforts targeting these groups could also prove beneficial.

The greatest learning seems to have taken place when the participants experienced the greatest 'a-ha' moment, and reports indicating the greatest learning often came from demonstrations. Interestingly the sample varied greatly on what gave the 'a-ha' moments, and this seems to have been influenced by previous life experience. This suggests that:

1. More dynamic teaching styles could prove more effective in teaching adults about building materials and health; and
2. Separating participants based on their previous life experience and adjusting the teaching to their particular needs could be more effective than teaching different groups together (e.g. teaching a group of mothers separately from a group of DIY renovators).

One important finding of the follow-up trial is that the correlations between the environmental concerns and the health rating of materials were stronger after the educational intervention. Although the small sample size does require confirmation with a larger sample, it suggests the norm-activation model could be acting here, with the higher scores on the environmental concerns being activated into faster learning. Furthermore, this indicates that the relative absence of significant correlations between environmental concerns and the health ratings of materials in the core study show the general population does not know much about the healthiness of building and furnishing materials.

Therefore, it is possible to conclude that the follow-up trial provided useful insights for answering all three research questions of this thesis. Possibly the most significant contribution is that it provided additional evidence to support the tentative conclusion from chapter 6 that people do not seem to know much about the healthiness of building and furnishing materials. The participants of the follow-up trial expressed this directly in the focus group, through the changes in their health ratings of materials after the session, and implicitly through the increased correlations. Based on the thesis results, it is possible to conclude that there is limited awareness of issues around the harmful impact building and furnishing materials could have on human health.

This study also reinforces the finding from the core study that gender is the most significant predictor of the health ratings of materials, with female participants providing the more accurate ratings. This is further strengthened by the follow-up trial, which additionally suggests that the female participants are more likely to make changes based on new information.

Finally, the evaluations after the educational intervention indicate that this approach can be effective, although this experience also suggest more specific targeting of attendees (such as mothers or DIY enthusiasts). The results also suggest that more pilot study evaluations should be undertaken prior to launching such programmes, because relatively subtle differences in content and context seem to impact the outcome.

Therefore, despite the very small sample size and pilot nature this study has answered most of the initial research questions, because of its limitations all conclusions should be treated with caution. Fortunately, the majority of conclusions drawn echo similar patterns to those from the core study and other literature.

Chapter 10

Conclusions

The outcomes of this thesis must be evaluated in relation to the three hierarchical and related questions, and the hypothesis, which were introduced at the start. The conclusions discussed here are grouped around these aspects.

10.1 Primary question:

How informed, or knowledgeable, is the general population about risks to human health associated with building and furnishing materials commonly used in domestic spaces? (Q1)

Most of the discussion in this thesis relates to answering this question. Part I introduced the patterns and key limitations in the existing literature and established the problems of determining which materials are safe and which pose risks. Chapter 2 specifically examined architectural sources, concluding that they are limited in terms of providing sufficient summaries of available knowledge. Three significant limitations were observed:

1. Existing knowledge summarising sources tend to take a relatively conservative perspective on risks, which by implication understates the extent of the problem;
2. Literature on sustainability provided very inconsistent coverage of the issue of healthiness of materials, which could be misleading for less informed people who could assume that what is recommended as good for the environment is also good for human health; and
3. An increase in design experimentation with materials has been noted, but these works rarely make reference to the healthiness of the materials used.

This situation suggests that there are multiple factors influencing a potentially low level of available information on the health risks associated with building and furnishing materials even within the architectural profession.

To compensate for these limitations, chapter 3 evaluated available knowledge in medical and other scientific literature. It introduced the four phases of recognition of risk from a particular substance as a useful framework for organising an overview of the available literature. From this it is clear that new knowledge is emerging, but that there are still significant gaps in scientific knowledge and delays in the process of formal recognition of risks. Some of the most significant problems include:

1. Absence of any clear example of eliminating use of a substance following agreement that it poses a health risk. Lead and asbestos come closest for such an elimination but:
 - These have only been eliminated in more developed countries, and their use continues elsewhere.
 - A better understanding of how harmful to human health these substances are is still developing.
 - Poor practices and unskilled removal of these substances remain even in the developed countries because of lack of appropriate protocols.
2. Significant delays in decreasing and eliminating substances which are recognised as potentially harmful.
3. The same patterns of ignoring early warning signs can be observed when new materials are developed. Current discussions of nanotechnology indicate that although there is a body of literature questioning the harmfulness of nanotechnology on the basis of its structural similarity with asbestos, much of the literature discussing it does not reflect these concerns. This suggests there is still a tendency to dismiss and ignore early warnings.

Based on these observations, chapter 3, and the whole of part I, concluded that even experts struggle to articulate risks adequately, which is why the precautionary principle offers the best protection through reacting to risks at the point of 'suspicion.'

However, the problems from disregarding early warning signs during the development of new materials, and problems of reduction in exposure even for well recognised hazards, translate into even greater problems for the general population when it comes to considering building and furnishing materials. The issues of partial and conflicting information could significantly limit not only the level of knowledge of the general population around these issues but also their desire to engage with such a field of uncertainty.

The main part of this thesis, the core survey was set up to investigate how a sample of the general population engages with these issues. Its primary purpose was to evaluate how informed, or knowledgeable, the participants were about the risks to the health of themselves and those living in the same household posed by common building and furnishing materials. Part II discussed the core survey and its results in chapters 4-8. While each chapter dealt with one aspect of the core survey, chapter 6 focused on analysis of the results to measure the level of knowledge expressed by the participants.

Analysis of the data from the core survey showed the total sample tended to rate building and furnishing materials around the neutral towards healthy range, with an overall mean of 3.36 (the scale was 'unhealthy 1,' '2,' 'neutral 3,' '4,' 'healthy 5'). Even the lowest rated material, 7+ years old underlay, had a mean of 2.38 which was not far from neutral. Generally, higher standard deviations of ratings were observed for materials with lower means (unhealthy), showing that even for seemingly unhealthy materials some participants provided ratings in the healthy range. In addition, materials with lower ratings also received a higher prevalence of 'I don't know' ratings, while the highly rated materials generally had the lowest prevalence of 'I don't know.' This indicated participants were more hesitant to provide negative than positive ratings, and suggests a lack of certainty in evaluating what is harmful. This could be reflective of the problems identified in part I, especially of continued rebuttal and conflicting information even around relatively recognised risks.

In addition, the three general samples showed poor differentiation between products with very different impacts on human health, illustrated by the similar health ratings received for two important material pairs:

- Vinyl and linoleum, and
- Particleboard and MDF, and low/zero formaldehyde particleboard and MDF.

Similar ratings for these materials with their very different health impacts, together with the neutral to high ratings received for most materials, strongly suggest that the participants from the three general samples struggled to recognise any significant health risks.

More qualitative data from the follow-up trial intervention (Part III, Chapter 9) support these observations. Although this sample was very small, making all conclusions indicative, the focus group discussions acknowledged the limited knowledge of the participants, and the changes to ratings after the educational intervention, with many materials rated as less healthy, further suggest that the three general samples did not have such knowledge.

Therefore, results from both core survey and the follow-up trial intervention support the conclusion that the sample of the general population surveyed had very limited knowledge about the healthiness of building and furnishing materials in their homes.

The NZ architects sample demonstrated a much higher level of recognition of the risks associated with building and furnishing materials, and this was especially clear for the two pairs of materials which the three general samples struggled to differentiate. The NZ architects thus demonstrated a much higher level of knowledge about the health risks of materials than the three general samples, although the question still remains as to whether their low ratings were low enough. As shown in table 6.3, only three materials received means lower than 2 from the NZ architects sample, while its BBE subgroup rated 9 materials in this range, including 2 that received the lowest possible means of 1.00. Similarly, the follow-up trial sample rated 7 materials under 2 after the follow-up session. Thus, the ratings from the NZ architects still seem relatively generous, meaning the knowledge held by this group might be less than ideal.

The results of this thesis suggest the lack of clarity, and repeated discussion and rebuttal of the unhealthy impact of building and furnishing materials as discussed in part I, could be reflected in the 'indecisive' in ratings of the general population, with the tendency to see most materials in the neutral towards healthy range. Although the NZ architects sample ratings differed in these areas from the three general samples, their ratings also indicated a milder but similar tendency, mediated by higher accuracy in differentiating between the materials and a generally higher level of knowledge about them. This suggests that lack of clarity in what is seen by experts as unhealthy in building and furnishing materials, translates into an even higher level of confusion and ignorance in the general population.

10.2 Secondary question:

Could any predictors be observed that relate to how informed participants are? (Q2)

This secondary question mostly relates to the results analysed in chapters 7-9. Although chapter 4 identified established frameworks from psychology that were anticipated to act as predictors of the health ratings of materials in the core survey, generally this part of the research was approached in an exploratory manner. In fact, the most significant result related to one of the least anticipated characteristics, gender. Chapters 7 and 9 both show that in all samples gender was the most significant predictor of the health ratings of materials, with male participants tending to rate materials higher regardless of whether they are healthy or unhealthy, while female participants gave somewhat lower ratings, more reflective of the healthiness of the materials. When evaluating the patterns in response to the educational intervention of the follow-up trial, gender was also a strong predictor of change both in repeated health ratings of materials and reports of change at home (Chapter 9).

As discussed in section 7.3, other scholarly work has also observed differences in ratings which correspond to gender. However, it is only in the last year or two that studies have appeared in psychology focused on explaining this phenomenon. For example, in 2010 Wilson and White

proposed differences in social dominance orientation as the explanation of differences of political conservatism observed in relation to gender. The same was subsequently tested for impact on environmental concerns (Milfont et al. 2013). This forms an area for further research in the field of buildings and furnishing material selection.

Another observed trend in both the core study and the follow-up trial was that in the three general samples familiarity with asthma or allergies was also a predictor, although though less strong, of more knowledge about the healthiness of materials (Chapters 7 and 9). Age and level of education had non-consistent results indicating a possible generational difference in views about materials, but again this is an area for further research.

When evaluating for the impact of individual psychological predictors no clear relationships were found between the health rating of materials and environmental concerns in the core survey (Chapter 7), but environmental concerns appeared as a predictor of change after the follow-up trial intervention (Chapter 9). Although further study is needed to explain this, these data sets suggest that absence of correlations between the environmental concerns and health ratings of materials in the core survey could be an additional indication of low level of knowledge about these risks. To an extent the five personality traits appeared to predict the health ratings of materials in the core survey (Chapter 7). Generally the more open participants were more correctly aware of risks, while agreeableness indicated a general tendency to give high ratings to all materials. Neither patterns were sufficiently strong or clear to be conclusive, nor were similar patterns found in the follow-up trial data (Chapter 9).

Therefore it is possible to conclude that there were some strong predictors were observed, and for others additional data is needed to better explain the findings.

Furthermore, the results and analyses support the hypothesis that there are observable demographic, individual, psychological, and cultural predictors of people's views of the health risks associated with building and furnishing materials. One clear limitation for this result was the relative absence of similar work exploring predictors of people's views on architecture with which to evaluate some of the conclusions drawn from the data collected. This lack of work to build on also affected the survey design. For example, it seemed that some of the health ratings of materials reflected people's preferences for these materials (what else could explain why openness correlated with higher ratings of glass which was already highly rated by everyone?). If previous study had revealed predictors of what materials people would like, these could have helped narrow the conclusions here in relation to the healthiness of materials. Consequently, this thesis was generally navigating very broad areas without much prior research to help this.

The analyses in this thesis produced a series of observations that could serve as the basis for future research. Generally, these were not discussed during the thesis, because they did not directly relate to the research questions, and also because it was difficult to explain such trends. What was observed indicates that more agreeable participants seem to prefer more natural materials, and that more open participants tend to live in older houses. Some strong groupings of demographic predictors were also observed, related to people who lived in new houses. While these surveys were not set up to explore these issues, they indicate that there is a possible field of study that could help architecture refine its own expectations from the perspective of its final users. In essence, people vary greatly in what they want/assume/value in architecture and only detailed investigations of the personal characteristics that might be influencing such variations can help architects understand this situation better. This is an additional reason for advocating the relevance of introducing psychological quantitative methods into the study of architecture.

10.3 Third question:

Could education affect both knowledge and action in relation to the health risks associated with building and furnishing materials?

The effectiveness of an educational intervention was evaluated by the follow-up trial intervention (Chapter 9), which only had 12 participants, limiting the conclusions that can be extracted from it. The main observations were that the participants only made very modest changes to do with the functional use of space following the follow-up session, and this perhaps suggests that the final follow-up questionnaire was sent too early (4-5 months after the session). However, it was possible to record changes to reported knowledge on the health risks associated with materials, and these were most clearly predicted by gender (female participants changed their views more), and experience with asthma and allergies. These predictors strongly indicate that more information does not simply translate into more knowledge and use of that information. Interestingly, past experience with house renovation seemed to predict participation in the follow-up session while younger female participants made the most numerous changes to their living practices. These two, together with the feedback from the session, suggested that possible future educational interventions in this area would need to be tailored to meet the demands of specific shared interest groups.

10.4 Limitations and further research

By focusing on exploring a fairly wide and relatively under-researched area, this thesis has opened itself to the potential pitfall of spreading itself too thin. While much was done to prevent this, it should be acknowledged that whenever the research had to step outside the discipline of architecture, which happened frequently, these were areas new to the author. The chances of thus

poorly identifying some of the key discipline-specific issues in any of those disciplines should be acknowledged. More collaborative work with experts in other areas would help mediate such problems, but is not appropriate for a PhD study. This explains the possible degree of conceptual 'roughness' when discussing non-architectural material.

Unfortunately, only after analysis of the results did the need for improvements to the original survey design become apparent. Rephrasing and retargeting some of the questions could have improved the comparability of data without making the questionnaire any longer. For example, the age groups were too big, and the earliest data set from the NZ long sample had even bigger groups. Thus, indications that there could be a generational difference in views about healthiness of materials, which does not simply correlate with older/younger participants, were impossible to explore adequately. To address this would need different sample groups relative to age.

Similarly, in retrospect some of the findings could have been anticipated during the design process, especially the finding for gender, because articles discussing differences in environmental concerns in relation to gender were identified before the questionnaire design. However, targeting samples on this basis was not attempted because of the exploratory nature of the study, and because no prior studies on predictors of health ratings of materials were found. If the impact of gender were to be anticipated, then two questions could be integrated into a similar study to obtain more refined insights into what gender differences really mean. Firstly, if others have found that male participants tend to rate risks lower (Section 7.3), introducing a question on rating risks could help identify and benchmark the attitudes of the individual participants towards risk. For example, it seems possible that people who rate risks from earthquakes or global warming lower than others, could easily also rate risks associated with building and furnishing materials lower. Doing this could help to make this trend clearer. Secondly, how people rate something on a scale is not necessarily a direct reflection of what they do. A method could be devised aimed at measuring everyday practices at home as a way of avoiding possible distortions due to attitudes towards having a ratings scale. However, such refinements are usually only possible after the first study is completed.

Similarly, some predictors of people's views towards architecture were recognised during this research, and any further research in this area should consider including questions on the general preferences for materials participants might have. Recording preferences for architectural styles could also be relevant. It seems possible that such factors could be influencing people's health ratings of materials. For example, a group of people who like natural materials and traditional houses could differ in their ratings from another group of people who like a modern, minimalist look and dislike natural materials. Questions of this type could be evaluated using architectural images or even material samples. Developing upon such strategies, it would be possible to refine the insight into people's views about the healthiness of building and furnishing materials.

This whole thesis can be seen as an attempt to explain what influences people's readiness to dismiss as unimportant issues around the healthiness of building and furnishing materials. Although some clear observations have been made as a result of this research, this essential question still remains unanswered. Perhaps a different approach is needed. It could be one that starts from other work dealing with a similar readiness to dismiss as unimportant issues such as climate change, or perhaps even more useful would be the psychological insights into people's continuation to smoke cigarettes after the readily available information on the health dangers they pose. The relative ignorance around the risks associated with building and furnishing materials observed here should be considered in this broader context, and there is much need for future studies that engage with such issues. It seems important not to be discouraged by the lack of conclusions stemming from this research, but rather to think about this thesis as placing some initial stepping stones into an important but not yet well understood territory.

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Appendix 1

1A-1

Questionnaire on Materials

We have all heard discussion of how unhealthy certain materials or substances in everyday use are for people. However, this is an area where even the experts struggle to agree, leaving much space for differing positions that are equally correct.

In the light of this, we are interested in your opinions on health in relation to building and furnishing materials and whether considerations of health influence your purchasing decisions.

There are no right or wrong answers, we simply want to know what are your current views and practices.

1 General Questions

To help us understand where you personally are coming from please answer some general questions about yourself and your household.

What is your home address? _____

What is your gender? ☐ Female ☐ Male

Approximately how old is your home (in years)? _____

What best describes your cultural background?

- ☐ New Zealand European
☐ Maori or Pacific People
☐ Other _____

Is your home?

- ☐ Owned or part owned by you or your family trust
☐ Rented
☐ Other _____

Have you ever lived in a country other than New Zealand for five years or longer?

☐ Yes ☐ No

How many people normally live in your home? _____

What best describes your education and training?

- ☐ High-school
☐ Trade qualification
☐ Bachelor or Honours degree
☐ Master or Doctoral degree
☐ Other, please specify _____

Please indicate the number of household members in the different age groups. Please circle your own age group.

- 0-4 years old _____
 5-9 years old _____
 10-19 years old _____
 20-49 years old _____
 50-75 years old _____
 Over 75 years old _____

What is your occupation (e.g. electrician, social worker)? _____

Does anybody in your household normally spend most of their time at home (e.g. babies, pre-schoolers, retired elderly, adults caring for young or infirm)?

☐ No ☐ Yes If yes, how many people _____

What is your approximate total household income?

- ☐ \$40,000 or less
☐ \$40,001 - \$70,000
☐ \$70,001 - \$100,000
☐ \$100,001 - \$150,000
☐ \$150,001 or more

Does anybody in your household suffer from asthma or other chronic respiratory problems?

☐ No ☐ Yes If yes, how many people _____

Does anybody in your household suffer from allergies?

☐ No ☐ Yes If yes, how many people _____

1A-2

2 Health Rating of Your House

	Very poor	Poor	Fair	Good	Very good	Excellent
What health rating would you think your house deserves as it is today?						

Briefly explain the main reasons for your assessment.

3 Attitude

Please consider following statements and indicate how much you agree or disagree with them. For each statement, place a tick in one of the numbered boxes that best represents your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Not applicable
	1	2	3	4	5	0
Living in a healthy home is important to me.						
I feel reassured that if a product was not healthy for me and my family it would not be on the market.						
I trust that the government and/or other bodies are controlling how healthy the products that are on the market are.						
I trust that my architect/builder has used healthy materials when working on my home.						
I prefer natural vs. human-made materials.						
The look and practicality of household items I buy is more important to me than what they are made out of.						
If choosing between two materials of almost identical price, I would give priority to the healthier one.						
If choosing between two materials of almost identical price, I would find another quality to help me make the choice.						
I believe that sustainable materials are good for my health and health of my family.						
I feel confident with my knowledge of how healthy the materials in my home are.						
I would appreciate learning more about what are the healthier options.						
I feel confused about contradictory information I have heard or read about what is healthy or not at home.						
If I knew where to ask, I would call a professional today to assess how healthy my home is.						
I like making improvements on my home.						
I believe that my partner and I have very similar views on health at our home.						
I believe that my partner and I would be equally ready to make healthier changes.						

1A-3

4 Health Rating of Interior Materials

Please rate the following materials commonly found in New Zealand homes based on how healthy you personally think they are. There are no right or wrong answers, we are interested in your individual views.

Please tick in the last column whether there is large or modest use of the particular material in your house. If none, please leave these boxes empty. If unsure, please use question mark (?).

	Unhealthy		Neutral		Healthy	I don't know	Have it in my home	
	1	2	3	4	5	0	Lots	Some
Wood based materials for furniture or structural use								
Wood – unfinished, natural								
Wood - painted								
Wood – varnished								
Wood with another treatment								
Particle board or MDF – unfinished, natural								
Particle board or MDF – painted								
Particle board or MDF – varnished								
Particle board or MDF – with wood veneer								
Particle board or MDF – with plastic veneer								
Particle board or MDF – with another treatment								
Plywood – unfinished, natural								
Plywood – painted								
Plywood – varnished								
Plywood with another treatment								
Other structural/non-structural materials								
Brick or concrete (subfloor or walls, plastered or not)								
Gib or other plasterboard								
Acoustic panels								
Artex/cottage cheese								
Metal								
Glass								
Rattan or cane								
Other								
Floor coverings								
Vinyl								
Linoleum								
Cork								
Laminated wood floor								
Ceramic, porcelain or stone tiles								
Polished/sealed concrete								
Wall-to-wall carpet								
Other								

Continued over page

Continued table: 4 Health Rating of Interior Materials

	Unhealthy		Neutral		Healthy	I don't know	Have it in my home	
	1	2	3	4	5	0	Lots	Some
Carpet or rug materials and treatments								
Wool								
Nylon								
Polyester								
Polypropylene								
Acrylic								
Wool-synthetic blends								
Synthetic blends								
New fibres, such as Rhino								
Stain, dust, moth protection built into carpet								
New foam carpet underlay								
7+ year old carpet underlay								
Other _____								
Wood varnishes								
Water-based polyurethane								
Normal, solvent-based polyurethane								
Oil with some effective solvent, such as Danish or Carl's oils								
Natural oils with very little use of solvent, such as Osmo oil								
Other _____								
Paint types								
Water-based acrylic paint								
Water-based low-VOCs acrylic paint								
Oil-based interior paint								
Plant and mineral paints, such as Bio Paints								
Other _____								
Curtains and roman blinds								
Thermal or blackout lined curtains or roman blinds								
Unlined or with separate lining curtains or roman blinds								
Net/sheer curtains								
Other _____								
Venetian and roller blinds								
Wood or bamboo blinds								
Metal venetian blinds								
Plastic venetian blinds								
PVC roller blinds								
Synthetic fabric roller/pleated blinds								
Other _____								
Insulation materials								
Fibreglass pink batts								
Wool								
Polyester, green batts								
Under-floor draped foil								
Inner wall spray foam								
Other _____								

1A-5

5 Current Practice

In the last two years have you made a purchasing decision to avoid for health reasons any of the materials or furniture you have scored 1 or 2 (or even higher) in the previous table (section 4)?

☐ No ☐ Yes If yes, please circle the rating of these materials where they appear in the previous table.

In the last two years have you removed out of your home primarily for health reasons any materials or furniture that you have scored 1 or 2 (or even higher) in the previous table (section 4)?

☐ No ☐ Yes If yes, please put a line or cross through the rating of these materials where they appear in the previous table.

Overall, what do you consider to be the most important health improvement currently needed in your home?

In the last two years have you bought or installed in your home any of the materials you have scored 1 or 2 in the previous table (section 4)?

☐ No ☐ Yes If yes, please give the reason(s) for your choice(s).

When making a purchasing decision, if I am unclear which product is healthier, I would:

- ☐ Ask the people working in the shop
- ☐ Ask my friends and family
- ☐ Research the products through the internet and/or books
- ☐ Not try to find out more

I feel that I know about health risks at home:

- ☐ More than most other New Zealanders
- ☐ About the same as most other New Zealanders
- ☐ More about risks in some areas, less in others than other New Zealanders
- ☐ Less than most New Zealanders

I trust that I would know if there was a real problem because:

- ☐ People that I know would also know about it
- ☐ There would be more information in the news
- ☐ The government would be making some legislative changes

If the healthiest option was more expensive I would be:

- ☐ Ready to pay extra regardless of price difference
- ☐ Ready to pay extra only if it was less than 10% more
- ☐ Ready to pay extra only if it was less than 30% more
- ☐ Not be ready to pay any difference
- ☐ My readiness to pay more would depend on what the product is for

If I knew we had to make some changes to our home to improve health:

- ☐ I would readily do that
- ☐ I would do that only if it was fairly simple
- ☐ I would do that only if it was fairly affordable
- ☐ I would do that only if it was what everyone else was doing
- ☐ I would not make changes

To help us compare your views with views of other people, please complete following three standard psychological questionnaires.

6 The ESS Human Values Scale

Here we briefly describe some people. Please read each description and think about how much each person is or is not like you. Tick the box to the right that shows how much the person in the description is like you.

How much like you is this person?

	Very much like me	Like me	Somewhat like me	A little like me	Not like me	Not like me at all
	1	2	3	4	5	6
1. Thinking up new ideas and being creative is important to him/her. He/she likes to do things in his/her own original way.						
2. It is important to him/her to be rich. He/she wants to have a lot of money and expensive things.						
3. He/she thinks it is important that every person in the world be treated equally. He/she believes everyone should have equal opportunities in life.						
4. It is important to him/her to show his/her abilities. He/she wants people to admire what he/she does.						
5. It is important to him/her to live in secure surrounding. He/she avoids anything that might endanger his/her safety.						
6. He/she likes surprises and is always looking for new things to do. He/she thinks it is important to do lots of different things in life.						
7. He/she believes that people should do what they're told. He/she thinks people should follow rules at all times, even when no-one is watching.						
8. It is important to him/her to listen to people who are different from him/her. Even when he/she disagrees with them, he/she still wants to understand them.						
9. It is important to him/her to be humble and modest. He/she tries not to draw attention to himself/herself.						
10. Having a good time is important to him/her. He/she likes to 'spoil' himself/herself.						
11. It is important to him/her to make his/her own decisions about what he/she does. He/she likes to be free to plan and not depend on others.						
12. It is very important to him/her to help the people around him/her. He/she wants to care for their well-being.						
13. Being very successful is important to him/her. He/she hopes people will recognise his/her achievements.						
14. It is important to him/her that the government ensures his/her safety against all threats. He/she wants the state to be strong so it can defend its citizens.						
15. He/she looks for adventures and likes to take risks. He/she wants to have an exciting life.						
16. It is important to him/her always to behave properly. He/she wants to avoid doing anything people would say is wrong.						
17. It is important to him/her to get respect from others. He/she wants people to do what he/she says.						
18. It is important to him/her to be loyal to his/her friends. He/she wants to devote himself/herself to people close to him/her.						
19. He/she strongly believes that people should care for nature. Looking after the environment is important to him/her.						
20. Tradition is important to him/her. He/she tries to follow the customs handed down by his/her religion or his/her family.						
21. He/she seeks every chance he/she can to have fun. It is important to him/her to do things that give him/her pleasure.						

1A-7

7 Ten Item Personality Inventory (TIPI)

Here are a number of personality traits that may or may not apply to you. Please write a number next to each statement to indicate the extent to which *you agree or disagree with that statement*. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

	Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Strongly agree
	1	2	3	4	5	6	7
I see myself as extroverted, enthusiastic.							
I see myself as critical, quarrelsome.							
I see myself as dependable, self-disciplined.							
I see myself as anxious, easily upset.							
I see myself as open to new experiences, complex.							
I see myself as reserved, quiet.							
I see myself as sympathetic, warm.							
I see myself as disorganised, careless.							
I see myself as calm, emotionally stable.							
I see myself as conventional, uncreative.							

8 Measuring environmental motives

People around the world are generally concerned about environmental problems because of the consequences that result from harming nature. However, people differ in the consequences that concern them the most. Please rate each of the following items from 1 (not important) to 7 (supreme importance) in response to the question:

I am concerned about environmental problems because of the consequences for

	Not important						Supreme importance
	1	2	3	4	5	6	7
Plants							
Marine life							
Birds							
Animals							
Me							
My lifestyle							
My health							
My future							
People in the community							
All people							
Children							
Future generations							

Appendix 2

1A-1

Questionnaire on Materials

1 General Questions

To help us understand where you personally are coming from please answer some general questions about yourself and your household.

What suburb do you live in? _____

What is your gender?

☐ Female

☐ Male

When approximately was your home built?

☐ Before 1919

☐ 1970-1989

☐ 1920-1949

☐ 1990-2004

☐ 1950-1969

☐ Since 2005

Please indicate your age group:

☐ Under 20 years old

☐ 50-64 years old

☐ 20-34 years old

☐ 65-75 years old

☐ 35-49 years old

☐ Over 75 years old

Is your home?

☐ Owned or part owned by you or your family trust

☐ Rented

☐ Other _____

What best describes your cultural background?

☐ New Zealand European

☐ Maori or Pacific People

☐ Other _____

How many people normally live in your home? _____

What best describes your education and training?

☐ High-school

☐ Trade qualification

☐ Bachelor or Honours degree

☐ Master or Doctoral degree

☐ Other, please specify _____

Does anybody in your household suffer from asthma or other chronic respiratory problems?

☐ No ☐ Yes If yes, how many people _____

Does anybody in your household suffer from allergies?

☐ No ☐ Yes If yes, how many people _____

What is your occupation (e.g. electrician, social worker)?

2 Health Rating of Your House

	Very poor	Poor	Fair	Good	Very good	Excellent
What health rating would you think your house deserves as it is today?						

Briefly explain the main reasons for your assessment.

Overall, what do you consider to be the most important health improvement currently needed in your home?

3 Attitude

Please consider following statements and indicate how much you agree or disagree with them. For each statement, place a tick in one of the numbered boxes that best represents your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Not applicable
	1	2	3	4	5	0
Living in a healthy home is important to me.						
I would appreciate learning more about what the healthier options are.						
I feel reassured that if a product was not healthy for me and my family it would not be on the market.						
I trust that the government and/or other bodies are controlling how healthy the products that are on the market are.						
I trust that my architect/builder has used healthy materials when working on my home.						
I believe that sustainable materials are good for my health and health of my family.						
Finance is the major obstacle for me to make substantial changes.						

4 Current Views

Tick as many as applicable

I feel that I know about health risks at home:

- ☐ More than most other New Zealanders
- ☐ About the same as most other New Zealanders
- ☐ More about risks in some areas, less in others than other New Zealanders
- ☐ Less than most New Zealanders

When making a purchasing decision, if I am unclear which product is healthier, I would:

- ☐ Ask the people working in the shop
- ☐ Ask my friends and family
- ☐ Research the products through the internet and/or books
- ☐ Not try to find out more

I trust that I would know if there was a real problem because:

- ☐ People that I know would also know about it
- ☐ There would be more information in the news
- ☐ The government would be making some legislative changes

If the healthiest option was more expensive I would be:

- ☐ Ready to pay extra regardless of price difference
- ☐ Ready to pay extra only if it was less than 10% more
- ☐ Ready to pay extra only if it was less than 30% more
- ☐ Not be ready/able to pay any difference
- ☐ My readiness to pay more would depend on what the product is for

If I knew we had to make some changes to our home to improve health:

- ☐ I would readily do that
- ☐ I would do that only if it was fairly simple
- ☐ I would do that only if it was fairly affordable
- ☐ I would do that only if it was what everyone else was doing
- ☐ I would not make changes

1A-3

5 Health Rating of Interior Materials

Please rate the following materials based on how healthy you personally think they are. Most of these are commonly found in New Zealand homes although this is not an all inclusive list.

	Unhealthy		Neutral		Healthy	I don't know
	1	2	3	4	5	0
5.1 Structural/non-structural materials						
Wood						
Particle board or MDF						
Metal						
Glass						
Artex/'cottage cheese' rough ceiling						
5.2 Floor coverings						
Vinyl						
Linoleum						
Laminated wood/pretend wood floor						
Ceramic, porcelain or stone tiles						
Wall-to-wall carpet						
5.3 Carpet or rug materials and treatments						
Natural materials such as Wool, Jute, Cotton						
Synthetics such as Nylon, Polyester, Polypropylene						
Stain, dust, moth protection built into carpet						
New foam carpet underlay						
7+ year old carpet underlay						
5.4 Varnishes and paints						
Water-based polyurethane						
Solvent-based polyurethane						
Wood oils and waxes						
Water-based acrylic paint						
Oil-based interior paint						
Plant and mineral paints, such as Bio Paints						
5.5 Drapes						
Thermal or blackout lined drapes						
Unlined or separately lined drapes						
5.6 Insulation materials						
Fibreglass						
Wool						
Polyester						
Inner wall spray foam						

6 Current Practice

In the last two years have you avoided buying certain materials for health reasons?

☐ No ☐ Yes If yes, please list the materials _____

In the last two years have you removed out of your home any materials you considered unhealthy?

☐ No ☐ Yes If yes, please list the materials _____

7 Ten Item Personality Inventory (TIPI)

Here are a number of personality traits that may or may not apply to you. Please tick one box next to each statement to indicate the extent to which *you agree or disagree with that statement*. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

	Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Strongly agree
	1	2	3	4	5	6	7
I see myself as extroverted, enthusiastic.							
I see myself as critical, quarrelsome.							
I see myself as dependable, self-disciplined.							
I see myself as anxious, easily upset.							
I see myself as open to new experiences, complex.							
I see myself as reserved, quiet.							
I see myself as sympathetic, warm.							
I see myself as disorganised, careless.							
I see myself as calm, emotionally stable.							
I see myself as conventional, uncreative.							

8 Measuring environmental motives

People around the world are generally concerned about environmental problems because of the consequences that result from harming nature. However, people differ in the consequences that concern them the most. Please rate each of the following items from 1 (not important) to 7 (supreme importance) in response to the question:

I am concerned about environmental problems because of the consequences for _____

	Not important						Supreme importance
	1	2	3	4	5	6	7
Plants							
Marine life							
Birds							
Animals							
Me							
My lifestyle							
My health							
My future							
People in the community							
All people							
Children							
Future generations							

Appendix 3

Bivariate correlations for the total sample between the five personality traits and the health rating of materials. Maximum number of responses 247.

			Extraversion	Agreeable- ness	Conscien- tiousness	Emotional stability	Openness
1	Wood	P.C.	.015	.119	.079	.098	.059
		Sig.	.027	.075	.238	.144	.377
2	Particleboard and MDF	P.C.	.060	.083	.037	.049	-.277**
		Sig.	.388	.229	.588	.476	.000
3	Low/zero formaldehyde particleboard and MDF	P.C.	-.077	-.005	-.016	.089	-.308**
		Sig.	.341	.947	.841	.274	.000
4	Metal	P.C.	.077	.107	.126	.155*	.104
		Sig.	.327	.173	.106	.046	.183
5	Glass	P.C.	.024	.152*	.073	.145*	.204**
		Sig.	.720	.022	.269	.029	.002
6	Vinyl	P.C.	-.047	.224**	-.008	.087	-.181**
		Sig.	.489	.001	.903	.709	.008
7	Linoleum	P.C.	-.054	.154*	-.007	.087	-.023
		Sig.	.436	.025	.925	.205	.737
8	Cork	P.C.	.032	.012	-.034	.254**	.007
		Sig.	.677	.878	.663	.001	.924
9	Laminated wood	P.C.	-.082	.220**	-.040	.049	-.100
		Sig.	.230	.001	.557	.471	.144
10	Ceramic, porcelain or stone tiles	P.C.	-.026	.216**	.121	.242**	.134*
		Sig.	.698	.001	.073	.000	.047
11	Wall-to-wall carpet	P.C.	.095	.103	-.006	.069	-.099
		Sig.	.154	.123	.923	.304	.136
12	Natural carpet materials	P.C.	-.067	.227**	.036	.085	.136*
		Sig.	.322	.001	.589	.204	.043
13	Synthetic carpet materials	P.C.	-.080	.138*	.046	.086	-.100
		Sig.	.241	.042	.499	.207	.140
14	Stain, dust, moth carpet treatment	P.C.	-.067	.104	-.009	-.028	-.203**
		Sig.	.348	.142	.897	.697	.004
15	New foam underlay	P.C.	-.012	.110	.010	.065	-.152*
		Sig.	.868	.126	.884	.366	.033
16	7+ year old carpet underlay	P.C.	-.022	.024	-.056	.112	-.096
		Sig.	.754	.734	.429	.110	.171
17	Water-based polyurethane	P.C.	-.009	.183**	.101	.099	-.025
		Sig.	.903	.008	.145	.154	.721
18	Solvent-based polyurethane	P.C.	-.005	.096	-.007	.025	-.165*
		Sig.	.938	.168	.919	.715	.018
19	Wood oils and waxes	P.C.	.108	.117	-.013	.161*	.015
		Sig.	.117	.090	.851	.019	.825
20	Water-based acrylic paint	P.C.	-.043	.115	.112	-.026	-.047
		Sig.	.536	.094	.103	.709	.493
21	Oil-based paint	P.C.	-.039	.061	-.048	.012	-.188**
		Sig.	.572	.381	.487	.860	.006
22	Plant and mineral paints	P.C.	.059	.201**	.052	.186**	.043
		Sig.	.414	.005	.471	.010	.549
23	Thermal/ blackout curtains	P.C.	-.058	.261**	.069	.003	-.030
		Sig.	.407	.000	.324	.968	.669
24	Unlined/ separate lining curtains	P.C.	-.056	.216**	.046	.118	.001
		Sig.	.415	.001	.503	.860	.988
25	Fibreglass	P.C.	.053	.062	-.058	.054	-.092
		Sig.	.439	.359	.394	.424	.174
26	Wool	P.C.	-.059	.220**	.039	.147*	.109

		Sig.	.391	.001	.564	.031	.108
27	Polyester	P.C.	.052	.102	.043	.080	.002
		Sig.	.463	.147	.545	.252	.977
28	Inner wall spray foam	P.C.	.151*	.086	.012	.075	-.142
		Sig.	.038	.237	.870	.302	.051

P.C. – Pearson correlation. Sig. – Significance (2-tailed). * Correlation is significant at the $p < 0.05$ level (2-tailed) (highlighted yellow). ** Correlations is significant at the $p < 0.01$ level (2-tailed) (highlighted yellow). All significant correlations highlighted with light orange field background.

Appendix 4

Bivariate correlations for the three general samples combined between the five personality traits and the health rating of materials. Maximum number of responses 183.

			Extraversion	Agreeable- ness	Conscien- tiousness	Emotional stability	Openness
1	Wood	P.C.	.083	.154*	.153*	.122	.070
		Sig.	.278	.044	.045	.111	.361
2	Particleboard and MDF	P.C.	.053	.012	.052	.093	-.171*
		Sig.	.513	.880	.523	.303	.034
3	Low/zero formaldehyde particleboard and MDF	P.C.	-.029	-.092	-.051	.131	-.231*
		Sig.	.772	.364	.613	.193	.021
4	Metal	P.C.	.077	.107	.126	.155*	.104
		Sig.	.327	.173	.106	.046	.183
5	Glass	P.C.	.022	.185*	.120	.139	.226**
		Sig.	.779	.016	.118	.070	.003
6	Vinyl	P.C.	-.093	.164*	-.071	-.049	-.085
		Sig.	.241	.038	.375	.538	.287
7	Linoleum	P.C.	-.020	.206**	-.046	.099	-.020
		Sig.	.804	.010	.568	.219	.802
8	Cork	P.C.	.010	-.004	.047	.234*	-.082
		Sig.	.915	.965	.619	.011	.382
9	Laminated wood	P.C.	-.141	.130	-.110	.017	-.105
		Sig.	.075	.101	.167	.833	.188
10	Ceramic, porcelain or stone tiles	P.C.	-.060	.206**	.127	.248**	.202**
		Sig.	.449	.008	.105	.001	.009
11	Wall-to-wall carpet	P.C.	.115	.064	-.018	.060	-.043
		Sig.	.133	.402	.811	.439	.581
12	Natural carpet materials	P.C.	-.062	.227**	.078	.057	.189*
		Sig.	.426	.003	.318	.465	.015
13	Synthetic carpet materials	P.C.	-.053	.027	-.005	.080	-.050
		Sig.	.505	.732	.954	.314	.529
14	Stain, dust, moth carpet treatment	P.C.	-.069	-.014	-.023	-.027	-.152
		Sig.	.408	.866	.786	.745	.066
15	New foam underlay	P.C.	-.033	.005	-.071	.077	-.071
		Sig.	.696	.955	.395	.355	.398
16	7+ year old carpet underlay	P.C.	.037	-.014	-.076	.130	-.042
		Sig.	.652	.865	.354	.110	.605
17	Water-based polyurethane	P.C.	-.011	.138	.121	.074	.074
		Sig.	.895	.090	.135	.361	.365
18	Solvent-based polyurethane	P.C.	.057	-.022	-.083	.015	-.060
		Sig.	.491	.786	.313	.859	.461
19	Wood oils and waxes	P.C.	.137	.125	-.030	.213**	.046
		Sig.	.088	.122	.715	.008	.571
20	Water-based acrylic paint	P.C.	-.035	.022	.042	-.014	-.019
		Sig.	.663	.788	.600	.882	.818
21	Oil-based paint	P.C.	.019	-.038	-.135	-.024	-.139
		Sig.	.814	.641	.094	.770	.085
22	Plant and mineral paints	P.C.	.045	.135	.011	.178*	.050
		Sig.	.589	.105	.892	.032	.547
23	Thermal/ blackout curtains	P.C.	-.095	.215**	.003	.056	.011
		Sig.	.240	.007	.968	.491	.891
24	Unlined/ separate lining curtains	P.C.	.025	.179*	.030	.142	.075
		Sig.	.756	.023	.702	.072	.344
25	Fibreglass	P.C.	.087	-.030	-.066	.091	.000
		Sig.	.273	.704	.407	.253	.995
26	Wool	P.C.	-.016	.179*	-.022	.144	.127

		Sig.	.843	.024	.779	.070	.111
27	Polyester	P.C.	.033	.016	-.065	.072	.008
		Sig.	.687	.846	.429	.385	.920
28	Inner wall spray foam	P.C.	.085	-.052	-.033	.089	-.032
		Sig.	.320	.548	.698	.299	.710

P.C. – Pearson correlation. Sig. – Significance (2-tailed). * Correlation is significant at the $p < 0.05$ level (2-tailed) (highlighted yellow). ** Correlations is significant at the $p < 0.01$ level (2-tailed) (highlighted yellow). All significant correlations highlighted with light orange field background.

Appendix 5

Bivariate correlations for the total sample and the three general samples combined between the three environmental motives and the health rating of materials.

			Biospheric Total sample	Biospheric 3 general samples	Egocentric Total sample	Egocentric 3 general samples	Altruistic Total sample	Altruistic 3 general samples
1	Wood	P.C.	-.017	-.016	.039	.075	.048	.094
		Sig.	.799	.831	.556	.333	.474	.223
2	Particleboard and MDF	P.C.	-.051	.018	.169*	.133	.009	.070
		Sig.	.463	.828	.014	.100	.898	.389
3	Low/zero formaldehyde particleboard and MDF	P.C.	-.121	-.042	.108	.110	-.109	-.085
		Sig.	.137	.680	.182	.275	.182	.398
4	Metal	P.C.	-.026	-.026	.097	.097	.092	.092
		Sig.	.741	.741	.216	.216	.239	.239
5	Glass	P.C.	.095	.097	.071	.082	.110	.111
		Sig.	.155	.206	.284	.288	.099	.147
6	Vinyl	P.C.	-.150*	-.075	.106	.085	.012	.125
		Sig.	.027	.347	.121	.287	.864	.115
7	Linoleum	P.C.	-.088	-.061	.059	.080	.003	.041
		Sig.	.205	.446	.394	.323	.966	.613
8	Cork	P.C.	-.010	-.024	-.065	-.047	-.011	-.050
		Sig.	.900	.797	.400	.617	.888	.596
9	Laminated wood	P.C.	-.010	-.115	-.065	.089	-.011	.053
		Sig.	.900	.147	.400	.261	.888	.502
10	Ceramic, porcelain or stone tiles	P.C.	.062	.089	.081	.075	.095	.104
		Sig.	.357	.259	.232	.340	.160	.186
11	Wall-to-wall carpet	P.C.	-.045	.017	.035	-.027	.036	.050
		Sig.	.505	.827	.597	.727	.586	.514
12	Natural carpet materials	P.C.	.138*	.226**	.046	.002	.168*	.170*
		Sig.	.040	.003	.493	.979	.012	.029
13	Synthetic carpet materials	P.C.	-.060	-.025	.105	.132	.060	.095
		Sig.	.375	.758	.124	.095	.377	.232
14	Stain, dust, moth carpet treatment	P.C.	-.058	-.027	.120	.076	.035	.057
		Sig.	.412	.748	.091	.359	.625	.496
15	New foam underlay	P.C.	-.066	.002	.107	.040	.020	.084
		Sig.	.361	.984	.135	.627	.785	.313
16	7+ year old carpet underlay	P.C.	-.153*	-.089	-.036	-.090	-.121	-.116
		Sig.	.029	.277	.605	.273	.084	.155
17	Water-based polyurethane	P.C.	.015	.086	.036	.000	.034	.062
		Sig.	.826	.290	.605	.997	.628	.447
18	Solvent-based polyurethane	P.C.	-.076	-.034	.058	.030	-.114	-.143
		Sig.	.278	.681	.405	.713	.103	.080
19	Wood oils and waxes	P.C.	.039	-.016	-.003	.004	.042	-.008
		Sig.	.570	.842	.971	.964	.546	.925
20	Water-based acrylic paint	P.C.	.060	.070	-.003	.029	.042	.028
		Sig.	.570	.388	.971	.722	.546	.731
21	Oil-based paint	P.C.	-.104	-.050	.012	.022	-.033	-.020
		Sig.	.131	.538	.857	.785	.634	.807
22	Plant and mineral paints	P.C.	.114	.119	.086	.010	.205**	.162
		Sig.	.117	.154	.238	.905	.004	.051
23	Thermal/ blackout curtains	P.C.	-.023	-.020	.019	-.074	.083	.112
		Sig.	.744	.805	.788	.359	.232	.162
24	Unlined/ separate lining curtains	P.C.	.010	.089	-.077	-.083	.083	.130
		Sig.	.880	.259	.265	.293	.229	.099
25	Fibreglass	P.C.	.014	-.025	-.044	-.077	-.027	-.055
		Sig.	.838	.754	.517	.331	.690	.486

26	Wool	P.C.	.065	.151	.047	-.011	.055	.049
		Sig.	.341	.056	.490	.895	.421	.542
27	Polyester	P.C.	.075	.085	.037	.081	.069	.071
		Sig.	.284	.301	.597	.324	.325	.389
28	Inner wall spray foam	P.C.	.023	-.002	.055	.013	-.014	-.008
		Sig.	.757	.980	.451	.882	.844	.928

P.C. – Pearson correlation. Sig. – Significance (2-tailed). * Correlation is significant at the $p < 0.05$ level (2-tailed). ** Correlations is significant at the $p < 0.01$ level (2-tailed).

Appendix 6

2A-1

End of Follow-up Session Questionnaire

1 Ease/Readiness/Ability to make changes

Has your family in the last ten years:

- ☐ done some serious house renovations (e.g. built an extension, changed room layout, completely redone the kitchen or a bathroom...);
- ☐ done some moderate house renovations (e.g. polished floors or re-carpeted the whole/most of the house, had most of the house painted inside, partly redone the kitchen or a bathroom...)
- ☐ done some relatively minor house renovations (e.g. painted a couple of rooms, put tiles in one room...)
- ☐ enjoyed the house as it is
- ☐ something else, please explain _____

Finance: Do you see your family as having:

- ☐ very limited financial means to invest into your home (some hundreds of dollars every so often);
- ☐ moderate financial means to invest into your home (a couple of thousands of dollars occasionally);
- ☐ would be financially able to invest into your home, if there was a real need (ten or more thousands of dollars);
- ☐ something else, please explain _____

Time: Do you see your family as having:

- ☐ very limited time to invest into your home;
- ☐ moderate time to invest into your home;
- ☐ would be able to find time to invest into your home, if there was a real need;
- ☐ something else, please explain _____

2 Knowledge self-assessment

Please consider following statements and indicate how much you agree or disagree with them. For each statement, place a tick in one of the numbered boxes that best represents your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Not applicable
	1	2	3	4	5	0
Content of this course was of value to me.						
I feel that now I have a much better understanding of health risks in our home.						
I was surprised to learn that some of the materials in our home could potentially be dangerous to our health.						
I have been surprised to learn how little I actually knew about the materials used in our house.						
I am pleased to find out that our home is healthy just the way it is.						
I expect that me and my family will make some changes based on this new knowledge.						
I expect that my partner's and my views will be similar on how important a healthy home is for our family.						
I expect that my partner's and my views will be similar on readiness to make needed changes to our house.						
I feel overwhelmed by all the information and how much change I should make.						
I feel eager to start making changes at home.						

3 Updated Health Rating of Your House

	Very poor	Poor	Fair	Good	Very good	Excellent
Considering the information from this course what health rating do you think your house deserves as it is today?						

Briefly explain the main reasons for your assessment.

Has your assessment changed since the beginning of the course?

Yes ☐

No ☐

If yes, please explain how and what has influenced the change:

Overall, what do you consider to be the most important health improvement currently needed in your home?

If intending to make changes, please note what you would like to change first:

Did you at any stage during the session think: 'If only I knew this before I/we did...'

Yes ☐

No ☐

If yes, please explain.

Which areas/material discussed during the course offered the greatest learning to you?

Do you have any additional comments on the course material or delivery?

Appendix 7

3A-1

Final Follow-up Survey Questionnaire

1 General experience

Since the Follow-up Session, I have made the following changes in my living environment:

Please consider the following statements and indicate how much you agree or disagree with them. For each statement, place a tick in one of the numbered boxes that best represents your opinion.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Not applicable
	1	2	3	4	5	0
Since the end of the session my enthusiasm for the topic is generally about the same.						
My partner's views have positively influenced my enthusiasm.						
Small changes seemed easier, so we started with these.						
Big changes seemed more important, so we started with these.						
Cost was a prohibiting factor against change.						
Once we looked into changes needed we found options we could afford.						
Once we started looking we were surprised how many options there were.						
Sales and trades people seemed generally knowledgeable about healthy products and materials.						
Sales and trades people were of great help in finding the healthiest solution for our home.						
Our home now feels like a healthier place.						
I feel like our home is now the way we want it to be.						
If needed, I would do it all again.						

Please include any other comments that best describe your experience.

2 Health rating of interior materials

Please redo rating of materials based on your current views. This is the same or a similar list to the one you did before as the intention is to measure your views several months after the Follow-up Session.

	Unhealthy		Neutral		Healthy	I don't know
	1	2	3	4	5	0
5.1 Structural/non-structural materials						
Wood						
Particle board or MDF						
Metal						
Glass						
Artex/'cottage cheese' rough ceiling						
5.2 Floor coverings						
Vinyl						
Linoleum						
Laminated wood/pretend wood floor						
Ceramic, porcelain or stone tiles						
Wall-to-wall carpet						
5.3 Carpet or rug materials and treatments						
Natural materials such as Wool, Jute, Cotton						
Synthetics such as Nylon, Polyester, Polypropylene						
Stain, dust, moth protection built into carpet						
New foam carpet underlay						
7+ year old carpet underlay						
5.4 Varnishes and paints						
Water-based polyurethane						
Solvent-based polyurethane						
Wood oils and waxes						
Water-based acrylic paint						
Oil-based interior paint						
Plant and mineral paints, such as Bio Paints						
5.5 Drapes						
Thermal or blackout lined drapes						
Unlined or separately lined drapes						
5.6 Insulation materials						
Fibreglass						
Wool						
Polyester						
Inner wall spray foam						

3A-3

3 Measures against possible unhealthy materials and substances

Based on your knowledge and experiences to date, please list five materials/substances commonly found in homes that are possibly unhealthy and note actions that you would take to decrease or eliminate the adverse impact these could pose. (Feel free to make a longer or more detailed list.)

	Possible unhealthy materials/substances	Strategies for decreasing/eliminating the problem
1		
2		
3		
4		
5		