VINYL AND LINOLEUM FLOORING: HEALTH ISSUES AS PERCEIVED BY LAY PEOPLE AND ARCHITECTS

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ABSTRACT

Recently more information has emerged on possible adverse health effects associated with some building and furnishing materials, leading to or initiating legislative changes towards their reduction or elimination in many parts of the world. However, more general knowledge of the health risks associated with building and furnishing materials could make a significant contribution to improvements in indoor air quality. A study was set up to evaluate the level of knowledge in the relevant literature and the general population (from New Zealand, United Kingdom and the United States), and New Zealand architectural professionals. The results for vinyl and linoleum are presented, these being two flooring materials very similar in terms of appearance and application, but different in terms of chemical content and possible impact on health. The article indicates significant issues with the level of reported knowledge, with participants from the general population struggling to differentiate between vinyl and linoleum, and professionals reporting more prevalent use of vinyl, which they rate as less healthy.

KEYWORDS

perception of materials; healthiness of building materials; vinyl; linoleum.

INTRODUCTION

Every so often it is uncovered that a particular human activity or behaviour is not beneficial long term and adjustments have to be made. This article deals with one such activity and focuses on the role played by the perception of building and furnishing materials as being healthy, or toxic, on choices people make and the consequent actual healthiness of their domestic environments. This problem is examined with the example of vinyl and linoleum, two similar looking materials with very different chemical makeups and their impact on indoor air and the natural environment. It is proposed that the popular perception of these materials, both in the general population and the architectural profession, could play a significant role in accelerating or obstructing the change. This article describes the key observed trends in such perceptions, and is a summary of a larger project (Petrović 2014), specifically focusing on issues associated with vinyl and linoleum.

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In recent decades a significant increase in the development and production of synthetic chemicals has been observed, impacting many aspects of human life and the natural environment. Between 1945 and the early 2000s the total production of synthetic chemicals increased more than tenfold (Baker-Laporte 2008: 272). Some 15 years ago it was estimated that there were more than 4 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), and that 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 forming about half of the materials in current use (Schörpfer 2011b: 19; Brownell 2006: 6). There is also a lack of research on the additive and synergistic effects of combinations of chemicals (Armstrong 2007: 61).

Chemicals used in building and furnishing materials are part of the larger problem. However, since the 1970s the increasing air-tightness of buildings has led to insufficient air exchange rates, and issues associated with the build-up of indoor toxicants (Clausen et al. 2011: 221; Sundell 2011). In the early 1980s, this culminated with the recognition of sick building syndrome (Andersen and Gyntelberg 2011; Rostron 1997). Over the same period it emerged that most people spend much of their time indoors; more recently that has been quantified as being 80-93% of their time indoors (Liu and Little 2012a; Guieysse et al. 2008; Sexton and Dyer 1996). Although building and furnishing materials are not unique in their negative contribution to indoor air quality and health, they are important contributors in this area (Andersen and Gyntelberg 2011; Clausen et al. 2011). While research leading to regulative changes would help solve this problem, there are concerns over a lack of new knowledge (Clausen et al. 2011: 225-226), and issues with the slow pace of regulative changes (Bradman in Curwell and March 2002: ix).

Investigations of ventilation rates since the recognition of sick building syndrome have established a need for their increase (Wargocki et al. 2002). However, the workplace has been the primary focus of developments in ventilation and occupational health (ASHRAE handbook 2009), and more recent studies indicate that 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 control of conditions in domestic spaces is also harder to achieve (Howden-Chapman and Carroll 2004). However, on a daily basis homes are where many people not specifically educated in this area make purchasing decisions and alterations to their homes which could impact on the health of themselves and their families.

This situation is additionally complicated by the poor patterns in the way already available knowledge on health risks is communicated to wider audiences. International organizations such as the International Agency for Research on Cancer (IARC), European Chemicals Agency (ECHA), Agency for Toxic Substances and Disease Registry (US) (ATSDR), and the Environmental Protection Agency (US) (EPA) conduct regular reviews of the available knowledge and make recommendations for change of treatment, including potential elimination of newly recognised substances of concern. Many chemicals spend decades being reviewed by such organizations. While much of their information is publicly available, their search portals and the language used in their reports are not easy for lay people to navigate. Once recommendations for change are made, the change is regulated through updated international or local standards. Such changes also take years from the formal decisions to eliminate particular substances to the full implementation of that elimination through the standards. Furthermore, the standards of many countries have been commercialised, requiring payment to read, which makes these recommendations and updated standards harder to access.

In architecture and construction literature the problem of accessing updated guidelines is also problematic as the literature is generally written from the position of the existing standards, some of which could be in the process of upgrade and change. For example the 1986 edition of Curwell, and March (eds) *Hazardous Building Materials* contained a list of levels of lead in paint by paint type and manufacturer, while during the printing of the book lead in paint was banned in the same country. Even the two most comprehensive recent publications available in this area: Curwell, Fox, Greenberg, and March (eds) *Hazardous Building Materials* (2002) and Pacheco-Torgal, Jalali, and Fucic (eds) *Toxicity of building materials* (2012), contain references to standards which were out of date soon after their publication.

Given the sizeable delays in the process of recognising the adverse impact certain substances can have and their subsequent regulatory elimination, a study was conducted to evaluate the level of knowledge on the healthiness/hazardousness of building and furnishing materials. It was hypothesised that this level of knowledge and personal views on materials could play a significant role in what people choose to have in their homes.

Similar studies are hard to find. The building user surveys, such as the Probe series, tend to use a single item that engages with health ('Do you feel less or more healthy when you are in the building?') and generally focuses more on the perceived quality of air in terms of air exchange, comfort temperature and level of user control over the indoor air environment (Cohen et al. 2001; Bordass, Leaman, and Ruyssevelt 2001; Baird 2010). Works in environmental psychology similarly omit significant mention of building materials. For example, the environmental appraisal inventory (EAI) focused on the rating of perceived hazards and only included two items possibly 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). This suggests that there is little research aimed at examining people's views on different building and furnishing materials.

Because of a general lack of similar studies, the primary focus of the broader project was to describe the key patterns in reported knowledge, and to establish if it is possible to talk about a measurable lack of knowledge in the general population (Petrović 2014). If an observable lack of knowledge exists, it could be acting against the uptake of healthier building and furnishing materials. Although the desire was to support change towards health materials and increase available knowledge, it was recognised that a record of what is known has to be the first step, preceding any evaluations of effectiveness of improvements. Furthermore, the project was set up to examine differences in views between the general population and architectural professionals, with the assumption that architectural professionals might know more and, thus, play an educational role in working with their clients. In addition to measuring the level of knowledge participants had about the materials, the survey evaluated individual demographic and psychological factors, values and attitudes as potentially influential on reported level of knowledge. This was analysed and reported in Petrović 2014.

BACKGROUND

In order to compare the reported level of knowledge on the healthiness/hazardousness of building and furnishing materials, a review of available information was first undertaken, and this article presents the results relevant to vinyl and linoleum as the focus materials of this article. Because the information available in architecture related sources was limited, medical studies became the primary sources for the review, such as the PubMed database. This was recognised as a suitable source of 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 MEDLINE, life science journals, and online books (PubMed 2015). In addition, complementary information was sourced from websites of official organisations or regulating bodies.

Vinyl and PVC

PVC was first invented in 1872, but its importance was not fully recognised until 1926 (Akovali 2012). In 1933 vinyl, plasticised PVC 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. The family of vinyl/PVC products raises the concerns over the use of polyvinyl chloride (PVC) as the base material and plasticisers as its additives. World production of polyvinyl chloride (PVC) is around 40 million tonnes, 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). This article primarily focuses on pPVC, commonly known as vinyl when used as a flooring material.

PVC is produced through polymerisation of vinyl chloride monomer (VCM) (Akovali 2012). There are serious concerns about the health effect of VCM, which is genotoxic (Kumar et al. 2012), a known human carcinogen, and toxic for immune and cardiovascular systems, liver, and organ development (ATSDR 2013). In addition, the process of manufacturing of PVC, its burning and final decomposition creates dioxins, which are highly toxic and persistent environmental pollutants (Lent, Silas, and Vallette 2009). The Greenpeace group has advocated the complete global phasing-out of PVC 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 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 rose 1%, with another 2.5% rise expected in 2011 (IHS Chemical 2011). Although this indicates some possible decrease in consumption of PVC in these countries, globally there was still little change, due to the increased use of PVC in Asian countries, which account for 80% of world consumption (IHS Chemical 2011).

While the health issues of VCM are reasonably recognised, because its release occurs during the manufacture and disposal of a product that contains it, such as vinyl flooring, explicit evaluations of the health and environmental impact of such products in normal use are less available. This potentially creates a grey area of uncertainty of the exact extent of the problem in this phase. However, for many people this type of use is the most likely point of contact with vinyl, making understanding of these issues paramount. The most significant concern in use is associated with the release over time of plasticisers from vinyl, and therefore this article reviews these in more detail.

Plasticisers 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). 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, but they are also 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). Flexible polyvinyl chloride (PVC) accounts for 80-90% of world plasticiser consumption (IHS Chemical 2011).

At a most general level all plasticisers are semi-volatile organic compounds (SVOCs) (Liu and Little 2012b; Xu et al. 2012; EPA 2012). SVOCs could be seen as a subgroup of volatile organic compounds (VOCs), with the only difference being in the level of volatility, and while VOCs are readily released in normal indoor air conditions, SVOCs are somewhat less readily released (EPA 2012). The most commonly used form of plasticisers are phthalates, although other plasticisers currently in use include aliphatics, epoxy, terephthalates, trimellitates, polymerics, and phosphates (IHS Chemical 2013). Phthalates are a group of aromatic chemicals containing a phenyl ring with two attached and extended acetate groups (ASTDR 2013).

Historically, different phthalates have been used in different periods. Di(2-ethylhexyl) phthalate (DEHP) is a short chain phthalate frequently found in older PVC products. Before 1999 the European Union regulated against its use in toys and other products followed (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, with their classifications based on animal studies. Studies of the health impact of DEHP on rats have established it as an endocrine disruptor with antiandrogenic activity, suppressing testosterone-related processes (Martinez-Arguelles et al. 2012). 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. 2012). Biomonitoring of concentrations of phthalate metabolites in the general population using blood and urine gave blood results suggesting that over 75% of the US population is exposed to phthalates, and as high as 95% for urine (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 currently most humans have estimated exposure levels of 3-30μg/kg/day from various products (Martinez-Arguelles et al. 2012). 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. 2012). 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. 2012).

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 with pubertal abnormalities, and obesity, testis and ovarian disease (Manikkam et al. 2013). This happened to such a degree that it was concluded ancestral environmental exposures could be generating trans-generational inheritance of disease, often with adult onset (Manikkam et al. 2013).

Evaluation of the release of phthalates from vinyl or pPVC in interiors established that because of saturation and sorption processes that establish 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), leading to the conclusion 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 found vinyl flooring should be considered a source of non-dietary exposure to phthalates and that, just as with lead paint dust, children, especially toddlers, are more at risk than adults (Gevao et al. 2012). DEHP was generally the predominant phthalate found in these dust studies (Gevao et al. 2012; Bornehag et al. 2005). Furthermore, 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, 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 means, unfortunately, complete epidemiological understanding of the effect of many phthalates on human health is still missing, and the studies on release levels of such SVOCs indicate great complexities even in measuring their indoor levels from materials such as vinyl flooring. Nevertheless, advisory organisations have begun acknowledgement of the harmfulness of phthalates. Between 2008 and 2013, the European Chemicals Agency (ECHA) included eight phthalates in their list of substances of very high concern (DEHP; DBP; BBP; DIBP; Bis(2-methoxyethyl) phthalate; n-pentyl-isopentylphthalate; DIPP; DPP; ECHA 2015). However, by 2013, the US Agency for Toxic Substances and Disease Registry (ATSDR) only lists four (DEHP, Di-n-butyl phthalate, DNOP, and Diethyl phthalate; ATSDR 2015). While these official organisations' recommendations to eliminate some phthalates seem encouraging, this is only part of the process, as it takes much longer for risk to be fully integrated into regulations. 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). From 2011-2018 world consumption of phthalate plasticisers is forecast to be reduced by 2.4%, due to lower-molecular-weight phthalates, such as DEHP, being replaced by nonphthalates (IHS Chemical 2013). Although these changes should be seen as the result of efforts to phase out use of some of the older phthalates, it is hard to assert that it represents a sufficient change. It is essential to emphasise the impact differences in regional regulations could have on delays, especially if Asian regulations are not in line with those of Europe and the US.

This illustrates some of the complexities in assessing the health impact of vinyl. In addition, it should be noted that the vinyl and PVC industry have repeatedly rebutted the relevance of such concerns. For example, in 2013, the journal Indoor Air 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 were employed in the vinyl industry) challenged the result based on a small number of procedural imperfections. Because any early work is likely to suffer from such imperfections, these types of studies have been going through the many challenges of developing a new body of knowledge.

In conclusion, it is possible to assert that although dangers associated with VCM, and the manufacture and disposal of PVC are more recognised, there is sufficient evidence of issues associated with phthalate plasticisers for their regulative elimination to have commenced. The rebuttal from the PVC industry, relatively slow phasing-in of regulations and regional differences in such efforts all obscure the clarity of the necessary change. Such contradictory information can also distract the public and professionals from observing these trends.

Linoleum

Linoleum was invented in 1860 by Frederick Walton, and was the first form of resilient flooring to replace more traditional bare wood or dirt floors (Lent, Silas and Vallette 2009). It is made by mixing oxidized linseed oil with resins from pine trees, wood flour, cork, and limestone fillers, with added pigments, which are then pressed onto a backing to make sheet linoleum (Lent, Silas and Vallette 2009). These are natural and renewable materials (Akovali 2012). This general formula has remained largely unchanged since linoleum was first made (Lent, Silas and Vallette 2009). However, during the 1960s, vinyl flooring rapidly overtook the use of linoleum as the predominant resilient floor covering (Lent, Silas and Vallette 2010). The last US linoleum plant closed in 1975 (Lent, Silas and Vallette 2009: 14) with only three linoleum producers in the world by the mid 1980s (BBC 2014).

More recently, with the recognition of the health and environmental concerns associated with vinyl, there has been an upsurge of interest in linoleum (Lent, Silas and Vallette 2009). In 2009, Lent, Silas and Vallette conducted a comprehensive review of the available resilient floor coverings for the Healthy Building Network and recommended linoleum as being either better than all other alternatives or more able to be improved. Their and similar comparisons show some possible concerns associated with linoleum. Because oxidation of linseed oil is at the core of the process, while the flooring is new, this oxidation can continue, leading to persistent odours (Lent, Silas and Vallette 2009; Wilke, Jann, and Brödner 2008). Recently, the VOC emissions of linseed based paints have also been investigated, showing that a number of aldehydes are produced in the early hours and days post application (Fjällström, Andersson, Nilsson and Andersson 2002). In one State of California study, two linoleum products failed due to the high emissions level of acetaldehyde (Lent, Silas and Vallette 2009). However, this is not an unavoidable problem, but rather indicative of the relative neglect of linoleum production during the second half of the 20th century. Not all samples of linoleum suffer from the same problems and by developing new combinations of linseed and other oils this chemistry can be significantly improved (Fjällström, Andersson, Nilsson and Andersson 2002; Lent, Silas and Vallette 2009). Similarly, farming of flax (linseed) as a crop has been associated with use of environmentally persistent pesticides (such as trifluran) and eutrophication (overloading of waterways by run off nutrients), both avoidable through improvements in farming practices (Lent, Silas and Vallette 2009).

Therefore, it is possible to conclude that linoleum should be reasonably healthy for the users and neutral for the environment, although it is important to research specific linoleum products, as these vary on both levels.

Comparison of vinyl and linoleum

Although this review indicates that linoleum is healthier than vinyl both in terms of its likely impact on indoor air quality and on the natural environment, the difficulties in obtaining unequivocal evidence for this are also very clear. Despite numerous issues repeatedly raised in relation to vinyl, plasticisers and PVC, debate over the validity of such claims still dominates the expert literature, with some research defending PVC explicitly financed by its industry. On the other hand, lack of development of the linoleum industry over the previous decades has led to manufacturing imperfections, which makes it hard to be certain of the quality of any newly purchased linoleum. While it is easy to see great advantages in further development of the linoleum industry, improvement of the product, and increase in its quality control, currently it is impossible to evaluate the impact of such future changes. Thus, even on the level of available knowledge in the relevant literature, it is possible to observe lack of certainty over which material should be used.

METHODOLOGY

The research was conducted in New Zealand (NZ) and therefore focused on local views and those of countries with an influence on local policies, such as the United Kingdom (UK) and the United States of America (US) (Petrović 2014). In 2012, a survey on Building Materials and Health was completed by 182 participants from the general population (61 from NZ, 60 from US, and 61 from UK). For comparison and in parallel, a similar survey was completed by 65 NZ architectural academics and practitioners. Approval for the survey was obtained from the Human Ethics Committee of Victoria University of Wellington. Most NZ general population participants completed a paper survey, while the US and UK responses were purchased through Qualtrics. Although there were noticeable demographic differences between the three general samples, they appeared more complementary than contradictory and had little or no impact on the general trends discussed here (differences are discussed in detail in Petrović 2014). The NZ architects received email invitations to participate through relevant professional organisations.

The general sample was 64% female, while the NZ architects were 31% female. In the general samples 59% were under the age of 50, while the NZ architects were 51% 50 years old or over. The general samples had approximately equal numbers of participants with and without university qualifications, while the majority of the NZ architects had such qualifications.

All samples completed a core questionnaire asking them to provide health ratings for 28 building and furnishing materials, including vinyl and linoleum, on a five point Likert scale: unhealthy 1; 2; neutral 3; 4; healthy 5, with an option of 'I don't know 0.' When designing the surveys it was anticipated that the general population 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 any indecisiveness. This article only focuses on vinyl and linoleum, and the additional questions about these materials contained in the questionnaire for architects.

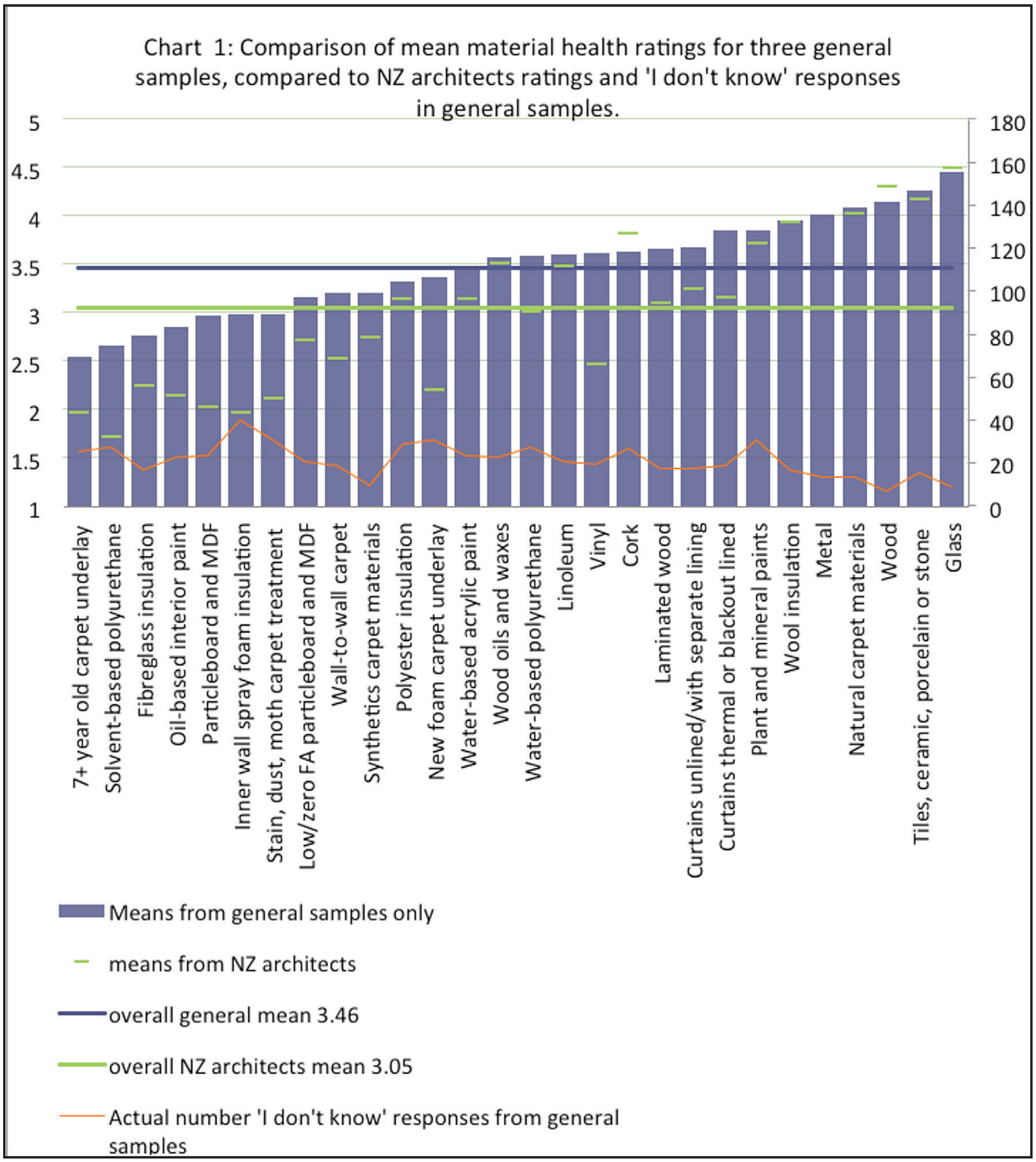
Much of analysis reported here uses descriptive statistics, however, inferential analyses are reported where required. One-way between subjects ANOVA tests were used where relevant to evaluate differences between samples, paired-sample t-test to evaluate differences between ratings of the same participants, and Pearson bivariate correlations were used to evaluate degree (strength) to which variables were related. The focus here is on the significant findings for vinyl and linoleum, which present some surprising trends.

FINDINGS

Popular perceptions of vinyl and linoleum

Results of health rating of building and furnishing materials

Chart 1 shows the means for health ratings of materials from the three general samples, compared with the overall mean of their ratings for all materials of 3.46. This overall mean indicates materials were generally rated as neutral towards healthy. Of the 28 rated materials, 5 had a mean rating over 4 (glass; tiles; wood; natural carpet materials; and metal), 7 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; and stain,



dust, moth protection built into carpet), while the remaining 16 materials received means between 3 and 4. Therefore, generally ratings differentiated between more healthy and less healthy materials.

A similar trend was seen with the NZ architects sample ratings (Chart 1). Although their overall mean for all materials was noticeably lower at 3.05, there is also a stronger polarisation of ratings, with somewhat higher means for the highly rated materials, and noticeably lower means for the low rated materials. Nevertheless, with minor exceptions, the extremes of the scales are held by the same materials.

Standard deviations and 'I don't know 0' responses were also considered indicative of the overall patterns in ratings. In the three general samples the average standard deviation for all materials was 1.08. Generally, low standard deviations were paired with high ratings of materials; for example, glass received the highest overall rating of 4.46 and had the lowest standard deviation of 0.80 and was followed in both by tiles (mean 4.27, SD=0.90), indicating that for these materials responses were most strongly grouped. As the means dropped, standard deviations increased. At the lower end of the scale, ratings tended to be less grouped and had much higher standard deviations. For example, the highest standard deviation was recorded for fiberglass insulation (mean 2.76, SD=1.26) and 7+ year old carpet underlay (mean 2.54, SD=1.25), which were among the lowest rated materials. Furthermore, the highly rated materials received a low level of indecisiveness rating, while all low rated materials received higher indecisiveness rates (Chart 1). This could indicate some participants opting for 'I don't know' instead of providing very low ratings. Additionally, several peaks in 'I don't know' responses for the mid-range rated materials generally indicate which materials are less known. While it seems reasonable participants might select 'I don't know' for less known materials, this seems to have occurred about equally for both unhealthy and healthy materials.

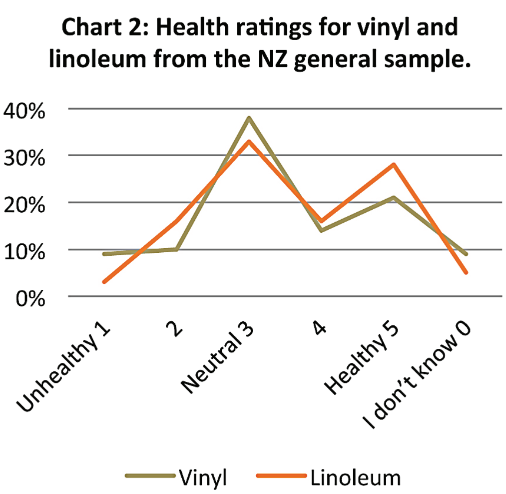
Jointly these features indicate that participants tended to consider materials as neutral or healthy, even for those materials that are currently discussed for their adverse health effects, such as vinyl and formaldehyde containing MDF and particleboard. There was also a clear trend to choose 'I don't know' instead of a low rating. Furthermore, the overall patterns in ratings strongly indicate that the more common, better known materials were more likely to be rated as neutral or healthy. This was the case even for materials currently viewed as problematic: vinyl and formaldehyde containing MDF and particleboard. This potentially indicates the conservatism of participants in accepting both healthier alternative materials and changing their views about the suitability of established materials, which have since been recognised as unhealthy. The ratings for vinyl and linoleum clearly show a number of related problems.

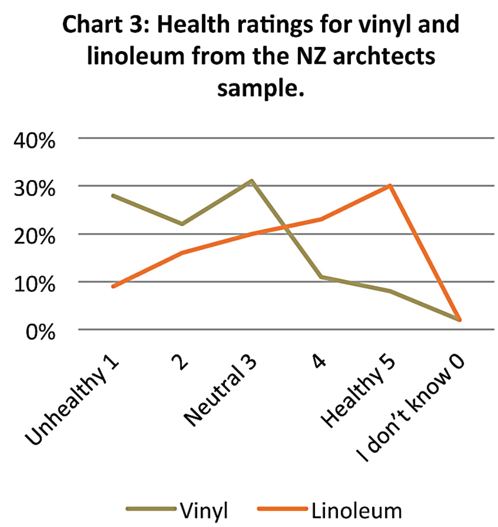
Health ratings of vinyl and linoleum from the general population

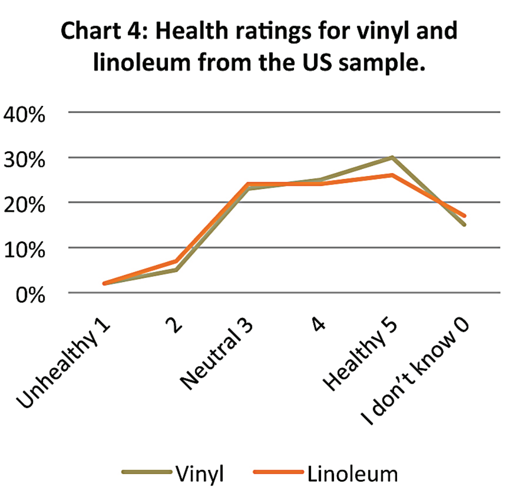
Charts 2-5 give the distribution of ratings per sample for vinyl and linoleum, showing a very similar distribution for the three general samples. The nominal difference between the means for the two materials in the three general samples is very small, 3.62 for vinyl and 3.60 for linoleum. Both materials received ratings in the full range, and had similar, higher standard deviations of 1.09 and 1.11 respectively. 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 (Table 1; Charts 2, 4-5). To further examine this apparent similarity of ratings, a paired-sample t-test was conducted, indicating no significant difference in the scores between vinyl (mean 3.62, SD=1.09) and linoleum (mean 3.60, SD=1.11; t(149)=0.11, p=0.92; 95% confident interval CI [-0.13, 0.12]), for the 150 participants from three general samples who rated both materials, confirming similarity in ratings.

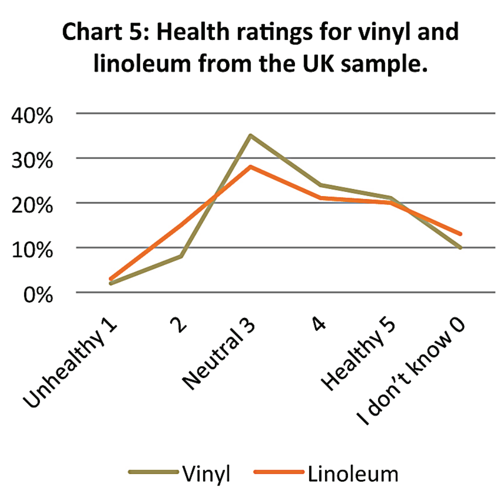
TABLE 1. Mean, standard deviation and standard error for health ratings of vinyl and linoleum.

	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









The high level of similarity in ratings for vinyl and linoleum in the general population samples from the three countries implies participants struggled to understand the difference between vinyl and linoleum. Realistically, these materials look very similar once installed, and others have also reported that the two are 'often mixed up' (Engman, Bornehag and Sundell 2007). However, this absence of differentiating patterns, even between samples from different countries (which might have a colloquial preference for use of one over the other term), is problematic given that vinyl is recognised for its adverse health effects, while linoleum has not raised significant concerns.

Perception of vinyl and linoleum amongst the NZ architects

The NZ architects ratings for vinyl and linoleum had a different pattern from those of the general samples (Chart 3). Their mean rating was 2.48 for vinyl (SD=0.15) and 3.49 for linoleum (SD=1.33), almost a whole point difference in mean. 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 also statistically significant, as confirmed by a one-way between subjects ANOVA test conducted to compare the effect of sample on health rating of vinyl ($F(3,220)=18.15$, $p<0.01$), with post-hoc Tukey tests indicating that ($p<0.05$) vinyl was rated lower by NZ than all other samples, and lower by the NZ general sample than the US sample, while the UK sample ratings were not significantly different from either the NZ or US samples. This shows that as a sample the NZ architects clearly differentiated between vinyl and linoleum. However, it is important to consider the other aspects of their ratings and especially whether these ratings are as low as they might be.

In order to evaluate this further it is important to note that the 65 NZ architects sample consisted of three separate groups. The core group was formed by 31 participants who responded to invitation through the New Zealand Institute of Architects (NZIA), the majority of whom are practising architects and thus can be called 'practitioners.' Of these, 13 listed sustainability as their specialisation, and 14 residential work and of those 6 listed both sustainability and residential work. The remaining 11 reported their specialisations were in commercial, educational, or religious architecture or urban design. The same survey questionnaire was sent through the Building Biology and Ecology (the BBE promotes healthy and ecological building) newsletter and the Designers Institute (DINZ). Eight participants specified they received the invitation through the BBE, and they reported diverse occupations, indicating a high proportion of clients of the BBE, and therefore are considered as a distinct group. Only two participants specified they received the invitation through the DINZ, and for six participants it is impossible to discern organisational background, and these are not considered further in this analysis. In addition, 18 responses were received by approaching architecture academics (from Victoria University of Wellington, University of Auckland, Unitec, Weltec and CPIT). Different questionnaires were used for the academics and practitioners, but containing the same core health rating of materials component. For the purpose of analysis, here the responses to the additional questions about practitioners' professional practice are especially useful. It is important to emphasise that while differences between these subgroups are illustrative and useful, none of these are large enough for statistical validity. Only the total group of 65 NZ architects is sufficient for this.

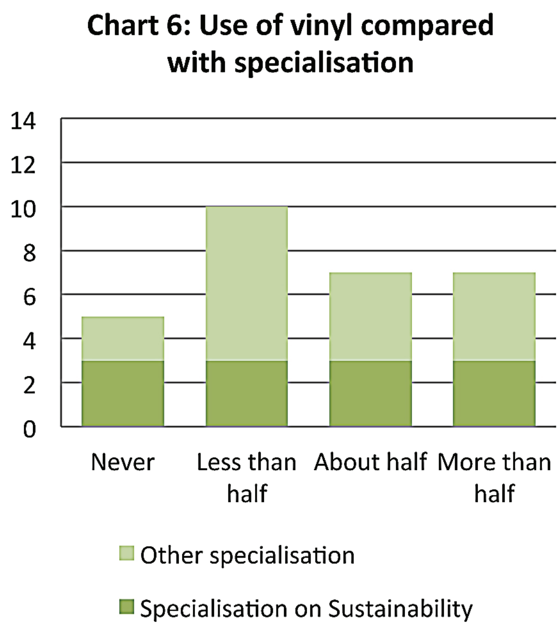
One of the most significant features of the health ratings for vinyl and linoleum received by the total NZ architects sample is that their ratings used the whole range and included both unhealthy and healthy ratings (Chart 3). When analysed in terms of subgroups, some differences are observable (Table 2). It is worth noting that the practitioners gave the highest ratings for both materials, and that the greatest difference in ratings between vinyl and linoleum can be observed in the BBE group (which due to its small size has the highest chance of statistical error). When reviewing the overall results, the same trend of highest accuracy in rating materials for healthiness came from the BBE sample when compared to the total data set, especially when rating the less healthy materials (Petrović 2014, 129-130). This is somewhat surprising given that only two participants in this group were architects, but suggests that this building biology subgroup with its potential role of 'whistle-blowers' has more proactive views than practicing or teaching architects.

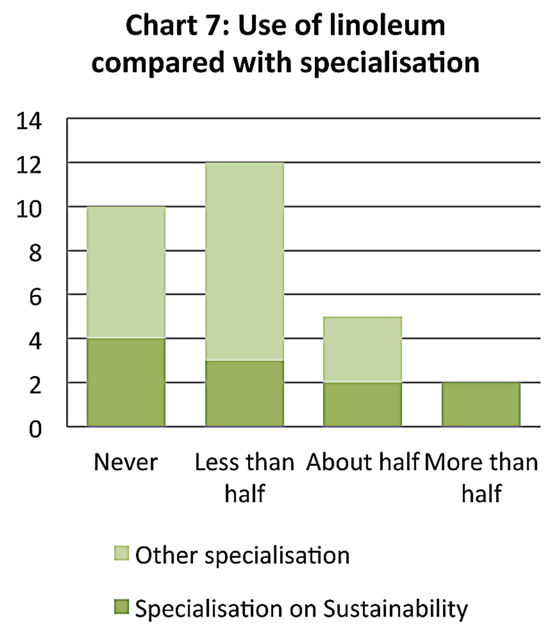
TABLE 2. Mean, standard deviation and standard error for health ratings of vinyl and linoleum for the NZ architects and the subgroups of this sample.

	Vinyl				Linoleum			
	N	Mean	Standard Deviation	Standard Error	N	Mean	Standard Deviation	Standard Error
NZ architectural practitioners	31	2.71	1.16	0.21	31	3.65	1.28	0.23
NZ architectural academics	18	2.50	1.30	0.31	17	3.47	1.23	0.30
BBE	8	1.50	0.93	0.38	8	3.00	1.60	0.57
Total NZ architects	65	2.48	1.23	0.15	64	3.49	1.33	0.17

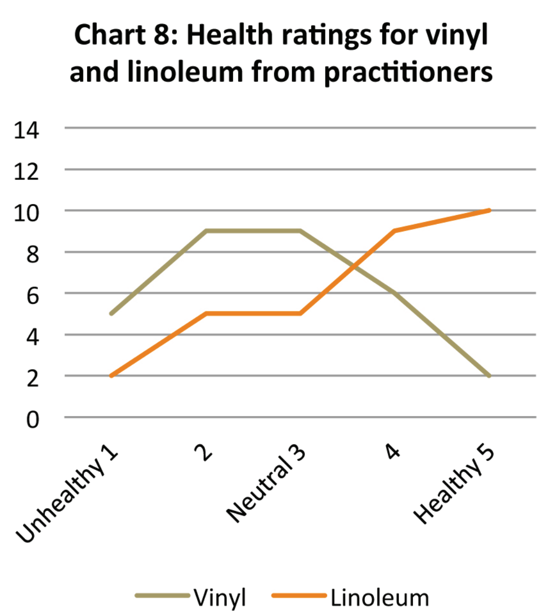
Although in the subgroup of practitioners the overall rating for vinyl was lower than for linoleum (mean 2.71, SD=1.16, vs. mean 3.65, SD=1.28), it was notable that this was not a consistent trend. Of the 31 participants in this group, 18 rated linoleum higher than vinyl, 10 gave the same health rating to both, and 3 rated vinyl higher than linoleum. Reported specialisation in sustainability was not predictive of this pattern, as this subgroup had somewhat lower mean ratings for both vinyl and linoleum (means 2.46 and 3.31, compared with means of 2.89 and 3.89 for vinyl and linoleum respectively for those with other specialisations). Of the three participants who rated vinyl higher than linoleum, two specified sustainability as their specialisation, and of the ten who rated vinyl and linoleum the same, three specified sustainability, which is comparable with the reported specialisation in sustainability for the whole sample.

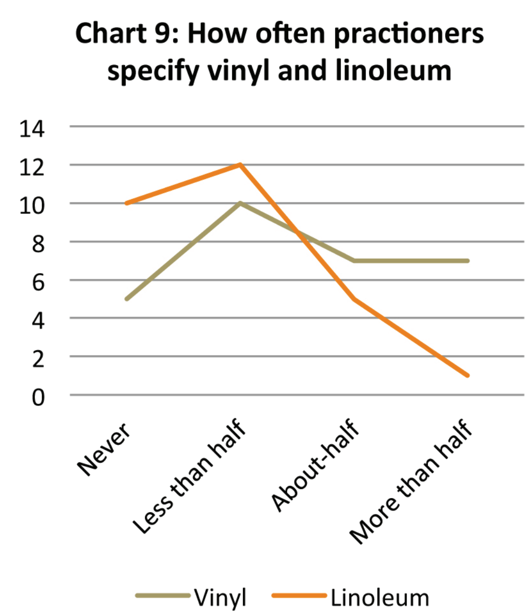
The practitioners were also asked whether they specify these flooring materials in their professional practice. Charts 6 and 7 summarise the responses to this question indicating that vinyl is more readily specified than linoleum, and that one third of the sample never specified linoleum, while another third did so less than half of the time. As with the health ratings of materials there was no clear relationship between specialisation in sustainability and use of either of the flooring materials. Unsurprisingly the practitioners who rated either material higher also reported that they specify it more often, as evidenced by





statistically significant bivariate Pearson's correlations (for vinyl r(25)=0.47, p=0.01; for linoleum r(26)=0.41, p=0.03). This correlation should not however distract from a much stronger overall trend: as a group, this sample rated linoleum as healthier, but specified vinyl much more in practice. Charts 8 and 9 illustrate this contradiction.





The questionnaire also asked practitioners to specify how they would explain the benefits/risks of these materials to their clients. Responses were received from 12 participants, which is only sufficient for an indicative analysis. In these, vinyl is generally discussed as durable, low maintenance, fit for purpose, easy to install, good for wet areas, and overall an economic, good material. Less than half of the responses included any mention of the negatives, and in most cases these were often balanced out with the positives. For example: 'Good floor covering for wet and commercial areas. Off-gassing a problem only early in life,' or 'Despite drawbacks this is almost the only product that meets infection control requirements and also performs as a floor.' Only two responses can be seen as negative, but even then the tone is neutral: 'phthalates, dioxin during manufacture' and 'medium off-gassing.' When analysed in terms of issues raised, three responses explicitly reflected on the adverse impact on indoor air quality, while two mentioned the impact on the natural environment or that of the production process. Based on these responses, recognition of issues associated with either indoor air quality or the natural environment seems to be mildly articulated by practitioners.

Although half of the participants mention linoleum as a natural material, 'nice' and even a 'great' product, overall the received comments could be seen as less favourable than those for vinyl. Poor performance in wet areas is often mentioned, as are issues with maintenance (including poor knowledge in this area), installation, and shrinkage and brittleness due to linseed oil leaching over time. It is also described as both a high and low cost flooring material. Half of the comments are only negative, and in the other half there is much neutrality and balancing between positives and negatives, for examples 'healthier, nice product, need to know maintenance regime, cost high.' Two comments also raise issues with client perception: 'Natural product, low allergy, benign. Client perception needs to change!' and 'Institutional clients in NZ wouldn't have it if you paid them.'

When considering the responses for both materials it is clear that although linoleum is acknowledged as the more natural material with less adverse impact on the natural and indoor air environments, there is an implied preference or at least acceptance of vinyl as the more prevalent material. This can explain the contradiction between higher health ratings received for linoleum, and a relative lack of its use in practice. Furthermore, these responses indicate two key challenges associated with the use of linoleum: issues associated with limitations of installation and maintenance, and a tradition of perception of such limitations as a norm, thus the poor perception of the material by the clients (and possibly also by the practitioners). While some of the reported limitations of linoleum could be seen as a misconception, they all fall in the range of necessary product improvements, which have already been acknowledged. However, any such efforts should also be prepared to address the issue of reversing the tradition of perceiving linoleum as more limited in terms of performance.

When analysed for any predictive patterns, it was clear that the health ratings of the two flooring materials, their level of use in professional practice, or the tone of the comments were not predicted by the reported specialisation in sustainability. Lack of any clear relationship between specialisation in sustainability and attitude towards these two materials is perhaps surprising. Further analysis indicated that age might be somewhat predictive of the ratings with practitioners over the age of 50 reporting they use linoleum more often, while those aged 35-49 tended to report more use of vinyl. The design of the questionnaire and the limited sample size prohibited more detailed statistical analysis of this, but there could be some generational trends with the children of the late 1960s and 1970s tending to be less concerned about possible adverse health risks associated with vinyl. A further, more refined study is required to quantify and explain this.

It should also be noted that when asked where would they expect to find the information about healthiness of materials, the majority of practitioners (61%) said from manufacturers, which was followed by almost equal groupings of government sources / standards

42%, BRANZ (Building Research Association of New Zealand) 35%, and their own research 32%. This reinforces the easy path of influence manufacturers have on continued use of their products.

In addition to health ratings of materials, the group of 18 academics were asked to provide examples of explanations they would give to their students for their health rating of materials, including vinyl and linoleum. After removing responses which indicated specialisation in a different field of architecture 12 sets of comments remained. The tone of these is balanced, educational, and often descriptive. Off gassing and toxicity are most commonly mentioned in relation to vinyl (8 responses), while a list of its natural components is most common for linoleum (5 responses). Because the academics were not asked about their professional practice, the explanations that they provided simply reflect and reinforce their clarity of differentiation between the two materials. However, it is noticeable that the academics provided responses which more often reflected the impact vinyl can have on indoor air quality, through off gassing and toxicity, indicating a potential higher awareness than practitioners of the problems associated with vinyl once installed. Academics also mentioned issues associated with the natural environment more often.

CONCLUSIONS

The examples of vinyl and linoleum illustrate the issues associated with the complex processes involved in negotiating views about building and furnishing materials. While there is a reasonable level of scientific acceptance that vinyl and PVC pose risks to human health, and some legislative changes have been made at least against the use of phthalate plasticisers in such products, it is currently hard to predict whether such efforts will continue towards a complete elimination of these. What is known is that for the other well-known risk substances, lead and asbestos, regulations aimed at reductions came long before regulations aimed at their elimination, easily 20-30 years before. Unfortunately vinyl and PVC seem to be in the relatively early stages of recognition of risks, and early moves towards some reductions. Adding to this, the PVC industry is encouraging and supporting research to challenge any claims that the issues are serious, elongating the process. Therefore, despite some tangible expert indications that elimination of these products is needed, current trends suggest that any such process will be slow.

Meanwhile, the general population seems poorly informed of any such discussions. Furthermore, the general population in this survey struggled to differentiate between the two materials, and considered both reasonably healthy. This clear confusion makes it harder to learn about the specific features of either. Comments from the NZ practitioners also indicate that the clients tend to see vinyl as a better material, at least in terms of performance.

Although the NZ architects clearly differentiated between the two materials in their health ratings, rating linoleum as healthier, results from the admittedly small BBE sample clearly indicate a stronger polarisation was theoretically possible. A much more disconcerting result of this study is the observation that even practitioners, who as a group rated linoleum as healthier, tended to use vinyl more often in their professional work. The other surprising finding was that specialisation in sustainability was not consistently reflected in the significantly lower health ratings or avoidance of vinyl.

What remains hard to quantify with this study is the total impact the contradictory expert information on vinyl and linoleum have on observed differences between knowledge and practice amongst practitioners. There is a clear difference in responses received from academics, with the latter referring to indoor air quality issues and impact on natural environment more than the practitioners. Although impossible to fully explain, this indicates the scientific information is making relatively slower progress towards practitioners than academics.

However, this study makes it clear that because vinyl and linoleum are commonly used in architecture and building construction, and architects and building experts are often involved in specifying such materials, it is essential for them to take a leadership role in this change. The noticeable gap between theoretical views reflected in health ratings and the choices in practice should be narrowed. Possibly, this will require some education of the general population, the first step in which will be ensuring the ability to differentiate between the two materials.

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