HEALTHY & SUSTAINABLE FLOORING

Choosing resilient flooring for the European healthcare sector

Health Care Without Harm

ACKNOWLEDGEMENTS

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Executive Summary

Increasingly, healthcare environments are attempting to reduce their ecological footprint, provide safer environments and reduce expenditure. The choice of resilient flooring—flooring that has a measure of 'give' or elasticity—is essential to ensuring the comfort, safety and health of patients and staff. The cost, surface characteristics, durability and the overall appearance of the floor are important criteria, but impacts on indoor air quality and the minimisation of hazardous chemical compounds in the flooring and during manufacture and installation are of at least equal importance.

Decision makers in healthcare environments need to look for the right balance between reasonable installation and maintenance costs and low environmental impact, including low toxicity.

The ideal resilient flooring is non-toxic throughout its life cycle, practical (hygienic and easy to clean), durable, safe, silent underfoot, visually pleasant and cost-effective. While this ideal material does not exist at present, some of the choices available come close to achieving these desirable features with fewer chemical hazards. Nevertheless, producers of flooring material should continue research and development to produce even more sustainable materials in the longer term.

In Europe, the choice of resilient flooring is between PVC, linoleum and rubber. In addition the final quality of the floor and the overall environmental impact of the materials chosen should be considered. This latter criterion can be greatly informed by the use of environmental certification systems.

Taking into account overall life cycle costs and low environmental impact as key decision criteria, PVC flooring should be avoided. Its manufacture and disposal involves the emission of unavoidable toxic compounds, particularly dioxins. Phthalates, a group of volatile compounds with toxic properties, are added to PVC to make it flexible and are released during the lifetime of the flooring. While being relatively cheap to install, higher costs incurred during use rapidly outweigh this apparent cost advantage. PVC needs extensive maintenance and may pose serious logistical problems during cleaning operations. It is not as pleasant and silent underfoot as alternative choices, nor as durable.

Neither linoleum nor rubber contains chlorine (responsible for the dioxins associated with PVC manufacture and disposal) and both are also generally free from plasticisers. While linoleum may be suitable for many areas, it is not recommended for treatment rooms or operating theatres due to its potential for moisture adsorption. Maintenance and staining may need special attention.

Unless the linoleum is coated, air quality issues may arise due to oxidisation. Product quality and repairability may also pose serious challenges. However, a number of available linoleum floorings have achieved ecolabel certification and if at all possible one of these should be chosen if deciding to use linoleum.

When considering rubber flooring, it is essential to choose wisely by avoiding rubber made from recycled tyres and focusing on high quality flooring with an appropriate ecolabel. The potential of rubber flooring for low or high toxicity greatly depends on how it is manufactured and what ingredients are used.

If chosen with an appropriate environmental certificate and appropriate surface quality, rubber flooring offers the best opportunity to combine reduced maintenance costs, good slip resistance, good acoustic properties and comfort. No stripping and waxing or use of aggressive chemicals for cleaning purposes is required to maintain rubber floors, reducing the exposure to chemicals of patients and carers alike. Eco-certified rubber flooring is also largely stain resistant, has a non-glare finish, has very low emissions and is recyclable.

Introduction

Flooring is a key component of any healthcare environment, and hospitals in particular. The wise choice of flooring material (and all its associated components) can make a major contribution to worker and patient health and safety over many years. The most common type of flooring used in the healthcare sector is resilient flooring, flooring that has a measure of 'give' or elasticity, and which is durable and resistant to stains and water. Floors with some elasticity maintain their shape better, withstand heavy traffic more easily, and are more comfortable to stand and walk on. This in turn reduces fatigue and other health problems in healthcare workers.

The purpose of this report is to survey resilient flooring choices available in Europe and report on the potential chemical hazards inherent in different material choices, noting some recent developments that have taken place to improve these products. This report also addresses other criteria relating to flooring choice to enable informed choices for health sector procurement. We can state at the outset that the perfect 'green and sustainable' resilient flooring material is not in existence. Clearly, producers of flooring material need to continue to intensify research and development to produce more sustainable materials. However some of the currently available choices entail fewer chemical hazards and use more sustainable materials than others. Ultimately the choice of flooring is largely dependent on the criteria that are most important in a particular healthcare setting.

The report is addressed to healthcare decision makers as well as healthcare workers, procurement officers, facilities managers, architects, engineers and installers. Its aim is to assist in negotiating selection of the most suitable sustainable resilient flooring for the particular healthcare environment.

THE RANGE OF CONSIDERATIONS

While the immediate cost of new flooring is inevitably a prime consideration, in recent years concepts of sustainability and 'green' practices have been developing. These are being incorporated into flooring specifications and have become key decision making factors in determining the type of flooring to be installed in healthcare environments. While much of sustainability focuses on the carbon footprint of material this emphasis tends to undervalue another vital aspect of sustainability: toxic and hazardous chemical compounds contained in the flooring itself, in associated materials and used during installation.

The potential for hazardous emissions of chemicals and their effect on indoor air quality are a key concern and should be a major factor in any flooring decision. Cost, surface characteristics (ease of cleaning and disinfection), durability and the overall appearance of the floor are also key decision criteria. While parts of the sustainability criteria focus on hazardous chemicals in the material itself, installation practices and associated compounds (glues, etc.) can also have an impact on the final overall quality.

It is also important to investigate production specifications within each category of flooring material. The quality standards of each material can vary considerably between flooring manufacturers. In addition, differences in the coatings applied to the same flooring material may result in very different performance and differing chemical emissions.

Furthermore, consideration of the environmental impact of disposal at the end of the useful life of the flooring can influence the choice, some materials being inherently more difficult and hazardous to deal with.

The use of ecolabels can be very helpful in decision making, as it will ensure the material has been tested against a number of criteria, such as the use of permitted or non-permitted chemicals in its production and the extent of indoor air emissions. The label has to be chosen carefully, with assessment of the criteria behind each label to determine its scope and stringency.

The most common products used in Europe are linoleum, PVC (also known as polyvinylchloride or vinyl) and rubber. PVC is widely used in France, the UK, Belgium, Finland, Sweden and large parts of Southern Europe. Linoleum is popular in Germany, Austria, Switzerland, the Netherlands and Denmark, while rubber is gaining in popularity. Some materials popular in the USA, such as vinyl composite tiles (VCT), are not used in the EU. Neither are synthetic thermoplastic polyolefins commercially available.

While PVC is currently the dominant product used for resilient flooring in the healthcare sector, concerns about the negative health and environmental impact of PVC products have become significant. Linoleum and rubber are not necessarily hazard-free, but can be an excellent flooring option if chosen with the appropriate environmental certification.

How to choose resilient flooring in the healthcare environment

BALANCING DECISION CRITERIA

Flooring is one of the most extensive and visible parts of the healthcare environment. It is literally everywhere and a 'bad' choice, whether for a new building project or during refurbishment, may have serious impacts on staff, patients and visitors. This is particularly the case because choice of flooring is usually a long-term decision that cannot easily be reversed.

Overall key elements in flooring choice include infection control, slip and stain resistance, aesthetic and visual aspects, acoustic control, cleaning and maintenance, environmental impact and cost (initial and lifetime). Budget considerations need to take into account not only how much money is available to purchase a particular material, but also consider the on-going maintenance costs and potential for hidden costs. Increasingly environmental/sustainability considerations are being taken into account, particularly toxicity issues, both short- and long-term.

Different demands on the floor depend on the type of use of a room, resulting in different key criteria dominating when choosing a flooring material. Areas of the hospital environment can be usefully divided into patient rooms, operating theatres, emergency rooms, nurses' stations, waiting rooms, lobbies, hallways, stairs and stairwells. Key features to consider in patient care areas are infection control, sound control, comfort, aesthetics, ease of maintenance, low chemical emissions and durability, while public areas require a non-institutional feel, good sound control and low-emission cleaning fluids (5).

A study of sustainable resilient flooring choices for hospitals in the US reported that cleanability, aesthetics, durability and initial cost were the key considerations that guided over 700 respondents to a survey of decision making on flooring (6). Subgroups within this survey however had slightly different priorities. For instance, architects and designers were chiefly interested in aesthetics and sustainability (i.e., energy consumption, health impacts and recycled content), while facilities managers focused on cleanability (essentially infection control and hygiene) and installers on initial and life cycle costs and durability.

INDOOR POLLUTION

Resilient flooring can be a major source of indoor air pollutants, such as certain organic chemicals (1). Indoor air pollution can contribute to a number of health issues, including cancer, chronic and acute pulmonary diseases, upper airways inflammatory diseases, allergic diseases such as asthma and allergies, infectious diseases, respiratory infections and cardiovascular diseases. Less severe adverse health effects include general discomfort such as odour perception and sensorial irritation and Sick Building Syndrome (SBS). Volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) and particulate organic matter (POM) are of chief concern in terms of potential health impacts. VOCs include aliphatic hydrocarbons, aromatic hydrocarbons, chlorinated hydrocarbons, aldehydes (including formaldehyde), terpenes, alcohols, esters and ketones (1).

FLAME RETARDANTS

Due to the high flammability of PVC flooring and other synthetic flooring materials, halogenated flame retardants are added in order to comply with fire safety standards. However halogenated flame retardants such as polybrominated diphenyl ethers (PBDEs) and chlorinated paraffins are persistent and toxic. They have been linked to immune suppression, reproductive and neurodevelopmental problems and cancers in animal studies (2). In the event of an actual fire, brominated and chlorinated flame retardants will give off toxic halogenated dioxins and furans which not only pollute the environment but which are very dangerous to fire service personnel and people trapped in fire, as dioxins and furans increase the release of carbon monoxide and hydrogen cyanide (3).

Disturbingly, recent investigations have accused flame retardant manufacturers of distorting evidence to inflate the need for and exaggerate the efficiency of their product (4). They also appear to have used front groups to boost demand for their products and infiltrated standards bodies with a view to furthering the use of their products.

It is prudent to be wary of alternatives to brominated and chlorinated flame retardants such as antimony trioxide as this is also a known carcinogen (2).

THE EU'S REACH LEGISLATION

In 2006, the EU passed legislation on the Regulation, Evaluation, Authorisation and Restriction of Chemicals, known as REACH (EC/1907/2006) (7). REACH recognises a number of categories of chemicals:

- Carcinogens, mutagens or reproductive toxic chemicals (CMRs)
- Persistent, bioaccumulative and toxic chemicals (PBTs)
- Very persistent and very bioaccumulative chemicals (vPvBs)
- And chemicals of 'equivalent concern' such as endocrine disruptors.

Dioxins, mercury and certain flame retardants are examples of PBTs, having toxic properties and also undesirable physical properties. Persistent chemicals do not break down rapidly in the environment and may travel long distances on a global scale, ending up a very long way from where they were originally manufactured or used. Bioaccumulative chemicals can get stored in fatty tissue, building up to potentially toxic levels along the food chain, including in humans and passing from one generation to the next.

Sustainability: low environmental impact plus low toxicity

The overall concept of sustainability includes consideration of many properties over the entire life cycle of the product. With regard to flooring, a particularly important property to consider is the overall environmental impact of manufacture, use and disposal, including any use of toxic chemicals. In an ideal world products would be manufactured from sustainably grown and harvested plant resources or non-toxic post-consumer recycled content and would be reusable, recyclable or compostable at the end of their lives. Raw materials would be grown without the use of genetically modified organisms (GMOs) and without the use of pesticides containing carcinogens, mutagens, reproductive toxicants or endocrine disruptors. Greenhouse gas emissions during the life cycle would be as low as practicable and water and energy use would be minimised. Such an idealistic scenario does not exist in practice for flooring materials, but it is possible to address elements such as the use of toxic chemicals.

While it is clearly important to use sustainable materials in flooring wherever possible, it is perhaps even more important to eliminate materials that use, emit or lead to production of hazardous chemicals (see Table 1). Such chemicals include persistent organic pollutants (POPs, as defined by the Stockholm Convention and which include dioxins), chemicals that are persistent, bioaccumulative and toxic (PBT) or very persistent and very bioaccumulative (vPvB). It is also important to avoid all materials that are known or suspected to contain carcinogens, mutagens, reproductive or developmental toxicants (CMRs), endocrine disruptors or any materials that emit certain levels of volatile or semi-volatile organic compounds (VOCs or SVOCs).

Flooring can emit a variety of different chemicals into hospital air. For example, the VOC formaldehyde is a known human carcinogen [8]. The solvent benzene is associated with the increased risk of leukaemia, toluene is associated with lung cancer and benzene, toluene and xylene are all associated with an increased risk of non-Hodgkin lymphoma [9]. The regulatory limits rarely account for the synergies of mixtures of VOCs that ultimately contribute to sick building syndrome and other health concerns even at low levels [1].

Table 1: Prioritising chemicals based on persistence, bioaccumulation, health endpoints and confidence in science

Very High Concern	Persistent Organic Pollutants (POPs) and other Persistent Bioaccumulative Toxicants (PBTs)	Highest priority to eliminate
High Concern	Known or likely carcinogens, mutagens, reproductive toxicants, developmental toxicants or endocrine disruptors	
Moderate Concern	Significant possibilities of above hazards but lower confidence or known or likely neurotoxicant, respiratory sensitisers or leading to chronic human or ecotoxicity endpoints	Use with caution. Avoid where possible
Caution	Moderate concern for any of the above health endpoints or preliminary indications of higher concern but with inadequate test data or acute human health concern	
Low concern	Tested with low concern for any of the above endpoints	Prefer

Adapted from Lent et al [2].

Whereas VOCs tend to be most strongly emitted in the first few hours or days after installation of a product, SVOCs will be released by products more slowly and over a longer period of time. SVOCs include phthalates and halogenated flame retardants, which can bind to dust particles and may be breathed in by patients and care-givers. Phthalates are suspected to interfere with endocrine systems [10] and emerging evidence links them to respiratory problems such as rhinitis and asthma in adults [11] and children [12], and both obesity and insulin resistance in adults [13]. Halogenated flame retardants have been linked to thyroid disruption, reproductive and neurodevelopmental problems, immune suppression and, in some cases, cancer in animal studies [14].

Clearly, wherever possible it is advisable to choose materials that are produced using ingredients of low concern.

The importance of eco-certification

The purpose of eco-certification is to assess the environmental credentials of a product, using a number of standardised tests, and then succinctly communicate the information to consumers, usually via a label if the product achieves the standard. The tests usually include toxicity assessments, preferably throughout the life cycle of the product. Importantly, the assessments involve certification by a third party and meet high standards of transparency and scientific rigour. However, ecolabels differ widely from each other and may require different tests with very different levels of stringency. The schemes are voluntary, rather than legally required.

Well known European ecolabels include the EU Ecolabel with its daisy flower logo, the Scandinavian Nordic Ecolabel scheme (using the Nordic Swan logo) and national labels such as the German Blue Angel and the Austrian Umweltzeichen (see Appendix 2). There are a number of alternative competing labelling/certification schemes for construction products, including resilient flooring, in Europe. Some schemes have been initiated by industry, while others have broad support from a variety of stakeholders such as environmental organisations, unions, churches and frequently including governments. Unfortunately, a pan-European scheme for resilient flooring is not available currently, as the existing schemes were developed for national markets. However, some schemes have gained wider acceptance at European level and there is a certain convergence between schemes.

Appendix 2 gives a summary of key flooring ecolabelling schemes in Europe. Some countries, such as Belgium and the UK, have not adopted particular labelling schemes for building material, including flooring, but use schemes from other jurisdictions.

As a minimum the scheme should promote low emis-

BLUE ANGEL CERTIFICATION

The Blue Angel scheme was created in 1978 in Germany as a government initiative and has very stringent criteria. Products and services receive certification with a view to environmental and consumer protection, by meeting high standards of serviceability and health and occupational protection. The label, while supported by the German government, is not mandatory and manufacturers choose to seek certification under this label. Approximately 11,700 products and services in 120 product categories carry the Blue Angel ecolabel.

If necessary, the criteria can be revised every 3 or 4 years. The German Federal Environment Agency does the technical preparation prior to a hearing organised by RAL, the German Institute for Quality Assurance and Certification. Important considerations include economical use of raw materials during production and use, a long service life and sustainable disposal. The standards are accessible to the general public.

The Blue Angel label is awarded by RAL GmbH, a subsidiary of RAL. The resilient flooring standards are titled RAL-UZ 120 (see Appendix 4 for a summary of these criteria). Since 2012 the Blue Angel label and the Austrian Umweltzeichen have largely harmonised their requirements for flooring and are now equivalent.

The Blue Angel and Austrian Umweltzeichen systems are among the strictest in Europe and we recommend their criteria as a good way of evaluating the environmental credentials of flooring.

sions and sustainability of a product. Additionally, when selecting a certification scheme it is important to consider the following points:

- How the sampling and preparation of test specimens is carried out.
- The analytical procedures that are used. These will determine how reliable and relevant the measurements are and should include a specific quality assurance scheme.
- Whether SVOCs in addition to VOCs are included in measurements.
- Any additional criteria that a scheme requires for certification. For example, it may specify that certain chemicals may not be used during production because of the risk they pose. Typically nitrosamines, plasticisers (phthalates) and halogens are excluded due to their toxicity risk during production or in cases of fire (e.g., hydrochloric acid or dioxin formation) and due to the problems of toxic chemicals being released during recycling.
- The scheme also should clearly identify the relevant occupational exposure limits with respect to carcinogenic, mutagenic, teratogenic and reproductive toxicants (15).

It is also important to remember that certification schemes evaluate sample materials only and do not test installed products. How materials perform *in situ* may depend on the time since installation, how coatings perform under different types of load, the interaction between the floor material and the installation environment, etc.

Another key differentiator between labelling schemes is how strict their SVOC and VOC requirements are. Two of the strictest are the German Blue Angel label and the Austrian Umweltzeichen, which cover many of the requirements listed above. Other European labels, e.g., the German AgBB scheme or the French labelling system (class A+), are based on less strict emissions requirements and do not exclude the use of toxic substances such as halogenated organic compounds (15).

All products should at least meet the legal EU or national minimum requirements (whether obligatory or not). Unfortunately, the actual requirements differ from country to country. For instance Germany requires AgBB certification as part of the Ü-mark process that is a condition for any building product wishing to enter the German market. In other European countries such basic regulations do not as yet exist. Only in France has a labelling system been introduced, one that requires the classification of all building products according to emissions classes. This system will become obligatory for all products on the French market in 2013. Emission limits between country systems also differ. A weakness of the German certification requirements is the relatively high permitted values of formaldehyde, while France has much stricter limits for these.

The conditions under which tests are performed are also of considerable relevance. This is especially true for VOCs and SVOCs emitted from PVC. One series of tests performed on six PVC materials and four adhesives showed significantly higher emission rates on site when compared to laboratory conditions. Alarmingly some of this tested material had been awarded the Finnish M1 ecolabel (16).

Key criteria: sustainable hygiene, cost effective life and comfortable safety

We have grouped key criteria into three sections as they tend to be related to each other. Criterion one, sustainable hygiene, is the most important consideration here, as a material that is toxic and has a high environmental impact should be excluded from any further consideration. Criterion two, cost-effective life, is traditionally considered the most important decision criteria as most facility managers endeavour to install flooring that is durable and cheap. However, cost considerations are liable to depend on what is defined as a ‘cost’ and it is essential to consider overall life cycle costs (installation, maintenance, longevity of material, repairability), rather than just initial installation costs. Finally criterion three, comfortable safety (i.e., a material that is comfortable underfoot, has good acoustics and is slip resistant) depends to some degree on the exact nature of the healthcare environment that is being considered.

GREEN WASHING - IS THIS FLOOR REALLY GREEN?

Green washing, or the attempt to advertise materials as 'environmentally friendly' in a misleading manner, is a common tactic. For example, a flooring material may be sold as 'green' because it uses natural raw materials instead of synthetic ones. What may be unspoken (for example) is that toxic chemicals could be used to process the natural raw materials, resulting in the same output of harmful and toxic chemicals as for 'conventional' flooring. Another apparently green credential may be a statement that the product uses recycled materials. However, this statement may omit the fact that these recycled materials are not suitable for indoor use due to their toxic components.

Green washing can often be recognised by the use of non-specific terms like 'all-natural', 'green', 'eco-friendly', or 'non-toxic', etc., without providing solid evidence such as an ecolabel. Another ploy is to highlight one small area of improvement in a product, without proof that the new alternative is safer or that the overall product has become more sustainable.

CRITERION 1 - SUSTAINABLE HYGIENE

The ability to keep the floor in a clean and hygienic condition is possibly the number one criterion in the healthcare environment. We have coined the term 'sustainable hygiene' to indicate that hygiene needs to be maintained efficiently over the lifetime of the flooring with the lowest possible environmental impact.

CLEANABILITY

Hygiene is of utmost importance in any healthcare environment and hence flooring must be easily and effectively cleaned. How often and what intensity of cleaning is required depends on the particular room usage. When considering cleanability, the use of harsh or toxic chemicals must also be kept in mind, in order to reduce patient and worker exposure to these.

SURFACE CHARACTERISTICS

Many resilient floor coverings are traditionally covered with polymer coatings (polyurethane or acrylic) to facilitate daily cleaning and maintenance. Mostly these are applied directly in the production process rather than by using the more costly option of regular application after installation during maintenance. While marketed as 'life-long', these coatings have been shown to need repair and additional care during cleaning. Cleaning may create further chemical emissions from cleaning fluids, consume large amounts of water and cause further problems with respect to the safe disposal of chemically polluted waste-water.

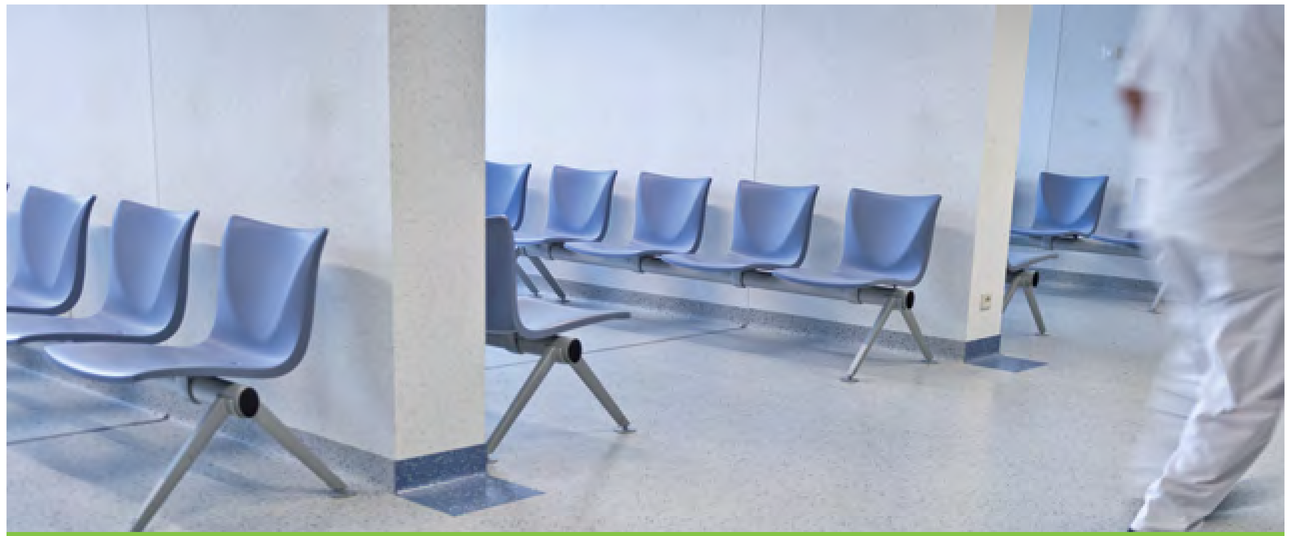
Preference should be given to a floor that does not need coatings to be applied during manufacture or when in use as this maximises ease of maintenance. It should also offer the ability to use green cleaning agents without the need for additional protective measures such as harsh chemical cleaners, waxes and other floor cleaning products that may be sources of indoor pollution. Ideally, removal of stains should be easy.

CRITERION 2 - COST-EFFECTIVE LIFE

Rather than using the term 'life cycle cost', we have coined the term 'cost-effective life' to capture the four key aspects of cost: initial cost, durability, maintenance costs and installation issues.

COST

The initial installation cost of flooring is often the major consideration when choosing resilient flooring. However on-going operational costs and hidden costs such as health impacts on staff and patients also need to be taken into account. Life cycle cost analyses of resilient flooring have shown that if the initial cost of a material is low then the costs of



maintaining this material over its life cycle may be very high indeed [17, 18], even without considering hidden costs.

DURABILITY

Most flooring in healthcare environments has to cope with high traffic volume and thus durability is essential. Replacement must occur infrequently to minimise patient care disruption. The typical flooring should last 15-20 years and still be aesthetically pleasing. Some types of resilient flooring such as linoleum or rubber may last up to 30 years or even longer. Indeed, some quality rubber floors have a usable lifetime of 30 to 40 years. Theoretically this longevity should have a positive effect on the overall cost. However, in practice few floors remain in place for that long.

MAINTENANCE

Maintenance can add substantial costs to the overall lifetime cost of flooring [17]. The cleaning process may not only be time-consuming, but may also need to be scheduled at inconvenient times to minimise disruption to patients and staff due to noxious odours. Alternatively whole areas may need to be shut down for extended periods of time. Floor coverings may also need to be repaired more often than initially anticipated, thereby adding additional cost and inconvenience.

INSTALLATION

Installing a floor correctly is a process that requires the consideration of the type of flooring material, experienced installers, use of correct adhesives, knowledge of sub-floor characteristics and sufficient time for proper installation. Problems during installation such as bubbling, adhesion, cracking, discolouration, warping, indentations and poor quality of welded seams [6] may occur with all types of flooring. Therefore the selection of installers and all materials used is critical to the overall success of a project.

A further possible source of toxic emissions is in the floor adhesives. We will not cover these in this report, except to say that ideally a low-emission water-based filler and dispersion adhesive should be used (as specified in the Blue Angel RAL-UZ 113 specifications on adhesives).

CRITERION 3 - COMFORTABLE SAFETY

The final criterion captures ergonomic as well as aesthetic criteria involved in choosing a flooring material.

APPEARANCE AND AESTHETICS

A pleasing and 'homely' appearance has become an increasingly important aspect of flooring choice in the healthcare environment, as an institutional or sterile look may negatively affect patient health. While stain resistance is important in many healthcare settings, a choice of pleasing colours and sometimes the possibility to incorporate signage directly into the flooring may also be important.

COMFORT AND SOUND CONTROL

Ideally flooring should be low-glare as high gloss flooring may induce falling anxiety in elderly people. The floor should also have at least some cushioning effect and absorb noise well. Ergonomic performance of a floor is important to medical staff, who often stand for long periods. The sound absorption qualities of a floor are also important as excessive noise may contribute to stress.

SAFETY

Flooring in healthcare environments needs to be slip-resistant and be able to absorb some degree of impact should a fall occur, a particular consideration in geriatric departments. Cleaning procedures should avoid any likelihood of back injuries or other injuries.

RESILIENT FLOORING CHOICES AVAILABLE IN EUROPE

In Europe, the choice of resilient flooring for the healthcare environment is essentially a choice between PVC, linoleum or rubber. Polyolefin, a material widely available in the US, is currently not commercially available and hence we will not cover its characteristics here.

The options: PVC, linoleum or rubber?

PVC

Polyvinylchloride (PVC, sometimes referred to as vinyl) was the third most widely produced plastic in 2010. Global PVC production was at 32 million tonnes in 2009, and is expected to grow to 55 million tonnes per year in 2020 [19].

PVC flooring, first commercialised in the 1950s, is used either in sheet or tile form. The latter is not used in Europe. It is produced by heating PVC resin with a number of additives – flame retardants, plasticisers to give flexibility, pigments to provide colour, UV stabilisers such as organozinc to protect against degradation by heat and light, mineral fillers to improve its properties and reduce cost.

Areas where PVC flooring is commonly used

Hallways, stairs and stairwells, operating rooms, waiting rooms, patient rooms, lobbies, nurses' stations.

PRODUCTION

PVC resin is composed of vinyl chloride polymers that are produced under high temperature from ethylene (derived from petroleum or natural gas) and chlorine. Numerous additional chemicals are required to facilitate the reaction including various solvents, emulsifiers, antioxidants, surfactants, coupling agents, initiator agents and additives.

PVC uses around 40% of the chlorine produced globally. Chlorine is a co-product of the process that produces sodium hydroxide (caustic soda), the principal strong base used in the chemical and paper industries. It is alleged that PVC use and expansion globally is largely driven by the need to use chlorine [20]. PVC is a major source of dioxins, a persistent environmental pollutant, during production and waste disposal.

PVC also requires the addition of plasticisers such as phthalates to make it softer and more flexible and a number of other chemicals to enhance or produce certain characteristics. Some of the toxic metals, once used during the production of PVC and used as heat stabilisers, have been phased out from PVC production in recent years.

CRITERION 1 - SUSTAINABLE HYGIENE

TOXICITY AND ENVIRONMENTAL IMPACT

There are a number of key toxicity issues relating to PVC flooring across its life cycle that make this type of flooring one of the most unsuitable materials for flooring in the hospital environment. These issues include dioxin formation during production and disposal, the use of phthalates, indoor air pollution and problems with waste disposal and recycling.

PVC PRODUCTION EXPOSES COMMUNITIES AND WORKERS TO TOXIC SUBSTANCES

PVC production may be hazardous to manufacturing workers through exposure to chemicals such as phthalates [20] and intermediate products. Certain chemicals released during PVC production contribute to global pollution by being highly persistent and bioaccumulative [20].

In this context, two intermediates in the production of PVC, ethylene dichloride (EDC) and vinyl chloride monomer (VCM), are also of concern. EDC is classified as a possible human carcinogen and VCM as a known human carcinogen implicated in causing angiosarcoma of the liver [22]. Not only are workers in the industry vulnerable, but also people living adjacent to PVC manufacturing facilities [23]. However, in recent years at least workers are protected by more stringent production methods which have substantially reduced the amount of VCM and EDC released. Accidental releases may still occur [23].

HEAT STABILISERS

Stabilisers are added to protect PVC from damage by heat and light. Historically these have been lead, cadmium and zinc, but cadmium use has been eliminated and lead is increasingly being phased out. Replacements are butyl tin and epoxidised soy bean oil [23].

THE PROBLEMS WITH PHTHALATES

Key ingredients that make PVC flooring functional are plasticisers. These may make up between 10 and 60% of the final product. Phthalates were and are the most common plasticisers used. But plasticisers do not fully bond to the material and hence their movement into the environment is inevitable and from where they may be inhaled or ingested. Phthalates are now found throughout the environment

DIOXINS

Dioxins are formed as an unintentional but unavoidable by-product during the entire life cycle of PVC, i.e., during production, disposal and recycling.

Dioxins are PBT chemicals that have been identified as being highly toxic, potent carcinogens, reproductive/developmental toxicants and endocrine disruptors [21]. Short-term exposure to high doses of dioxin may result in skin lesions and altered liver function, while long-term exposure has been linked to several types of cancer and impairment of the immune system, nervous system, endocrine system and reproductive functions. Dioxins are cited in the Stockholm Convention on persistent organic pollutants (POPs) with a view to worldwide phase-out. Many governments around the world monitor dioxin levels in their populations and environment, especially for dioxins contaminating food [21].

BIO-PLASTICISERS?

The PVC industry has recently begun to introduce a new generation of so called bio-plasticisers as an alternative to phthalates. These are based on natural materials (sugar cane, hydrogenated castor plant oil, citric acid, soya bean oil) which undergo a chemical process to turn them into plasticisers. Removal of phthalates is a positive step in the right direction, if only addressing part of the problem of toxic substances and PVC.

Practical experiences with floorings containing these new bio–plasticisers have as yet not been reported.

globally, including in wildlife and in humans. Recent studies showed that the human uptake of phthalates is clearly related to environmental factors such as building materials and especially PVC flooring (24). Furthermore, once phthalates escape from the PVC, the floors will harden over time and require extra and costly maintenance.

Their detrimental effects are widespread and well known (24), despite concerted denial by the plastics industry (22). Animal studies have shown damage to sexual development in young rats, as well as causing liver cancer. In humans they also appear to impair the male reproductive system (24). It has also been shown that phthalates pose a risk to the management of allergy-related diseases (25).

Common flooring PVC plasticisers such as DEHP (diethylhexyl phthalate) and BBP (benzyl butyl phthalate) have recently been replaced with DIDP (diisodecyl phthalate) and DINP (diisononyl phthalate) to allay concerns about their toxicity (23).
DINP may be implicated as a developmental toxic in animal studies, as well as having well-documented anti-androgenic effects with links to syndromes such as undescended testes and abnormal development of reproductive tissues (26).

Experience with other new generations of phthalate-containing PVC (DINP or DIDP) showed increased reactivity with adhesives and increased shrinkage at joint seals resulting in hygienic risks due to bacterial invasion (27). The practical performance of these new versions of PVC floors still has to be proven. Additionally, these new types of floors come with factory-applied polyurethane finishes that, depending on the thickness of the finish, may wear off rapidly.
Despite the numerous issues with toxic chemicals, the industry however maintains that PVC has 'inherent sustainability related characteristics' (28).

THE MERCURY PROBLEM IS SLOWLY RECEDING

Chlorine, a major ingredient in PVC production, may be produced using a mercury cell process. This process has been a significant source of mercury pollution. Mercury is a neuro- and developmental toxic that can damage the neurological development of children, amongst other health concerns. The PVC industry has responded to the issue by encouraging its producers to switch to a mercury-free and more energy efficient process. In 2010 half of the European production was mercury-free, with phase out of the mercury process to be completed by 2020. Apart from the industry's own efforts, REACH legislation will also force the complete phase-out of the mercury process (21).

OTHER HEAVY METAL USE IN DECLINE

Cadmium-based stabilisers have been largely phased out in line with the industry's own voluntary 10-year target. By 2011 the use of lead-based stabilisers had been reduced, resulting in a 76% substitution with calcium-based stabilisers (29). While the phase-out of cadmium and the slower phase-out of lead is laudable, recycled PVC and PVC that is already *in situ* still contain these metals and will do for many years to come (30). When installing new flooring the disposal of old PVC flooring containing heavy metals needs to be considered.

TOXIC WASTE DISPOSAL

Landfilling has been the predominant method for PVC disposal, but PVC products are very resistant to biodegradation. Landfilled PVC may take in the order of a thousand years to break down (30). However, a significant issue is the fate of additives, especially plasticisers, which may leach out and contaminate groundwater and soil (30). Many EU countries now restrict or prohibit the landfill disposal of flooring materials. The alternative of waste incineration is problematic, as it may result in increased dioxin and halogen emissions (30).

THE LIMITS OF LIFE CYCLE ASSESSMENT

Life cycle assessment (LCA) is a tool to identify environmental impacts of products across most life cycle stages from 'cradle to grave'. It relies heavily on known datasets and assumptions, i.e., it compares impacts based on well understood and quantified flows of materials. It has serious limitations in relation to the analysis of toxicity hazards, especially those with uncertain or unknown data. LCA is not suited to inputs that are not yet well quantified, which are affected by user patterns or which are subject to maximum limits or absolute restrictions. LCA is neither comprehensive nor unbiased and is not complete. Some researchers assert that LCA has hidden biases in favour of materials with key negative environmental health impacts, particularly PBT chemicals [31]. For instance, in an LCA study which compared PVC and linoleum, PVC appears the better environmental performer, because overwhelming weighting was given to the potential of linoleum to promote eutrophication, excess agricultural nutrient run-off, while growing the flax plants to produce the linseed used in the linoleum. Potential health impacts of either material were incompletely or not at all accounted for [32].

LCA has limitations and should not be relied on to give definitive answers when choosing between PVC and its competing materials.

IS RECYCLING PVC A GOOD IDEA?

Post-consumer recycling rates of PVC materials (building materials, pipes, cables, car parts, etc.) were traditionally very low in Europe (<3%). The industry responded by establishing Vinyl2010 in the year 2000. The organisation's purpose is to increase and monitor PVC waste management. In 2011 Vinyl2010 stated that recycling had increased from around 40,000 tonnes of post-consumer PVC waste in 1999 to just over 260,000 tonnes in 2010, a significant increase [29]. However a closer inspection of the annual figures reveals that, while overall PVC recycling had increased significantly, the proportion taken up by PVC flooring was very small – less than 1% of the PVC recycling in 2010.

While the concept of recycling waste material is in principle a sensible idea, in practice there are a number of issues to consider. PVC contains a wide range of additives as discussed above and depending on the recycling method used these may be released and become toxic to the environment, or these may have to be removed and disposed of responsibly. If the recycling involves heating, volatile and toxic compounds may escape into the air. PVC recycling may also use various ancillary reagents (detergents and flocculants), which may contaminate the environment [33].

A key issue to consider with recycling is the issue of toxic additives being spread into new products. It is for this reason that the Blue Angel label permits no recycled content in any material.

CRITERION 2 – COST-EFFECTIVE LIFE

An important factor in overall cost is the cost of maintenance of a floor. PVC needs a lot of maintenance, including stripping and waxing, which is time-consuming and costly. Additionally the area to be cleaned may need to be shut off and the process scheduled overnight to minimise the disruption to patients and staff from the noxious fumes from the chemicals used in the process [6].

To minimise daily maintenance, higher quality PVC is coated with polyurethane in the factory, but this coat needs to be renewed after several years. This is costly as whole departments may have to be closed for floor renovation. Alternatively, costly non-permanent coatings may be applied as well and are usually maintained with a relatively expensive cleaning method.

Undoubtedly for many healthcare facilities the initial lower cost of PVC is extremely attractive. But when installing flooring it is important to look beyond this. While vinyl is typically the cheapest of all flooring options, maintenance costs can be 9-15 times the costs of installation [17]. Additionally the introduction of new types of plasticisers and coatings may result in lower durability and unexpected repair issues [27].

CRITERION 3 – COMFORTABLE SAFETY

While PVC flooring has an attractive appearance, it can be noisy, lack underfoot comfort, and, as mentioned above, needs frequent cleaning and waxing when coatings are worn off [5].

VERDICT ON PVC

In our view, PVC flooring should not be used. There are many disadvantages and no advantages apart from the initial low cost. No PVC flooring product can possibly achieve the Blue Angel certificate as it is impossible to eliminate chlorine, dioxins and many of the other toxic substances associated with its production.

Case Study 1:
Antwerp University Hospital, Belgium

RUBBER FLOOR COVERINGS REPLACE PVC

Founded in 1979, Antwerp University Hospital (Universitair Ziekenhuis Antwerp, UZA) is a modern and efficient general hospital that provides a full range of care facilities. With its 573 beds, every year around 26,200 inpatients and almost 30,000 outpatients are treated here and about 17,000 operations performed. In 1996 the hospital decided to gradually replace the old PVC coverings. After testing a range of different resilient floor coverings a high quality rubber flooring was chosen. The rubber flooring can now be found in all parts of the hospital, including in the operating theatres, patients' rooms, accident and emergency department, MRT and x-ray rooms, laboratories and corridors as well as in the administration wing.

HYGIENIC FLOORING WITH JOINT-FREE INSTALLATION

The purchased floor coverings do not contain any plasticisers. This not only results in a lower environmental impact but also means that they remain dimensionally stable and do not shrink, hence no joint-sealing is required. This in turn allows the floors to be disinfected more effectively according to the hospital's technical director. The claim is confirmed by tests which are regularly conducted by hygienists at the request of the hospital operator. Rubber floor coverings are also insensitive to stains and resistant to surface disinfectants, solvents, diluted acids and sodium hydroxide. Iodine-containing substances can be easily removed as well. Another advantage of a joint-free installation is the uniform appearance of the floor area.

NO COATING REQUIRED, EASY AND ECONOMICAL TO CLEAN

In contrast to other resilient coverings, quality rubber flooring does not require any extra coating or lacquering. This means that it does not suffer from wear, ingrained dirt, chipping, scratches or discolouration of the coating.

IDEAL INSULATION FOR FOOTFALL NOISE

Another aspect which plays a key role for the hospital is the excellent footfall noise absorption of rubber floor coverings. Consequently, a quiet atmosphere prevails in those areas of the hospital that are fitted with rubber floor coverings in spite of the heavy public traffic. Alongside the acoustic benefits, the ergonomic qualities of rubber coverings are also advantageous for patients and staff. Due to superior elasticity the rubber floor is more comfortable for staff who are often on their feet for long periods and is kinder on patients who have difficulties in walking and standing.

TIPS FOR PROCUREMENT OF HEALTHIER RESILIENT FLOORING

When procuring resilient flooring, whether for a renovation project or for a new installation, it is important to be very specific about the desired material. Here are some tips and questions to ask:

- Investigate which flooring is the most suitable on the basis both of environmental impact and of other factors such as cost and intended use.
- Identify your needs and specify them via clear and precise technical specifications, using environmental factors where possible (with pass/fail conditions).
- Specify conditions with reference to eco-certification standards.
- Require best practice of all contractors.
- Include environmental performance parameters, such as the use of raw materials, sustainable production methods, energy efficiency, emissions, waste disposal, recyclability, use of toxic chemicals, etc.
- Establish selection criteria based on your specifications.
- Use contract performance clauses to set relevant and extra environmental conditions.

A useful guide is the European Commission's booklet 'Buying green! A handbook on environmental public procurement' [34].

Linoleum

Linoleum was first developed in 1855 and became the floor covering of choice until the 1960s for high-use areas. It was largely replaced by PVC but has recently started to make a comeback. It is largely made of renewable materials and is biodegradable.

In residential applications, traditionally linoleum has been used in kitchens. Commercially, linoleum has been popular for areas subjected to extremely high foot traffic, such as bus stations, airports and schools as well as hospitals and art galleries. It has good resistance to gouging, good acoustical dampening properties and overall durability.

Appropriately ecolabelled linoleums are available (see Appendix 3 for more detail), but as always it is important to obtain a high quality product.

PRODUCTION

Traditionally linoleum was made from dried milled flax seed and limestone, mixed with other plant material (pine rosin, wood flour, ground cork) and pigments. Flax seed is now commonly replaced by tall oil, a by-product of pulp and paper milling. Traditionally linoleum also has a jute backing. It requires the application of adhesives during installation. Ideally the adhesive should also be eco-certified to avoid possible air quality problems.

CRITERION 1 - SUSTAINABLE HYGIENE

TOXICITY AND ENVIRONMENTAL IMPACT

One of the key issues with linoleum is that harsh chemicals cannot be used on it. While on some level this is an advantage as it results in gentler cleaners being used, it also means that maintaining a strict hygiene regime can be challenging [6]. Other environmental advantages of linoleum are well known. It is anti-static and will repel dust and other small particles and hence has hypoallergenic properties. It is made of renewable materials, is 100% biodegradable and no PBTs are used or released during its manufacture or life time [6].

While the flax seed, used as an ingredient in linoleum, is renewable, it is important to consider how the flax is grown. Considerations include whether it has been treated with pesticides or herbicides during its production and if so which. Commonly used herbicides include the PBT trifluralin (a carcinogen, endocrine disruptor and aquatic toxicant), the fungicide mancozeb (a carcinogen and endocrine disruptor), bromoxynil (developmental toxicant) and the insecticide trichlorfon (neurotoxicant). Ideally, flax seeds cultivated without toxic chemicals would be used. How realistic this demand is, given the relatively high price of organic flax seed (used chiefly for human consumption), is another matter altogether. We are not aware of such a product being available.

The use of tall oil or liquid rosin (a by-product of wood pulp manufacture from mainly coniferous trees) in lieu of flax seed, may also introduce a number of potentially hazardous chemicals into the chain such as benzene (slowly being replaced with n-butane), acetaldehyde and formaldehyde used in the pulping industry [2]. Again ideally the trees themselves should be produced sustainably, without toxic pesticides, etc. Dust may be a problem during manufacture and without proper precaution may lead to bronchial and dermal irritation in workers [2]. Because linoleum is naturally fire resistant, it does not require the addition of flame retardants.

INDOOR AIR QUALITY ISSUES

Indoor air quality issues may arise due to the adhesives used during installation. Linoleum itself may produce an unpleasant odour as a result of the oxidation process of the linseed. Aldehydes are released during this process, and while these are partly responsible for the anti-bacterial, fungicidal properties of the floor, they may also have detrimental effects on human well-being and health ranging from an unpleasant smell to headaches, coughs and dermatitis [35].

To overcome the problems of these odours linoleum may be coated with UV-cured polyurethane or polyacrylates. While this treatment also improves resilience and reduces maintenance, it comes with its own toxicity problems. In recent times manufacturers have started using less odorous linseed varieties [2].

SUSTAINABILITY

Eighty percent of linoleum is made from renewable resources or post-industrial recycled material (wood flour, tall oil). While renewability of the resource is one consideration, how the renewability is achieved is also important. For example, the type of agricultural/forestry production methods used, the overall impact of the production on the environment and its inhabitants (humans and otherwise).

Life cycle assessment studies of linoleum frequently cite eutrophication of water (caused by agricultural runoff) as a key negative effect of linoleum production. However, sustainable farming practices can solve this issue, as well as the pesticide toxicity issues discussed above [36].

End-of-life options for the disposal of linoleum include incineration, landfill or recycling. The most common option for linoleum is landfill, where it decomposes safely into mostly benign substances (depending on the adhesives used). It is also possible to compost linoleum, but this is still quite rare and includes the challenge of adhesive removal (which is also required for recycling options).

CRITERION 2 – COST-EFFECTIVE LIFE

COST, DURABILITY & MAINTENANCE

Linoleum is less expensive than other resilient flooring options [6], but has a number of costly maintenance challenges. Overall, when PVC, rubber and linoleum are compared in terms of life cycle cost, linoleum incurs rather low initial costs but higher life cycle costs, driven by the need to apply protective polyurethane (PU) or acrylic coatings. These coatings may come with either a UV-hardened surface or water-based protection. Water-based coatings require additional protection at least once or twice a year, resulting in extra costs. UV-hardened PU-based coatings may crack under direct load (e.g., castors) or will be worn off by intensive foot traffic or cleaning [18]. Also, over time, welded seams may come apart, requiring repair. Often, damaged PU coatings are repaired with reactive two-component PU coatings that do not show the same characteristics as the original UV-hardened

Areas where linoleum is commonly used

Hallways, waiting rooms, patient rooms, lobbies, nurses stations.

Linoleum is not recommended for treatment rooms or operating theatres due to potential moisture problems (it cannot be flooded for cleaning) and is also susceptible to staining with iodine [6].

coating or they are simply covered with temporary polymer protections that need annual renewal and costly maintenance.

INSTALLATION

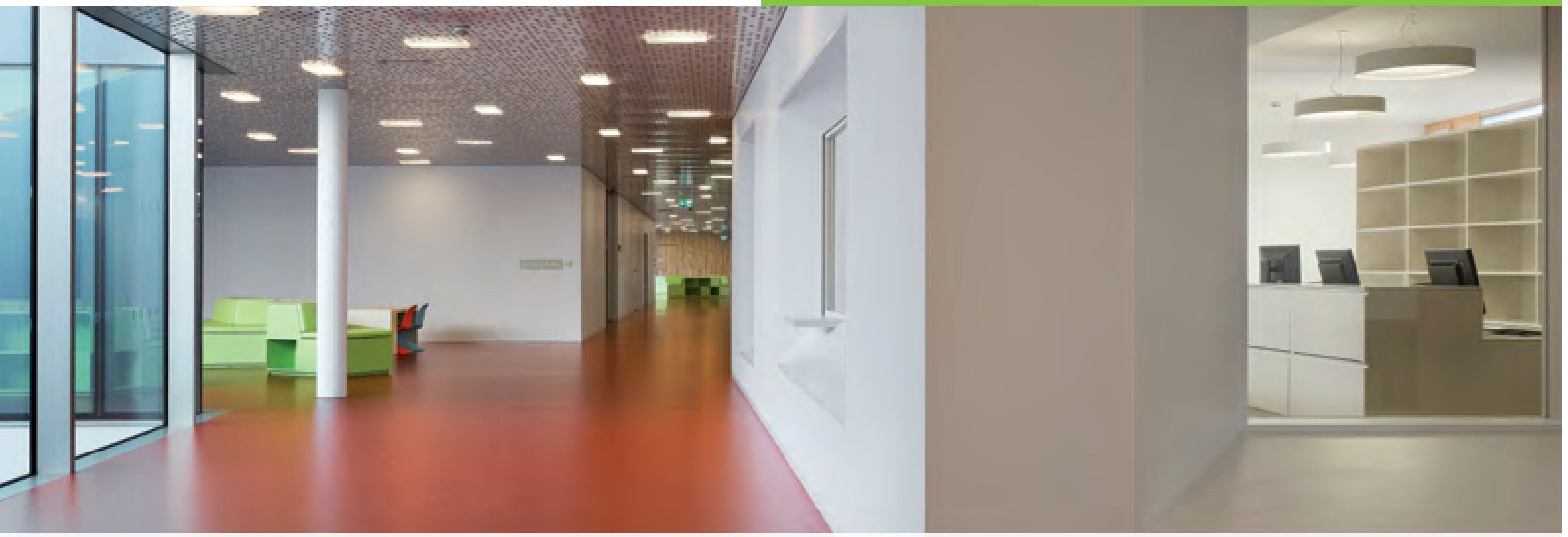
Key installation problems with linoleum include bubbling, shrinkage and discolouration. Linoleum may also not be suitable for time-critical renovation projects as it cannot withstand heavy traffic for 72 hours after installation [6].

CRITERION 3 – COMFORTABLE SAFETY

Linoleum provides a natural colourful look that is relatively soft and quiet underfoot. The ability to use a variety of patterns and designs can also be useful in certain environments such as paediatric areas.

VERDICT ON LINOLEUM

Linoleum may present an attractive option in many situations, especially as initial costs are rather low, but it is unsuitable for certain conditions such as infection control. However, product quality and repairability may pose serious challenges [6]. A number of available linoleum floorings have achieved certification by the Blue Angel or Natureplus ecolabels (see Appendices 3 and 4). The latter requires a very high percentage of natural content.



Rubber flooring

Apart from linoleum, rubber flooring is the most widely used alternative flooring to PVC flooring [6]. Until the beginning of the 20th century, rubber floors were chiefly manufactured from natural rubber until difficulties in supply resulted in the development of synthetic rubber. The first and still most commonly found synthetic rubber is styrene butadiene rubber (SBR), but today other formulations such as polybutadiene, ethylene propylene (EPDM), acrylonitrile-butadiene (NBR, also called nitrile rubber), polychloroprene (also called neoprene), synthetic polyisoprene, silicone and ethylene vinyl acetate (EVA) are also available [2].

Natural rubber flooring is also again being made and used. It is made from the sap of mature rubber trees (*Hevea brasiliensis*) and is ideally supplemented by raw mineral materials extracted from natural deposits and coloured by pigments produced in an environmentally sustainable fashion. Some manufacturers use a mix of synthetic and natural rubber to produce rubber flooring e.g., 1/3 natural rubber, 2/3 SBR, as well as naturally occurring minerals that are opencast mined in Germany [35].

Rubber flooring is hard wearing and relatively resistant to fire. It is suitable for very high traffic areas and can be made slip resistant. Maintenance requirements are very favourable if the right quality is chosen, requiring no waxing or buffing. These floors have good acoustic properties (low noise) and are comfortable underfoot due to the inherent resilience of rubber.

Areas where rubber flooring is commonly used

Hallways, stairs and stairwells, operating rooms, nurses' stations, patient rooms.

Depending on the quality of the rubber flooring there may be problems with indoor air quality and it is essential to choose a rubber floor with an appropriate ecolabel. For instance if the floor contains recycled rubber, air quality issues may become a serious problem (see Case Study 2 below).

PRODUCTION

Synthetic rubber is produced from petroleum or petroleum by-products. Similarly to PVC, it requires numerous additional chemicals as intermediates and additives, including catalysts, polymerisation accelerants and stoppers, solvents, emulsifiers, antioxidants, surfactants, coupling agents, initiator agents and modifiers.

Flooring products made entirely from natural rubber may be available, but it appears these products are not used in the healthcare sector [2].

CRITERION 1- SUSTAINABLE HYGIENE

The production of synthetic rubber flooring does not require plasticisers and no amounts of dioxins are released during production. However the actual production of synthetic rubber, especially SBR flooring, can contain significant amounts of other PBTs, including lead, mercury and polycyclic aromatic hydrocarbons.

Flame retardants may also be used as additives in SBR and other rubber floors. Rubber floors may also include PBTs known as possible carcinogens, endocrine disruptors and aquatic toxicants. End-user exposure may include flame retardants and residues of styrene, a possible carcinogen, likely neurotoxicant and endocrine disruptor. Depending on the quality of the rubber flooring indoor air quality may be a problem.

SBR is manufactured from styrene, possibly carcinogenic, and 1,3-butadiene, a known carcinogen. As noted above, many additional chemicals are needed as intermediates and additives.

Mercury can also be a serious problem in rubber flooring as it can be used as a catalyst in the manufacturing process. SBR plants may release many

thousands of highly toxic chemicals into the air and workers and communities may be exposed to an increased risk of leukaemia and heart disease. Chemicals released may include hazardous lead, mercury, acrylonitrile, ethylbenzene, benzene and other toxicants [11].

How much of these toxic by-products is released depends very much on the production facilities of the floor manufacturers as well as of the manufacturers of the raw materials and their capabilities to produce a very high quality product. As always eco-certification is helpful in discerning which rubber flooring has the least toxic by-products or contains the least toxic materials. Blue Angel certification is reliable in most aspects. However, some municipalities in Germany and their scientific advisors have pointed out that permitted styrene emission levels should be in line with the recommendations of the German Indoor Air Hygiene Commission (IRK) criteria and thus be considerably lower [28]. Ideally the manufacturer should also state what results have been achieved according to the guidelines for indoor air quality using, for instance, the German IRK criteria [37].

A particular note of caution must be reserved for rubber flooring containing post-consumer recycled content. This consists largely of tyres and may contain significant amounts of toxic materials and makes its use unsuitable for interior environments.

WASTE DISPOSAL

Rubber flooring waste disposal can be problematic, especially with SBR. Most rubber flooring is destined to be landfilled or to be incinerated. Currently no studies are available on potential toxic chemicals that may be emitted, but given the ingredients in SBR rubber a number of problematic chemicals can be expected [2].

Some flooring manufacturers practise systematic reuse by utilising factory waste such as cut edges, sanding dust, etc., to produce other products. They may also offer to take back cutting waste, packing and old flooring (if purchased from them). These measures are possible only if the waste rubber does not contain halogens or other toxic substances.

Unlike old tyres, these waste rubber floorings are designed for indoor use and hence can be continued to be used indoors [40].

Rubber floors with suitable eco-certification such as Blue Angel and the Austrian Umweltzeichen are certified not to contain these chemicals and may be disposed of safely. They are readily accepted for incineration as they do not contain halogens; additionally incineration costs are lower than for PVC.

CRITERION 2 - COST-EFFECTIVE LIFE

Rubber flooring, depending on type and quality, can have a long life expectancy and while the cost may initially appear higher than for other flooring materials this may be offset by savings in maintenance and repair, as well as in an improved environment for staff and patient health [6].

Quality rubber flooring has the advantage of easy maintenance, requiring no waxing and stripping and no harsh chemicals. Floors can also be cleaned while they are occupied, minimising disruption for staff and patients. Rubber floors are relatively non-staining, suffer from fewer colour abrasions and have minimal or no shrinkage [6].

There are many different qualities of rubber floorings on the market, so it is essential to check and evaluate the choices carefully before purchasing to ensure they will perform to the highest possible level. Additionally it is vital to provide exhaustive tender specifications, including all relevant criteria in relation to sustainability, floor performance, cleaning requirements, etc.

CRITERION 3 - COMFORTABLE SAFETY

Rubber floors have excellent acoustics and are comfortable underfoot for long periods. They do not produce glare and are non-slippery when wet [6].

VERDICT ON RUBBER

Rubber flooring's potential for low or high toxicity very much depends on how it is manufactured and what ingredients are used. Some rubber floorings clearly have a very high toxic potential, but at the other end of the spectrum some manufacturers have achieved the Blue Angel ecolabel and additionally could give results according to guidelines for indoor air quality such as those of the IRK.

When choosing rubber flooring it is essential to choose wisely, for example avoiding rubber flooring containing recycled tyres, and focus on rubber flooring with appropriate eco-certification.

Case Study 2:
Choosing the wrong floor can be expensive!

When in 2004 the German Federal Environment Agency (UBA) decided to build a new headquarter in Dessau it was to be a paragon of sustainability. The aim was to use only materials that in terms of production, transport, use and waste would have the highest possible health and environmental credentials.

The Agency decided on rubber flooring – 18,600 m² of it. An Italian manufacturer was chosen, partly to keep initial costs to a minimum and perhaps with the idea that some of the flooring was made from recycled material and appealing in terms of sustainability.

After only a few weeks it became clear that the flooring did not perform as expected and it had to be removed. Measurements showed that naphthalene in the air was three times above the AgBB criteria, while levels of 1,3 dichlorpropanol, a toxic organochlorine compound, were 22 times above EU permitted limits.

Further investigations revealed that the recycled material used for the acoustic dampening layer was made from old car seats that contained toxic flame retardants.

The Agency took the suppliers to court and lost. It was clearly a case of buyer beware. Unfortunately the Agency had failed to specify sufficient details in the tender's key requirements (as stipulated by the European tender laws for public procurement).

Perhaps the only good news is that the Agency did not give up on rubber floors. They made sure that the next flooring material (even though much more expensive initially) had the appropriate eco-certification.

Source: Däumling 2012 [39]

Which flooring to choose?

When choosing resilient flooring it is essential to choose wisely, for example avoiding rubber flooring containing recycled tyres, and focus on rubber flooring with appropriate eco-certification.

Given the various environmental and health characteristics of resilient flooring in the healthcare environment, the ideal resilient flooring is non-toxic throughout its life cycle, practical (hygienic, easy to clean), and durable, safe, silent underfoot, pleasant visually and cost-effective. While this ideal material does not exist at present, some of the flooring choices available today come fairly close.

Table 2 summarises the key characteristics of the three flooring materials and our recommendations.

PVC flooring should be avoided

In brief, we believe that PVC flooring should be avoided because of the toxic chemicals involved in its manufacture and disposal and maintenance problems. It is less comfortable than either linoleum or rubber.

Linoleum may be suitable for many areas

Linoleum avoids the issues of halogens and dioxins but air quality can still be an issue. Linoleum may be suitable for many areas, but it is not recommended for treatment rooms or operating theatres due to its potential for moisture adsorption. Maintenance and staining may also be a problem.

Rubber flooring, if chosen with an appropriate ecolabel ... offers the best opportunity

Rubber flooring, if chosen with an appropriate ecolabel such as Blue Angel and of appropriate surface quality, offers the best opportunity to combine reduced maintenance costs, very good hygiene characteristics, acoustics and comfort.

Low quality rubber flooring should be avoided

Finally, key considerations when choosing particular floorings are installation and maintenance requirements. Flooring is part of a building system and it is important to use compatible and environmentally sustainable materials , low-toxicity adhesives, appropriate sub-flooring, etc. The installers should be experienced in installing the system. Depending on the flooring installed it will also be important to fully brief the maintenance personnel on maintenance routines, especially if the new floor is different from the previously installed floor.

Case Study 3: Clinique Pasteur, Toulouse, France

Clinique Pasteur in Toulouse decided to approach re-flooring their 80,000 m² atrium pragmatically yet with an eye to introducing sustainability concepts into their hospital environment. The key criteria here were balancing costs versus durability and ease of cleaning. Air quality issues were also at the forefront of the thinking, with a specific aim to achieve air quality levels of VOCs less than 300 μg/m³. The resulting decision was for a high quality German rubber floor with Blue Angel certification. The choice has been enthusiastically received by staff and patients alike.

The key to this approach was to make everyone—employees, doctors and patients—feel involved and responsible for the introduction and implementation of green practices and sustainable changes.

Clear criteria for an environmental management system (ISO 14001 certification in 2011) and a policy of green procurement are two of the tangible cornerstones of Clinique Pasteur's approach. The commitment to green practices extends to a number of areas and the hospital is enthusiastically taking part in the carbon footprint reduction campaign 'Two For Ten'. This campaign aims to reduce carbon emissions by 2% every year for 10 years. Water consumption has also been successfully reduced by 37% and infectious waste by 25%.

Table 2: Evaluation criteria for PVC, linoleum and rubber resilient flooring

CRITERIA	PVC	LINOLEUM	RUBBER
Manufactured without hazardous chemicals	impossible	possible	possible
Free from indoor air pollution problems	no	some	partially or yes
Free from pollutants that may interfere with product recycling	no	some	partially or yes
Free from plasticisers	no	yes	yes
Free from halogenated organic compounds	no	yes	partially or yes
Hygiene potential	high	medium	high
Life cycle cost	medium – high (depending on quality)	high	low
Maintenance	manageable	manageable	easy with high quality flooring products only
Slip resistant	yes	yes	yes
Good acoustics	no	limited	yes
Comfortable	less so	yes	yes
Free from glare	dependent on surface treatment	dependent on surface treatment	yes
High quality eco-certified product available	no	yes	yes
Recommended?	no	yes, in particular situations and conditions and if it carries suitable eco-certification	yes, if quality is high and it carries suitable eco-certification

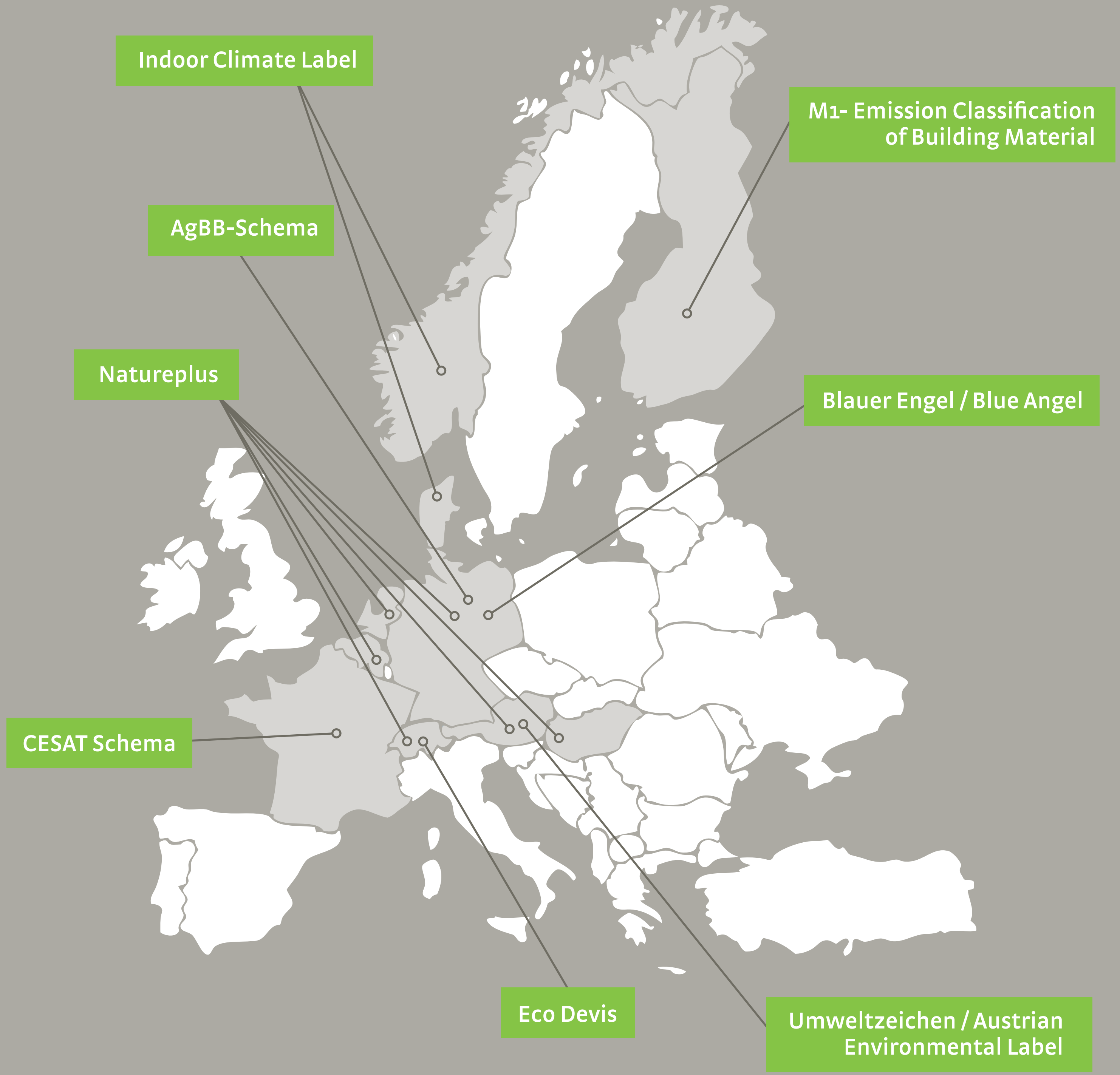
Appendix 1
Relevant EU legislation

Under EU law all floor coverings are classified as building materials and subject to building regulations. Considering the need for low environmental impact and sustainability the following EC legislation is also relevant:

- EC Directive 89/106/EEC on construction products.
- Regulation EC/1907/2006 on the Regulation, Evaluation, Authorisation and Restriction of Chemicals (REACH).
- Regulation EC/1272/2008 on classification, labelling and packaging of substances and mixtures (substances that are considered to be toxic, carcinogenic, mutagenic and/or teratogenic as well as toxic for aquatic organisms or hazardous to the ozone layer).
- EC Directive 98/8/EC on biocidal products.
- Regulation EC/850/2004 on persistent organic pollutants.
- DIN EN 14041 for floor coverings, a European standard which specifies the health, safety and energy saving requirements for resilient floor coverings manufactured from plastics, linoleum, cork or rubber.

In Germany, flooring is subject to approval by the German Institute for Building Technology (DIBt) via the 'Ü-Zeichen', as well as the EC Directive 89/106/EEC and the German Bauproduktengesetz (construction products law). The AgBB-Schema is a key element of this framework and in the context of resilient flooring is mainly concerned with test-chamber measurements of VOC and SVOC emissions from building products. The assessment rating takes account of substance concentrations and harmful properties. Importantly some of the Blue Angel label emission standards are more stringent than those of the AgBB-Schema.

Appendix 2:
European indoor emission labelling schemes



Appendix 2:
European indoor emission labelling schemes

EU MEMBER STATE	LABELLING / CERTIFICATION	LEGAL STATUS	CRITERIA
Denmark & Norway	Indoor Climate Label www.dsic.org/dsic.htm	Voluntary, but supported by government.	The tests focus on VOC emissions and release of particulate matter.
Germany	AgBB-Schema www.umweltbundesamt.de	Tied to the legal requirements relating to building codes.	Criteria for testing and an evaluation scheme for VOC/SVOC emissions. Not as stringent in some areas as the Blue Angel system.
Germany	Blauer Engel / Blue Angel Ecolabel www.blauer-engel.de	Voluntary, but supported by government agencies. The German Institute for Quality Assurance and Labelling (RAL) awards the Blue Angel on behalf of the Federal Environmental Agency.	Tested for substances and materials used during the manufacturing process, transport, use, disposal of used floor coverings. Not permitted are chemicals on the REACH 'candidate list', phthalates, N-nitrosamines, halogens, restricted use of flame retardants. Indoor air quality is tested.
Finland	M1- Emission Classification of Building Material www.rts.fi	Voluntary, but supported by government agencies.	The emission classification has three grades: M1 (best), M2 and M3 (higher emission rates).
France	CESAT Schema www.cstb.fr	Voluntary, but supported by government agencies.	Tests for VOCs, formaldehyde and odour emissions. Total VOCs permitted are very high when compared to other schemas.
Austria	Umweltzeichen / Austrian Environmental Label www.umweltzeichen.at	Voluntary, but supported by government agencies.	Harmonised with Blue Angel label.

Adapted from ECA Report No 24 (15) and Natureplus criteria (41).

EU MEMBER STATE	LABELLING / CERTIFICATION	LEGAL STATUS	CRITERIA
Austria, Belgium, Germany, Hungary, Netherlands, Switzerland	Natureplus www.natureplus.org/en/current-news/home/	Voluntary, awarded by an association whose members include manufacturers, retailers, consumer and environmental organisations, planners, consultants, users and testing laboratories.	Only linoleum products are covered; requirements are a minimum of 85% natural ingredients.
Switzerland	Eco Devis www.eco-bau.ch	Voluntary	Uses life cycle assessment methodology.

Appendix 3: Summary of Natureplus RL1201 criteria for linoleum floor coverings

REQUIRED

- 98% of materials must be renewable raw materials and/or minerals.
- Any protective surface-coating materials containing acrylates must be renewable, and must not negatively affect the natural properties of the linoleum.

NOT PERMITTED

- The use of arsenic, lead, cadmium or mercury compound additives, including as catalysts or colour pigments is not permitted.
- The use of organic halogen or cobalt compounds is not permitted.
- Surface-coating materials must be free of aromatics (≤ 0.1%) and free of tensides based on alkylphenol ethoxylates (APEO). (APEOs are synthetic surfactants used in some detergents and cleaning products.)
- The use of colourants that might release carcinogenic aryl amines, as per the German Food and Commodities Ordinance, Appendix 1, No. 7 (BGVO).
- Biocides (e.g., triclosan).
- Synthetic pesticides/herbicides containing active ingredients which are:
  - prohibited according to the German Prohibited Chemical Substances Regulations (GefStoffV) or according to the Stockholm Convention on Persistent Organic Pollutants;
  - environmentally dangerous according to the German Prohibited Chemical Substances Regulations (GefStoffV);
  - those in Class 1 according to the World Health Organisation (WHO) or classified as carcinogenic, mutagenic or detrimentally affecting fertility (CMR Cat 1-3 according to TRGS 905 (German Technical Regulations for Dangerous Substances).

LIMITS

- Any titanium dioxide used must have been produced in accordance with Directive 92/112/EEC.

ODOURS

- The product must not exhibit any unpleasant or foreign smells or odours. It must be a very low-emission product.

Adapted from Natureplus criteria (41)

Appendix 4: Blue Angel criteria for floor coverings

PRINCIPLES

- Environmentally friendly manufacturing processes;
- No health concerns for the indoor living environment;
- Does not contain any pollutants that may interfere with product recycling.

NOT PERMITTED: HAZARDOUS SUBSTANCES

- Very hazardous substances: carcinogenic, mutagenic and/or toxic to reproduction in Categories I and II of REACH legislation;
- Persistent, bioaccumulative and toxic substances (PBT);
- Very persistent and very bioaccumulative substances (vPvB).

NOT PERMITTED: HEAVY METALS

- Non-essential heavy metals: lead, cadmium, mercury.

NOT PERMITTED: CERTAIN OTHER SUBSTANCES

- No plasticising substances from the class of phthalates may be used in the manufacture of floor coverings;
- No halogenated organic compounds (e.g., as binders or flame retardants) may be used in the manufacture of resilient floor coverings.

NOT PERMITTED: RECYCLED/WASTE MATERIALS

- The use of recycled materials for the manufacture of floor coverings shall not be permitted except:
  - waste wood - Category A1 according to the Altholzverordnung (German Waste Wood Ordinance); and
  - waste paper grades 1.02 and 1.04 according to EN 643.

LIMITS

- The contribution of floor coverings to the content of VOCs in the indoor air in an average-sized living room with an air change rate of 0.5 per hour after 28 days limited to 300 µg/m³.
- Carcinogenic N-nitrosamines according to German standard TRGS 5527. May not be detectable in rubber-based floor coverings (detection limit: 3.6 µg/kg, determination limit: 11 µg/kg).

PERMITTED

- Flame retardants: inorganic ammonium phosphates, other dehydrating minerals (aluminium hydroxide or the like) or expandable graphite.

Adapted from RAL-UZ 120 (42)

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We collaborate with doctors, nurses, hospitals, healthcare systems, professional associations, NGOs, governments and international organisations to promote the development and implementation of safe and environmentally healthy practices, processes and products in the healthcare sector.
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