The Healthiness and Toxicity of Common Building Materials

Dr Emina Petrović

(Athena Thompson, *Homes that Heal and those that don't*, 2004: 255)

Based upon:

Emina Petrović. 2014. Building Materials and Health: a study of perceptions of the healthiness of building and furnishing materials in homes. PhD thesis, Victoria University of Wellington.

Emina Petrović, Brenda Vale and Marc S. Wilson. Forthcoming March 2016. Vinyl and Linoleum Flooring: health issues as perceived by lay people and architects. *Journal of Green Building*, Volume 11, number 2.

The Problem

World-wide

over 4,000,000 registered human-made chemicals

about 60-80,000 in common use

about 1,000 added every year

1945 – less than 10 million tons produced

‘now’ – over 110 million tons produced **(about 10 years ago)**

BUT

less than 2% tested for their effects on human health

more than 70% not tested at all

For 95% of chemicals used in construction products there are insufficient health assessments

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

Recognition of problems with poor air quality since the World War Two

With increase of air-tightness of buildings since the 1970s, recognition of problems with insufficient air exchange and build-up of indoor toxicants

Recognition of Sick Building Syndrome in the early 1980s

Most people spend 80-93% of their time indoors

Materials are not alone in their negative contribution to indoor air quality, but are relevant

Research in this area has been developing since the World War Two, and especially in the last 20-30 years

Still, many consider that it is not keeping up with the needs for new knowledge in this area

This is problematic given the increases in modern diseases such as cancer, multiple allergy syndrome, allergies, asthma, autism, attention deficit disorder and similar

The Boiled Frog Syndrome: *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.*

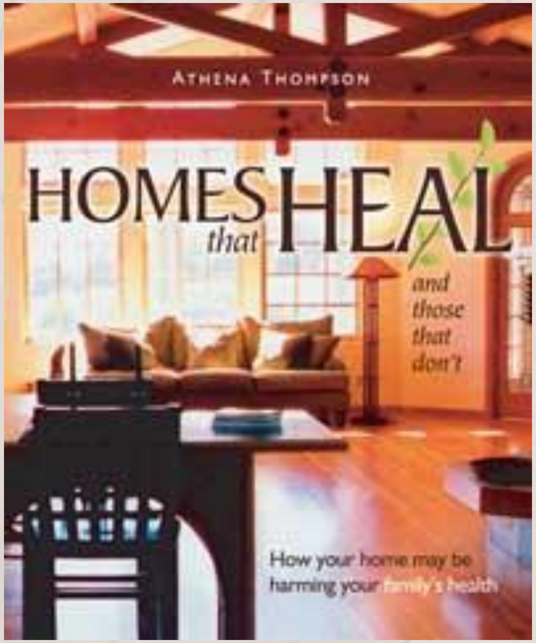
(Thomas Saunders, *The Boiled Frog Syndrome*, 2002: 5)

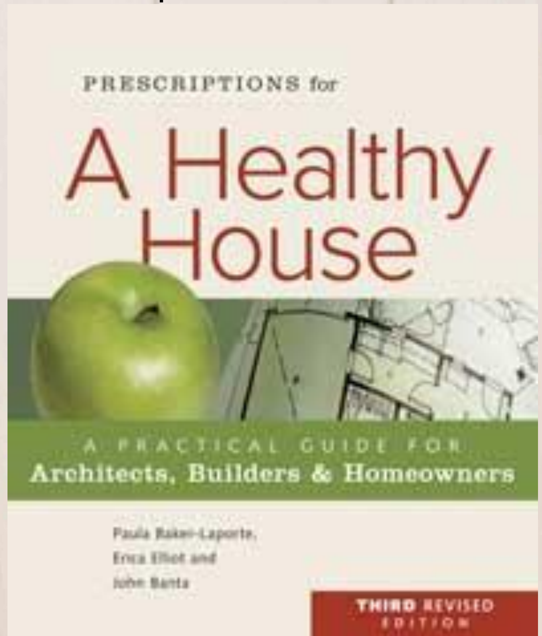
Prudent avoidance or the precautionary principle:

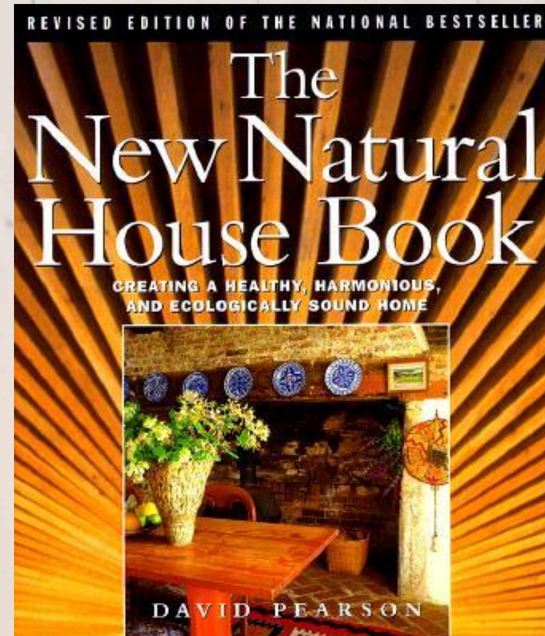
‘Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation’ or in this case, human health

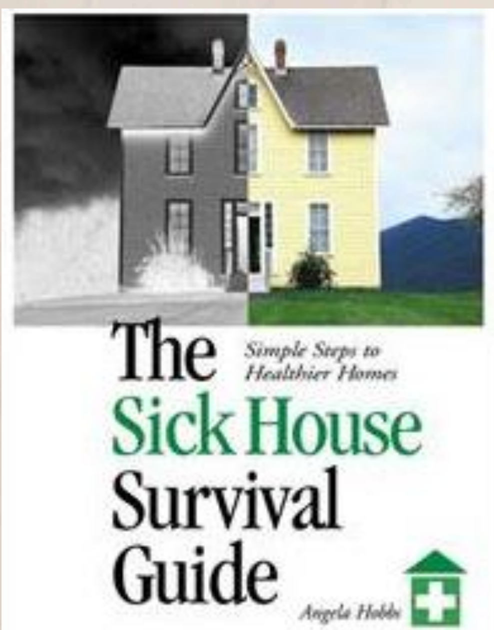
(Principle 15 of the 1992 Rio Declaration on Environment and Development, Philip, 2001)

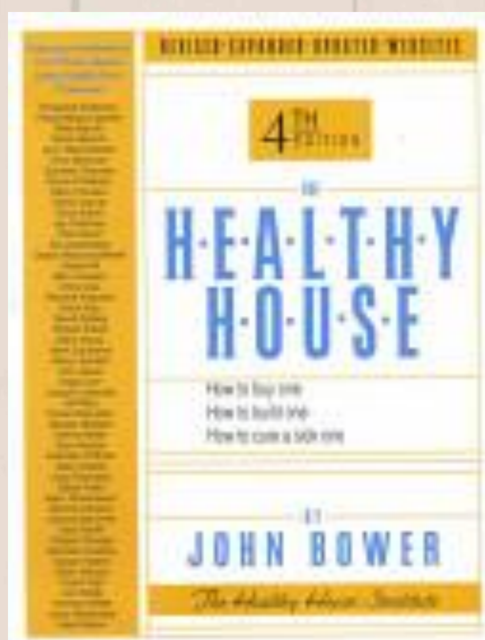
Good quasi-scientific sources

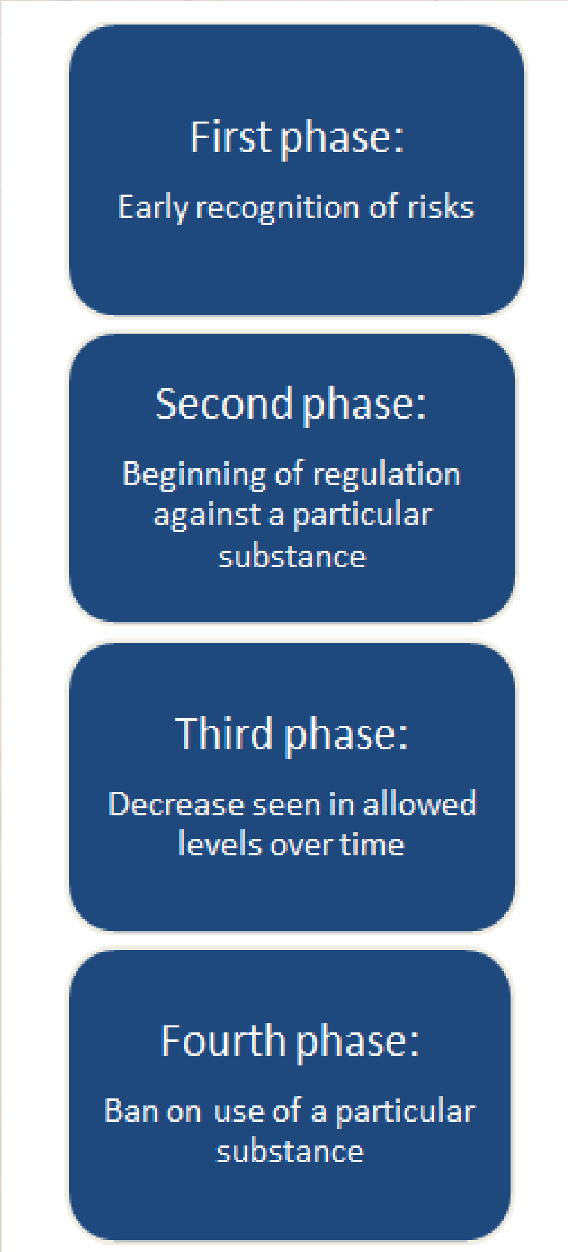












First phase:

On-going use, replacements, new materials and substances

Second and third phase:
VOCs, formaldehyde, vinyl and phthalate plasticisers

Fourth phase:
Lead and asbestos

First phase:

Early recognition of risks

- More indications than complete assessments/proofs of adverse health effects;
- 1st generation risks, with the most obvious risks studied;
- Shorter term observations, e.g. studies that can be done in 1-2 years;
- Animal studies more than human subjects – problems of comparability with human bodies make conclusions difficult (especailly for cognitive processes/behaviours);
- No proper longitudinal and prospective studies; and
- Often assessments of high level exposures, less work on long term low level exposures.

Second phase:

Beginning of regulation against a particular substance

- Stage of formalised acknowledgement that certain levels of the particular substance are harmful, and starting to limit exposure to these levels;
- Results of larger numbers of longitudinal and prospective studies become available;
- In addition to initially recognised risks, 1st generation risks, new 2nd generation risks are identified; and
- Regulated levels set higher than the subsequent ones.

Third phase:

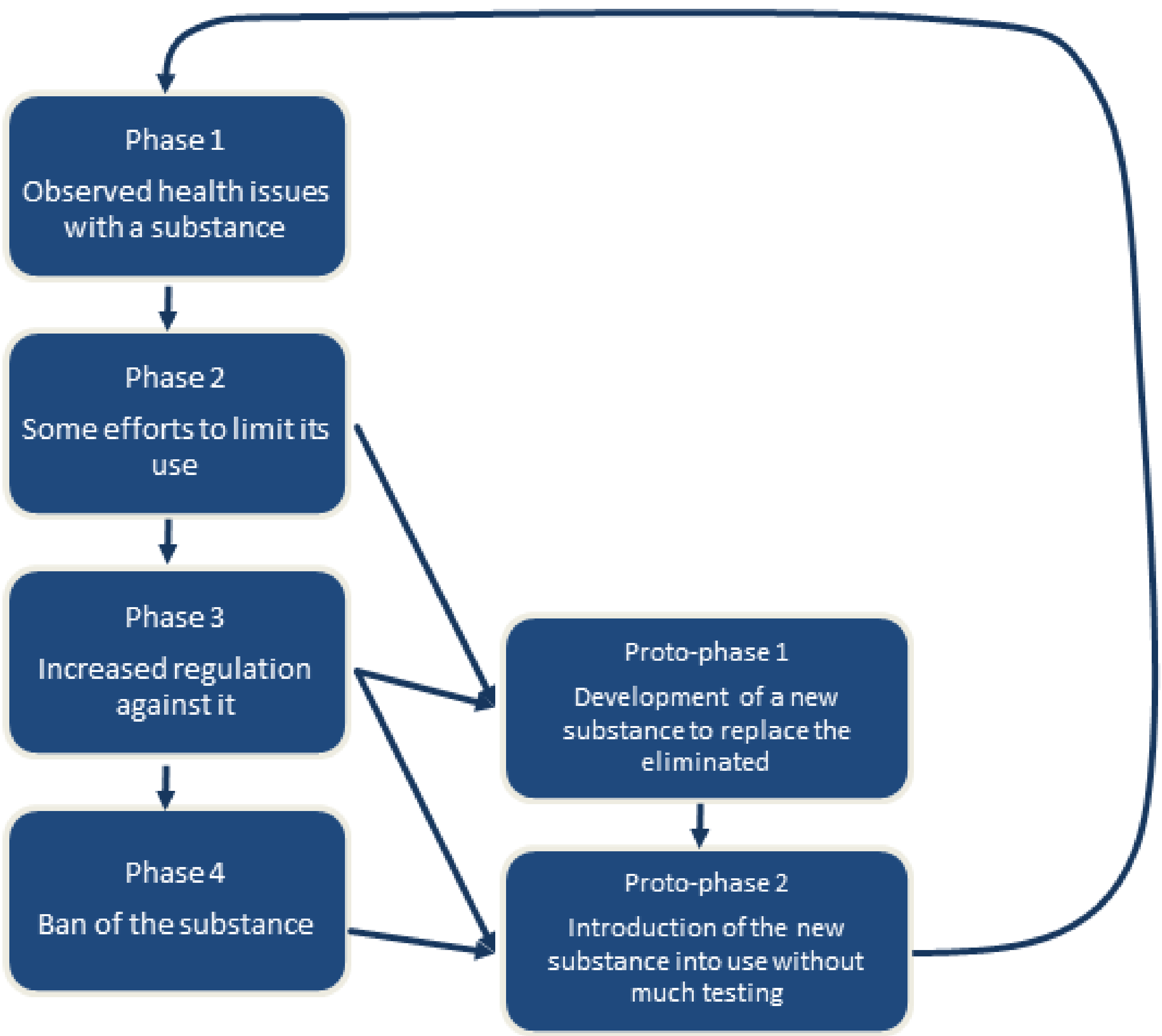
Decrease seen in allowed levels over time

- More research results available, including results on both 1st and 2nd generation risks;
- Results from longitudinal and prospective studies start giving more evidence of the harmful mechanisms;
- For some substances 3rd generation risks are identified, often dealing with issues of much lower levels of exposure which can only be studied after the initial regulations have been set;
- The available research results are more conclusive; and
- Decrease in allowable levels regulated.

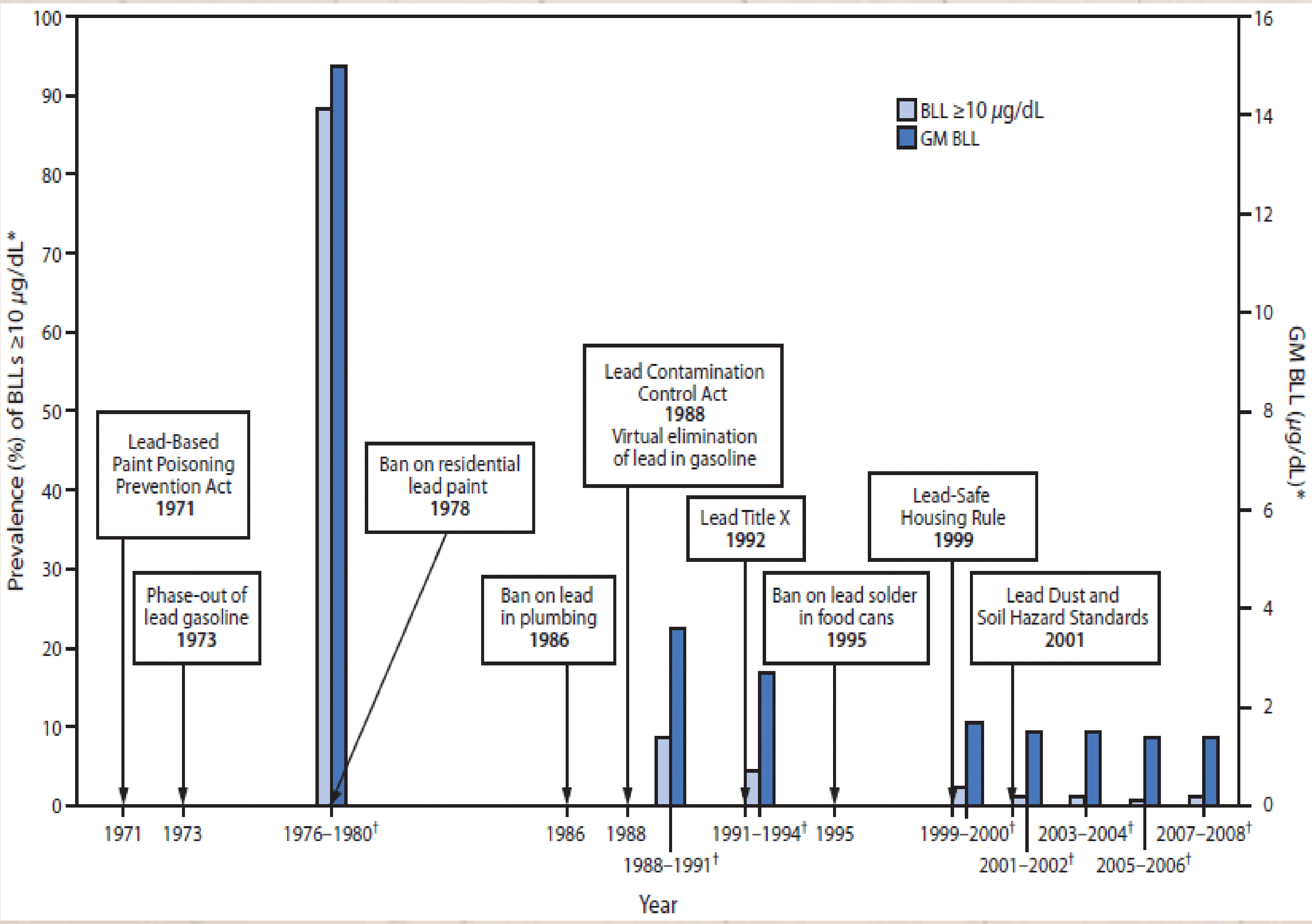
Fourth phase:

Ban on use of a particular substance

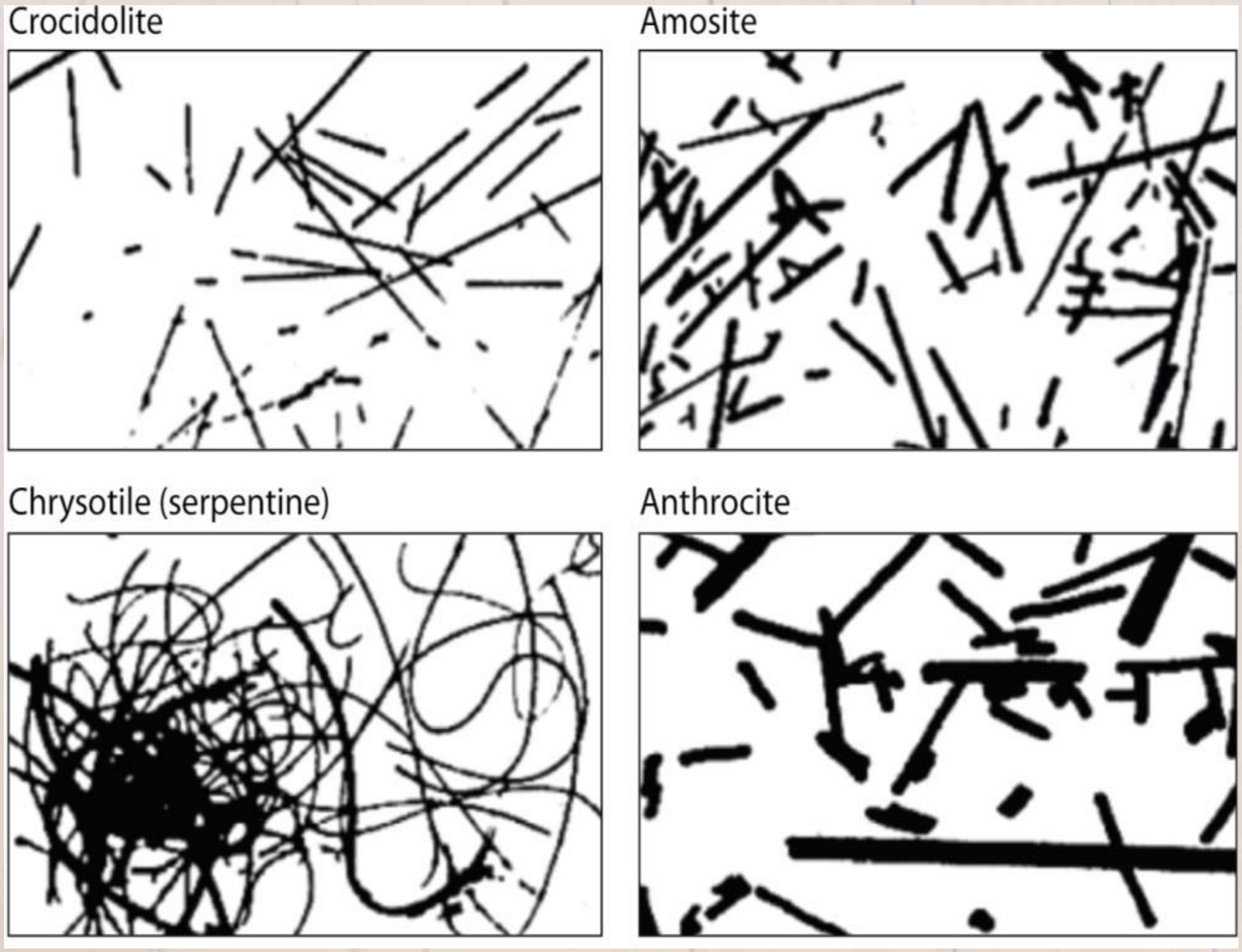
- Many conclusive results available for all three generations of risks;
- Results on lower levels of exposure becoming available;
- Enough factual information to ban the use of the particular substance;
- Limitations to existing knowledge are still observed, and more time needed for more complete understanding;
- Future of existing, built in materials under previous regulations is not dealt with by the ban; and
- Knowledge about the problem substance continues developing.


Phase 1
Observed health issues with a substance
Phase 2
Some efforts to limit its use
Phase 3
Increased regulation against it
Phase 4
Ban of the substance
Proto-phase 1
Development of a new substance to replace the eliminated
Proto-phase 2
Introduction of the new substance into use without much testing

Fourth phase:	Lead and asbestos
Second and third phase:	VOCs, formaldehyde, vinyl and phthalate plasticisers
First phase:	On-going suspicion, replacement and new chemicals



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.)



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

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)

(Source: EPA 2013.)

Aromatic compounds: benzene, toluene, ethylbenzene, xylenes, and styrene

Vinyl

Vinyl = polyvinyl chloride (PVC) + plasticisers (often phthalate plasticisers)

PVC was first invented in 1872, more actively used from 1926

In 1933 vinyl flooring was displayed at the Century of Progress Exposition in Chicago

Vinyl became commercially available after the World War Two

PVC produced through polymerisation of vinyl chloride monomer (VCM)

VCM is known human carcinogen, genotoxic, toxic for immune and cardiovascular systems, liver, and organ development

Manufacturing of PVC, its burning and final decomposition create dioxins (highly toxic and persistent environmental pollutants)

The Greenpeace group has advocated the complete, global phasing-out of PVC

Vinyl is the second largest plastic by volume in the world (after polyethylene (PE))

About 70% of PVC used in construction industry

Plasticised PVC (pPVC) – in flooring, wiring, wallpaper
Unplasticesd PVC (uPVC) – in pipes, cladding

In 2011, some reductions were observed in the world consumption of PVC

Most of those were in developed countries

Asian countries contributed about 80% of world consumption of PVC in 2011

For indoor air quality, the most significant concern for vinyl are the phthalate plasticisers

Phthalates are a group of aromatic chemicals containing a phenyl ring with two attached and extended acetate groups

They are added to PVC (or other plastics) to increase their flexibility and transparency

Because they are not part of the chain of polymers that make plastics, plasticisers can be slowly released from these products

Phthalates can be 10-60% of final PVC products/ vinyl

pPVC accounts for 80-90% of world plasticiser consumption

Some reductions in use of phthalate plasticisers in recent years, but still China accounted for nearly 38% of their world consumption in 2012

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	

Based on: European Chemicals Agency (ECHA), 2013

The US Agency for Toxic Substances and Disease Registry (ATSDR) only lists 4 phthalate plasticisers

In 2005, European Union has banned use of all phthalates in toys that can be put into a baby’s mouth

A similar regulation took effects in the US in 2009

Di(2-ethylhexyl)phthlate (DEHP) is a short chain phthalate often found in older PVC products and most researched

There is still limited epidemiological evidence related to phthalates

In rats DEHP is an endocrine disruptor with antiandrogenic activity, suppressing testesterone-related processes

Combination of phthalates (BPA, DEHP, and DBP) have been found to have increased impact in subsequent generations, suggesting that ancestral environmental exposures could be generating trans-generational inheritance of disease, often with adult onset

75% of US population had phthalate or their metabolites in blood

95% of US population had phthalate or their metabolites in urine

Also found in semen, saliva, amniotic fluid, umbilical cord, blood, human milk, and baby formula

3-30μg/kg/day estimated current exposure levels of most humans

Studies of what happens in space have found:

A very small area/amount of pPVC emits almost as many phthalates as a large area, and this did not change with increased ventilation rates

Once emitted into indoor air, phthalates settle into household dust, increasing exposure for children, especially toddlers

In addition vinyl/PVC industry are very active in financing rebuttal of relevance of these issues

In 2013, the *Indoor Air* journal published in the same issue two articles on vinyl:

One, report on uptake of phthalates in babies exposed to vinyl flooring in bedrooms

The other industry rebuttal focused on procedural imperfections

Linoleum

Made by mixing oxidized linseed oil with resins from pine trees, wood flour, cork, and limestone fillers, with added pigments, pressed onto a backing

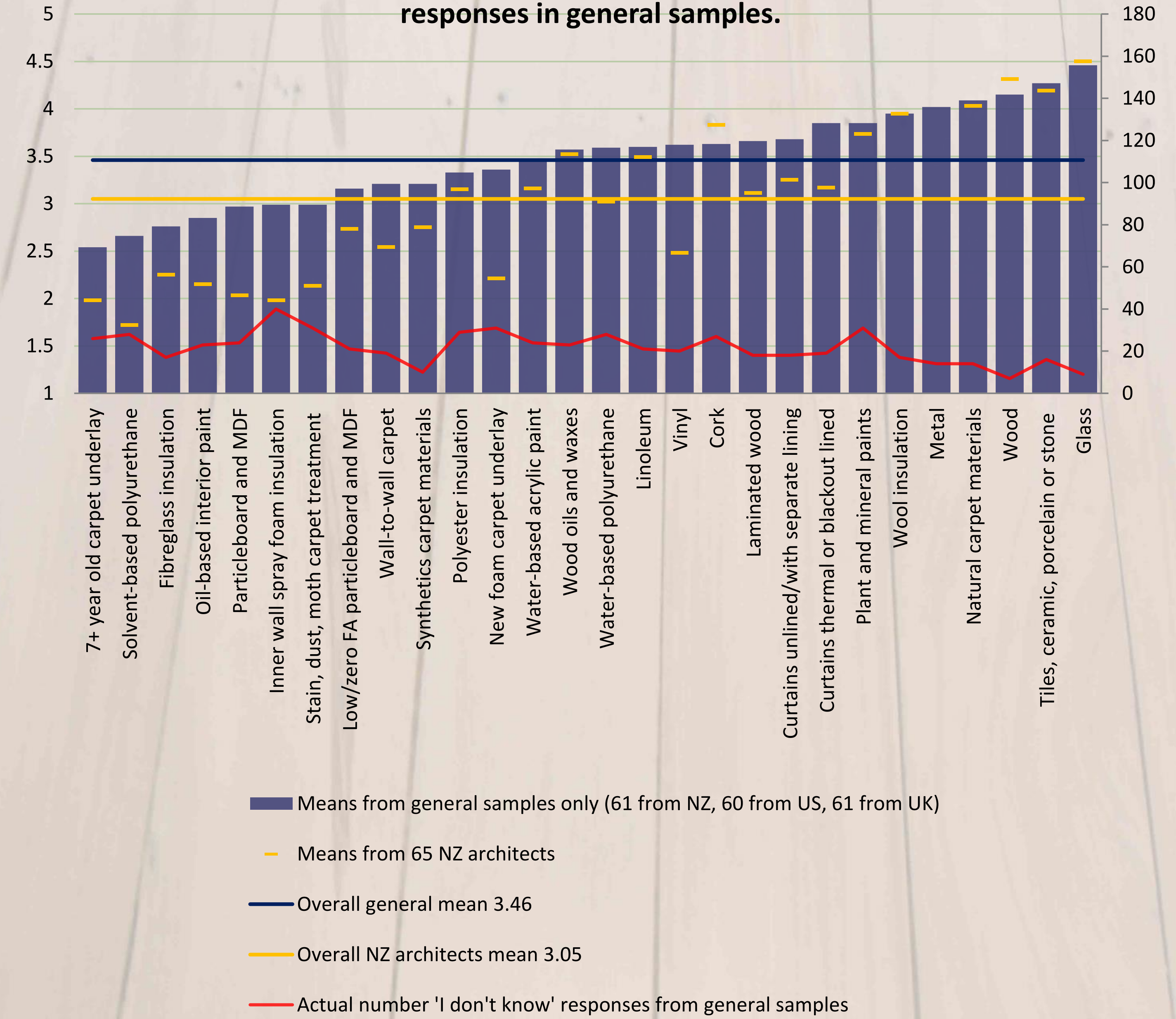
When new, linoleum can continue to the process of oxidation of linseed oil, leading to persistent odours (due to release of various aldehydes)

Some linoleums were found to have very high emissions levels of acetaldehyde

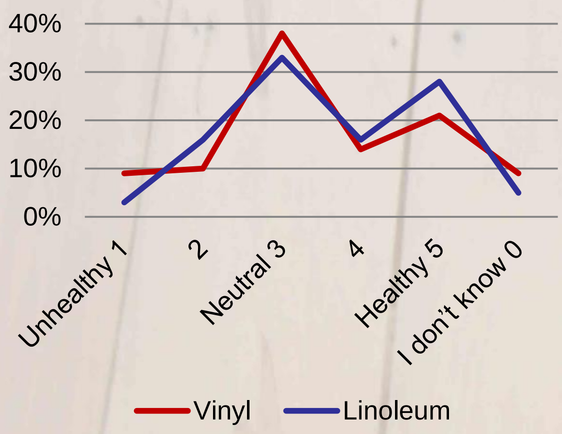
Farming of flax/linseed is associated with the use of environmentally persistent pesticides and run off of nutrients (eutrophication)

Research indicates that these problems could be avoided through development of industry which was neglected for decades: in mid the 1980s only three linoleum producers in the world operated

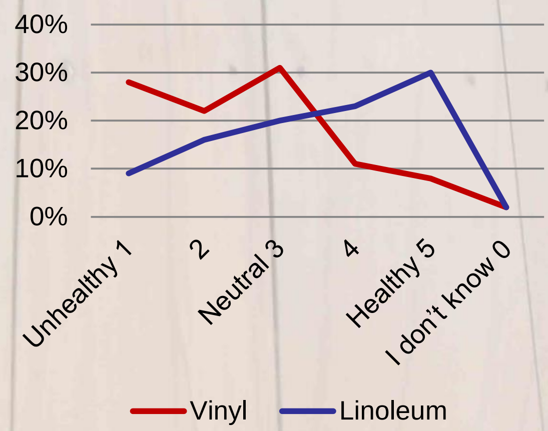
Comparison of mean material health ratings for three general samples, compared to NZ architects ratings and 'I don't know' responses in general samples.



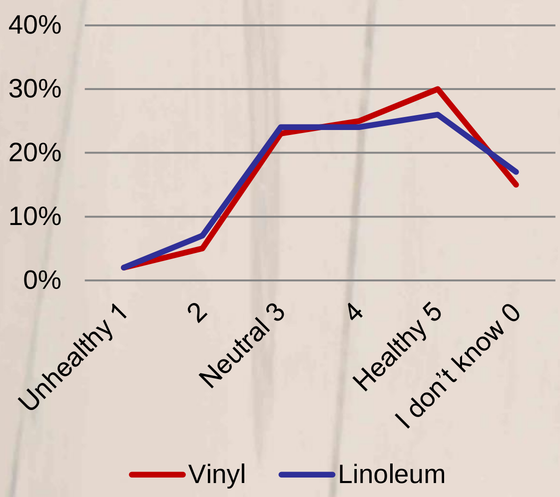
Health ratings for vinyl and linoleum from the NZ general sample.



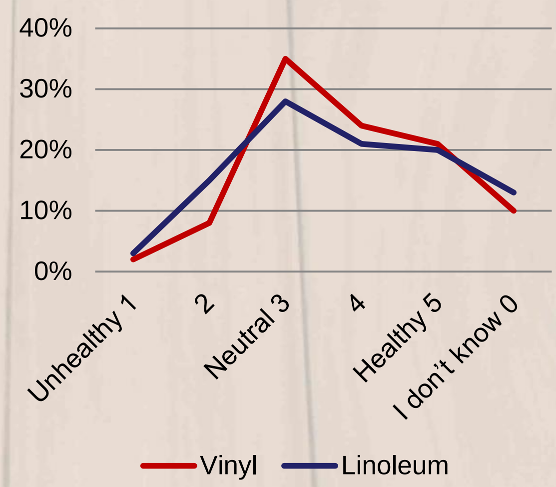
Health ratings for vinyl and linoleum from the NZ architects sample.

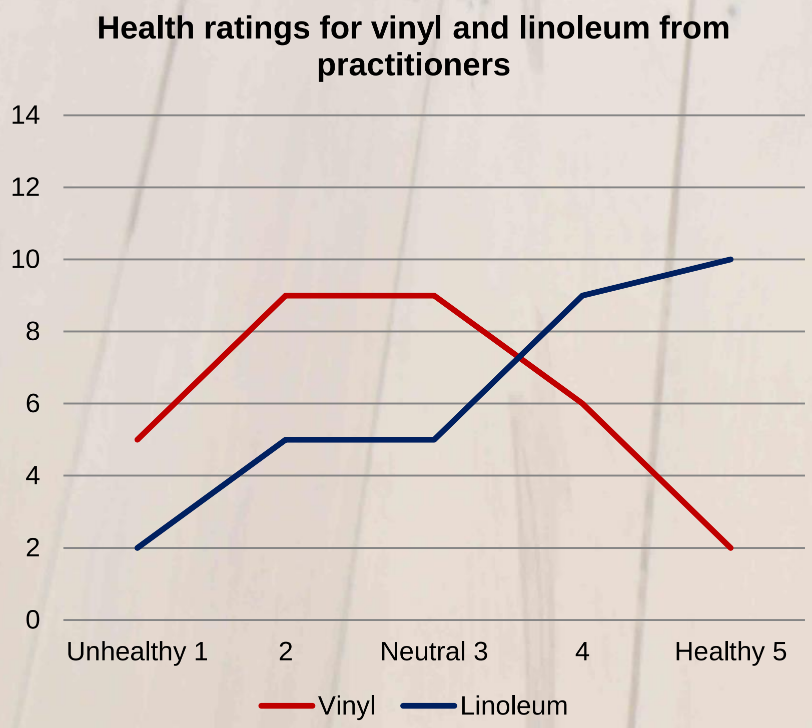


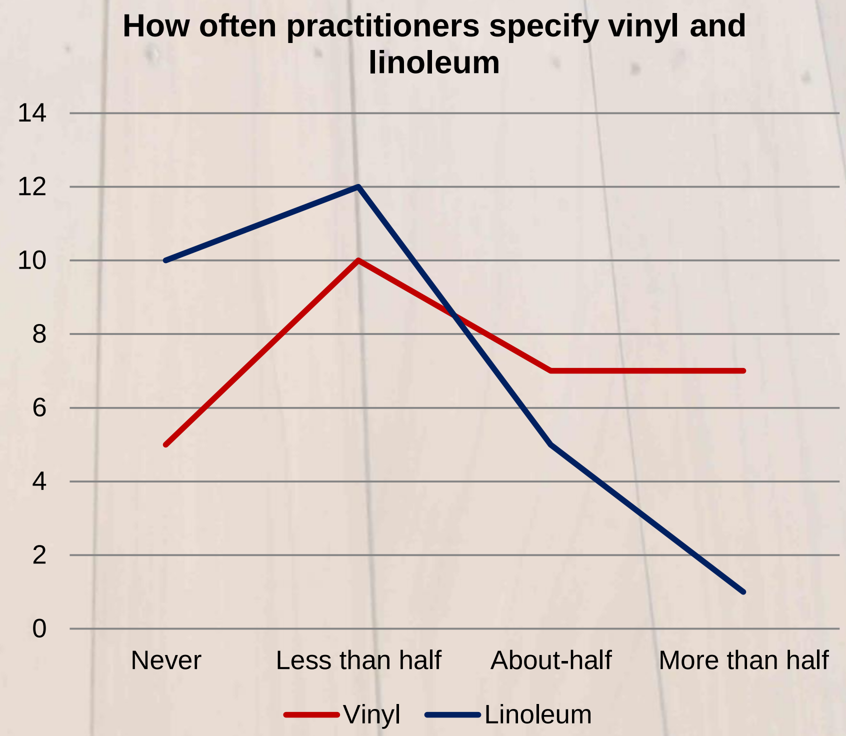
Health ratings for vinyl and linoleum from the US sample.



Health ratings for vinyl and linoleum from the UK sample.







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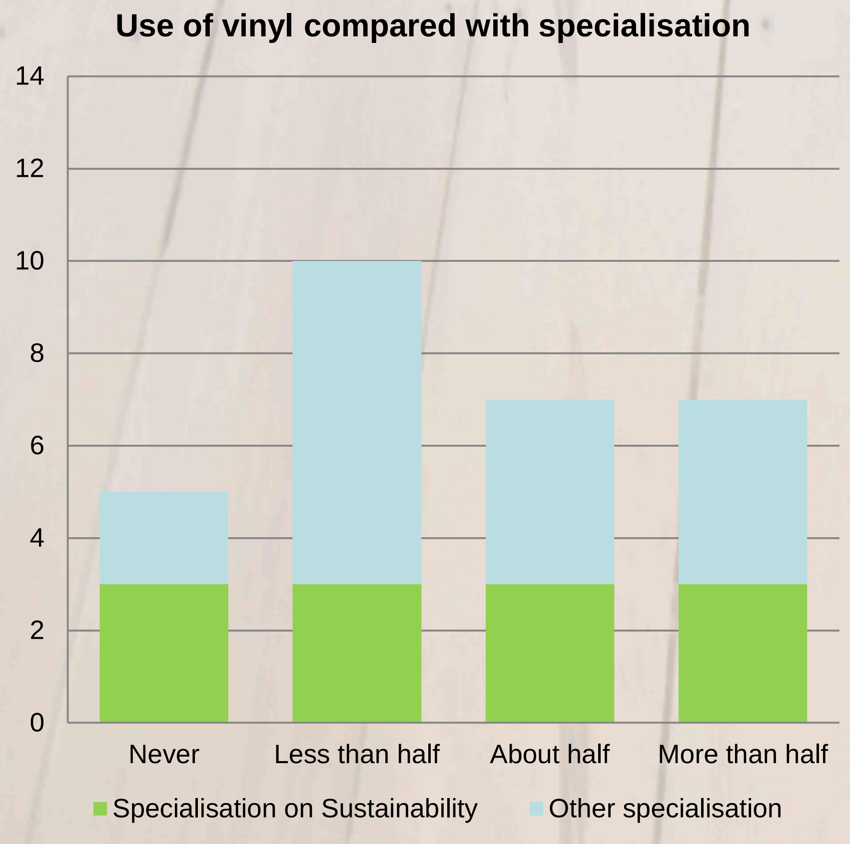

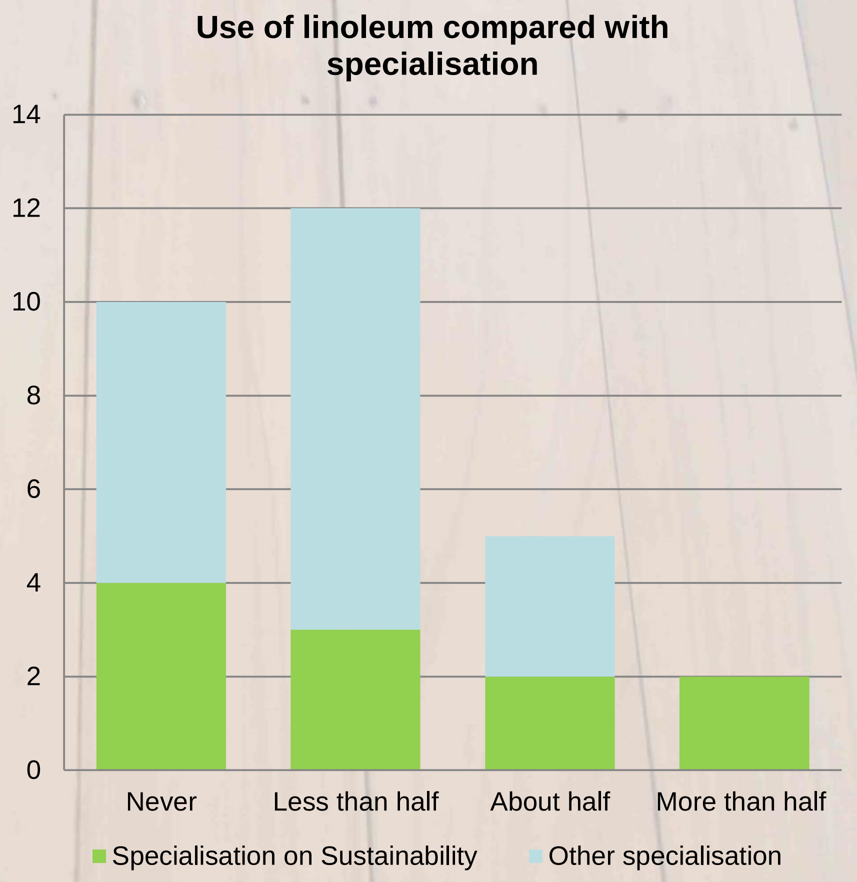

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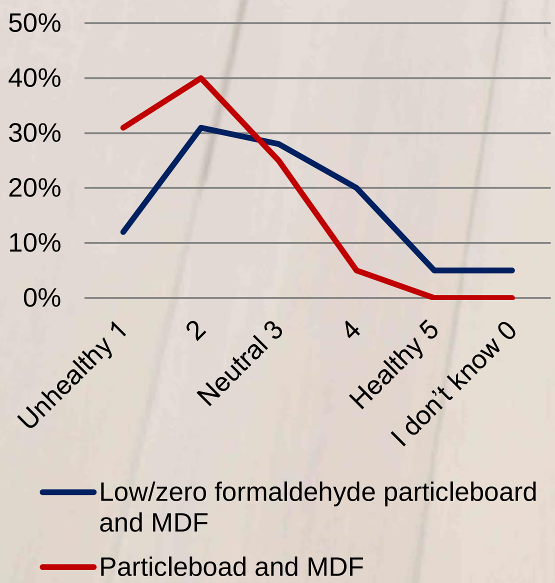
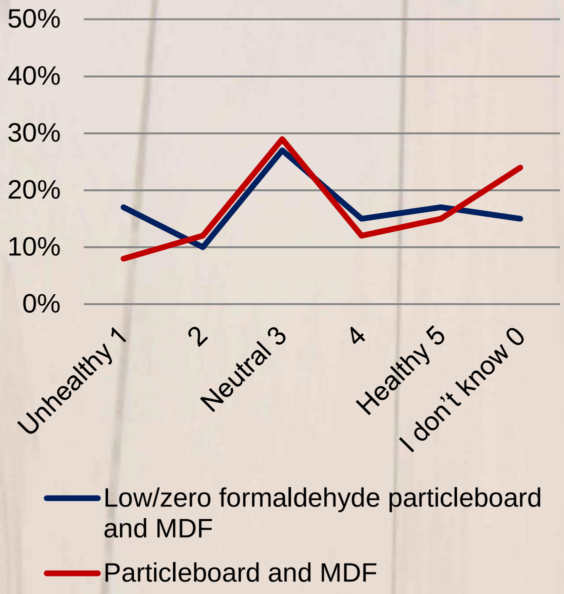
Health ratings for particleboard and MDF normal and low/zero formaldehyde from the NZ architects sample.



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



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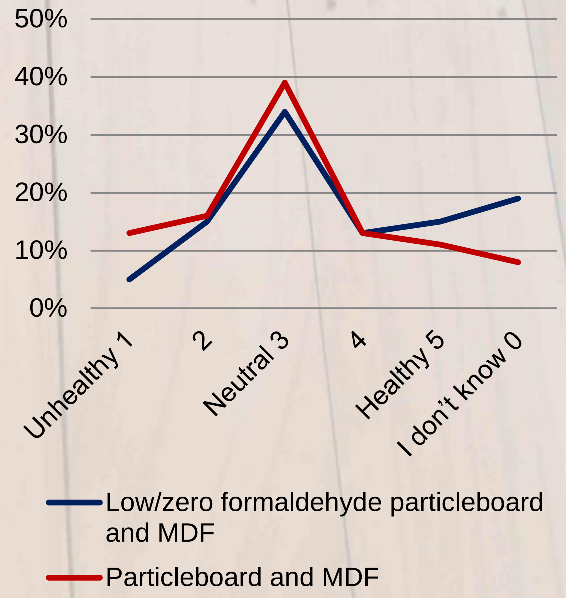
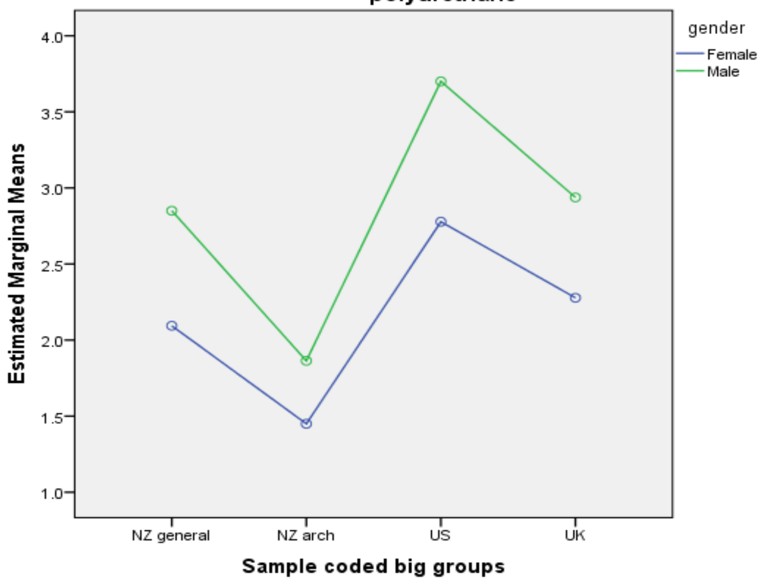
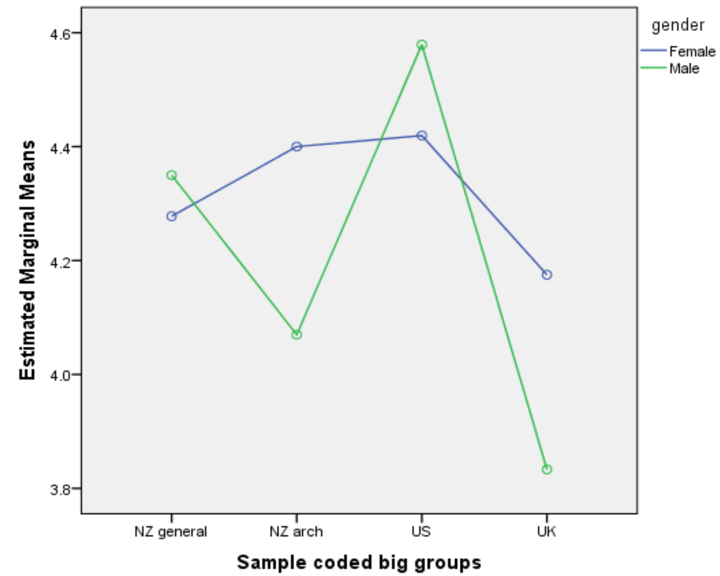


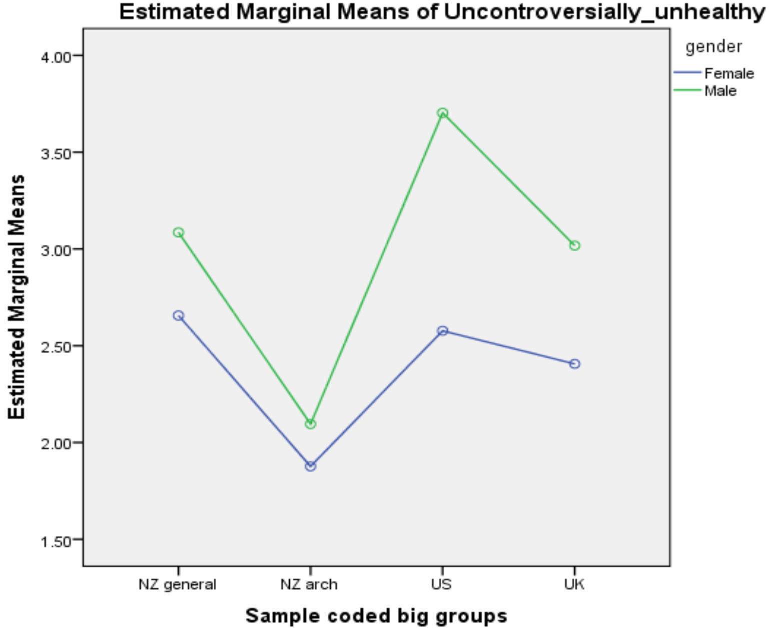
Estimated Marginal Means of 5.4 Varnishes and paints -Solvent-based polyurethane



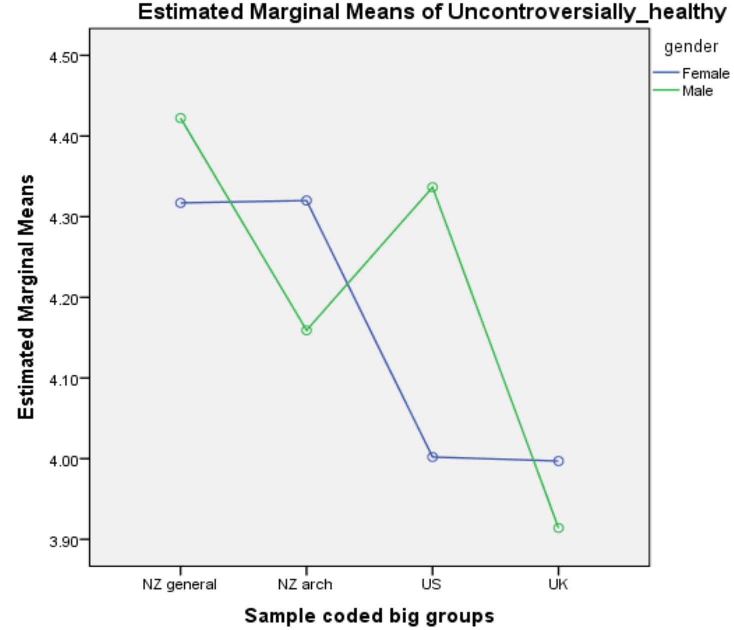
Estimated Marginal Means of 5.2 Floor coverings -Ceramic, porcelain or stone tiles



Estimated Marginal Means of Uncontroversially_unhealthy



Estimated Marginal Means of Uncontroversially_healthy



First phase:
On-going suspicion, replacement and new chemicals

Table 3

Requirements by various labeling schemes for emissions (or test chamber concentrations) by building materials

	AgBB	CESAT	M1	LQAI	Natureplus	Blue Angel	Austrian Ecolabel	GUT	Emicode EC1
TVOC	3d: 10000 $\mu g\,m^{-3}$ 28d: 1000 $\mu g\,m^{-3}$	3d: 5000 $\mu g\,m^{-3}$ 28d: 200 $\mu g\,m^{-3}$	28d: 200 $\mu g\,m^{-2}\,h^{-1}$	3d: 5000 $\mu g\,m^{-2}\,h^{-1}$ 28d: 200 $\mu g\,m^{-2}\,h^{-1}$	28d: 200–300 $\mu g\,m^{-3}$	3d: 1200 $\mu g\,m^{-3}$ 28d: 360 $\mu g\,m^{-3}$	28d: 380 $\mu g\,m^{-2}\,h^{-1}$	3d: 300 $\mu g\,m^{-3}$	10d: 500 $\mu g\,m^{-3}$
HCHO	28d: 120 $\mu g\,m^{-3}$	28d: 10 $\mu g\,m^{-3}$	28d: 50 $\mu g\,m^{-3}$	28d: 10 $\mu g\,m^{-3}$	28d: 36 $\mu g\,m^{-3}$	28d: 60 $\mu g\,m^{-3}$	–	10 $\mu g\,m^{-3}$	1d: 50 $\mu g\,m^{-3}$[a]

[a] Also acetaldehyde should not exceed the same chamber concentration.

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

Substance Description	AU ACCS Max emiss. (24 hr) µg/h/m²	NZ Env. Choice for syn. carpets µg/m³	US Green label plus Max emiss. (24 hr) µg/h/m²	Classification by: -ECHA -IARC -CAL/OSHA
Benzene C_6H_6	55	30	55	-1 ECHA 2008 -1 IARC 2012 - Cal classified
Formaldehyde CH_2O	10	16	16	-1 ECHA 2012 -1 IARC 2012 -Cal classified
Toluene $C_6H_5 - CH_3$	280	150	280	-2 ECHA 2004 -3 IARC 1999 -Cal classified
Styrene C_8H_8	410	220	410	-Not classified -2B IARC 2002 -Cal classified
Acetaldehyde C_2H_4O	20	4.5	130	-Not classified -2B IARC 1999 -Cal classified
Vinyl Acetate $C_4H_6O_2$	400	100	190	-Not classified -2B IARC 1995 -Cal classified
Naphthalene $C_{10}H_8$	20	4.5	8.2	-Not classified -2B IARC 2002 -Cal classified

Substance Description	AU ACCS Max emiss. (24 hr) µg/h/m²	NZ Env. Choice for syn. carpets µg/m³	US Green label plus Max emiss. (24 hr) µg/h/m²	Classification by: -ECHA -IARC -CAL/OSHA
Caprolactam $C_6H_{11}NO$	120	100	130	-Not classified -4 IARC 1999 -Cal classified
1-Methyl-2-Pyrrolidone C_5H_9NO	300	160	300	-Not classified -NA -Cal classified
Nonanal $C_9H_{18}O$	24	13	24	-Not classified -NA -NA
Octanal $C_8H_{16}O$	24	7.2	13	-Not classified -NA -NA
2-Ethylhexonoic Acid $C_8H_{16}O$	46	25	46	-NA -NA -NA
4-Phenylcyclohexene $C_{12}H_{14}$	50	2.5	50	-NA -NA -NA

Based on: ECHA, IARC, CAL/OSHA 2013.

On-going use

4-Phneylcyclohexene (4PCH)

2-Butoxyethanol

Replacements

For fire retardants change from polybrominated diphenyl ether (PBDE) to tris(1,3-dichloroisopropyl) phosphate (TDCPP) which is suspected human carcinogen

For phthalates, change from shorter chain phthalates such as DEHP to longer chain phthalates such as DINP, and non-phthalate plasticizers, all less researched

New materials and substances

Nanotechnology

Conclusions

Natural and less changed materials less likely to be harmful, but use them wisely

Many natural chemicals can negatively impact human health if used in un-natural proportions/distorted

Highly inert materials, such as aluminum, steel or glass, pose no health risks once installed, but should be evaluated for their total impact on the natural environment

More transparency on what is in the materials and products is needed

Testing prior to introduction on the market is needed, but uncommon

This is rapidly changing and there is much room for leadership