An Investigation into the Potential for PVC Reduction in Building Floorings

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ABSTRACT

The University Of British Columbia (UBC) is one of the leading universities in North America and around the world in the pursuit of campus sustainability. UBC's SEEDS (Social Ecological Economic Development Studies) Program started in year 2000. It is currently western Canada's first student and faculty member collaborative program to find workable solutions to real life sustainability issues affecting the campus.

This report will look at the controversial use of PVC based floorings in the campus and a potential alternative that can be used to replace it. PVC has long been a stable product to use for building construction, piping and flooring due to its wide range of attractive properties and cheap cost. However, PVC has been known to degrade over time and leached out chlorine particles into the surrounding areas, contributing to potentially unsafe environmental conditions. The alternative chosen to be compared to PVC will be linoleum. These two types of flooring will be assessed based on a triple bottom line assessment.

The triple bottom line assessment compares and grades the suggested materials based on environmental, economic and social aspects. The scope of this report will only extend to looking at flooring replacements in residential and institutional use areas in the UBC campus. This excludes the food sector areas as they require different criteria of flooring requirements.

Through comparing the assessment of both materials, it is evident that PVC contributes the most to harmful environmental pollution during production with its additives while the linoleum is very environmentally friendly due to the use of raw natural ingredients.

In terms of recycling, linoleum is better as it is biodegradable. Financially, linoleum is a better alternative in the long run as it is cheaper to operate and maintain and holds potential as an income source as the waste linoleum can be sent to waste-to-energy faculties as fuel. Socially, PVC holds lots of potential health risks and has been known to affect child development with its multitude of carcinogenic additives.

In conclusion, PVC proves to be a less desirable flooring product to be used when compared to linoleum. Through the environmental and social aspects, linoleum stands out as a better alternative. The main attraction of PVC flooring is its low initial cost but that can get offset by operation and lifecycle cost of linoleum flooring. Although linoleum flooring can't be used in areas prone to water leakage, it is suggested that linoleum be used as the main flooring material in place of PVC in future UBC building projects.

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GLOSSARY

Acetylene:	A chemical compound that is used one method of production of PVC
Catalyst:	Any substance that speeds up a chemical reaction
Carcinogen:	A substance capable of causing cancer
Eutrophication:	Excessive nutrients in bodies of water, such as lakes, caused by run-offs from land
Exothermic Reaction:	A chemical reaction that releases heat into the environment
Jute:	A rough and strong vegetable fiber that is used in the process of making linoleum
Mercuric Chloride:	A chemical compound that is a catalyst for turning acetylene into vinyl chloride
Plasticizers:	A chemical compound added to plastics to make them more bendable
Phthalate:	A chemical compound used as plasticizer in PVC
Sublimation:	Process of a solid turning directly into a vapor without going through a liquid phase
Vinyl Chloride Monomer:	A gas that is a crucial material in making PVC

LIST OF ABBREVIATIONS

EDC	Ethylene Dichloride
PVC	Polyvinyl Chloride
VOC	Volatile Organic Compounds
VCM	Vinyl Chloride Monomer

1.0 INTRODUCTION

Polyvinyl chloride, commonly known as PVC, is one of the most widely used construction material. The versatility and low cost of the material makes it stand out in a long list of building material choice. PVC has been used in everything from piping, to flooring and even to product casings. But hiding behind all its useful features are the many negative aspects associated with it, especially in the environmental and social aspects.

This SEEDS report will assess and examine the use of PVC materials in the UBC campus along with an alternative: linoleum. Linoleum is an all-natural product that was invented in 1860 by Frederick Wilton and was a popular choice for flooring and walls until PVC floorings came along around the 1960s (Bellis, 2005) . Recent improvements in the quality and aesthetic of linoleum flooring have begun to make it a contender once again for commercial and home flooring material.

At UBC, in order to reach a common goal of becoming a sustainable campus, picking out a cost effective and environmentally friendly material for flooring is needed. In order to fully determine which product is a more suitable choice to be used in a sustainable future, PVC and linoleum will be compared on three different aspects: economical, environmental and social aspects. The environmental front will look at the production and recycling options associated with both products. The economic front will compare the costs of buying these materials and its lifetime operational fees. Finally, the social front will be looking into the potential health risks of these floorings and the guidelines governing the minimum building requirements of materials used in UBC.

2.0 ECONOMIC IMPACTS OF PVC AND LINOLEUM

Both PVC, also known as vinyl, and linoleum are considered to be resilient flooring which means that they are fairly durable and resistant to stains and water. One aspect of PVC flooring that makes it appealing is the low purchasing costs. Both linoleum and PVC are relatively cheap when compared to other floors such as hardwood and ceramic but when compared to linoleum, PVC has a lower initial cost. However, it is generally found that PVC has a higher overall life-cycle cost when compared to PVC.

2.1 Residential and Institutional Uses

The economic considerations for institutional and residential areas at UBC are fairly similar as the overall cost and lifetime of the materials play the biggest role. The environmental considerations also play a large role as well. In general, linoleum and PVC are used in kitchen and dining areas in residential areas and high-traffic areas, such as hallways and corridors, in institutional areas. At UBC, These resilient floorings are stated to be used in corridors, lecture theatres, classrooms, areas where undergraduates work, bathrooms and laboratories. In addition, the use of linoleum is already recommended wherever it is practical because of the natural materials in linoleum and low VOC content make it environmentally friendly (UBC, 2013).

2.2 Initial and Lifecycle Costs

When compared to linoleum, PVC flooring is cheaper to purchase and becomes an attractive choice for anyone looking for and for an affordable floor. The main reason for the higher initial cost of

linoleum is due to the fact that linoleum is manufactured mainly in Europe and has to be shipped to companies in North America (Jones, 1999). However, after the operating costs and life-cycle costs are considered, linoleums larger initial cost are off-set and become a cheaper choice than PVC. It was found that the operating and maintenance cost of linoleum was approximately 73% of the cost for PVC (Moussatche, Languell, 2001).This can be attributed to reduced need for sealers and waxes to maintain the appearance of linoleum .In Table 1 below, the initial cost and life-cycle cost of vinyl sheets, linoleum and other resilient flooring are shown. It can be seen that linoleum and vinyl sheet have an initial cost of $\$4.50/sq^2$ and $\$2.05/sq^2$ and lifetime cost of $\$116.94/ft^2$ and $\$156.71/ft^2$ respectively. The Figure 1 below shows a more visual comparison of the initial and lifetime cost.

2.3 Lifetime of PVC and Linoleum

Another important aspect when considering the economic impact of PVC and linoleum, is the lifetime of the material when they are properly maintained. In the Table 1, the lifetime of linoleum is shown to be 30 years and only 15 years for vinyl sheets. The innate durability of linoleum and its self-healing nature attributes to the longer lifetime of linoleum (Moussatche, Languell, 2001). With these numbers, linoleum only needs 1 replacement in a 50-year service life while vinyl will need 3 replacements (Moussatche, et. al 2001). However, these are under ideal conditions and in typical usage, linoleum may not last twice as long as PVC. Lifetime estimations from other reports put the lifetime of linoleum at 20-25 years and PVC at 15-20 years (Bowyer, Bratkovich, Fernholz, Lindburg, 2009). With this said, linoleum generally has a longer lifetime than PVC and thus will need fewer replacements.

RESILIENT FLOORING SYSTEMS									
IDENTIFICATION NUMBER & RANKING	FLOORING SYSTEM	CAPITAL COST	SYSTEM SERVICE LIFE	NUMBER OF REPLACEMENT SYSTEMS	NPW OF REPLACEMENT SYSTEMS	MAINTENANCE AS A PERCENTAGE OF CAPITAL COST	MAINTENANCE COST	TOTAL NPW OF O&M	TOTAL COST OF SYSTEM IN NPW
1	Linoleum (.125") Adhesive	$4.50	30	1	$10.92	20.00%	$0.90	$101.52	$116.94
2	Vinyl Composition Tile (VCT) Adhesive	$1.43	15	3	$11.11	86.00%	$1.23	$138.72	$151.25
3	Vinyl Sheet Adhesive	$2.05	15	3	$15.92	60.00%	$1.23	$138.74	$156.71
4	Rubber Sheet (1/8") Adhesive	$5.30	10	4	$46.85	23.00%	$1.22	$137.50	$189.65
5	Cork (1/8") Adhesive	$3.43	6	8	$66.11	36.00%	$1.23	$139.28	$208.82

Table 1 : Initial cost, life cycle cost and lifetime of resilient flooring (per ft^2)
Adapted: Moussatche et al., 2001, p. 336

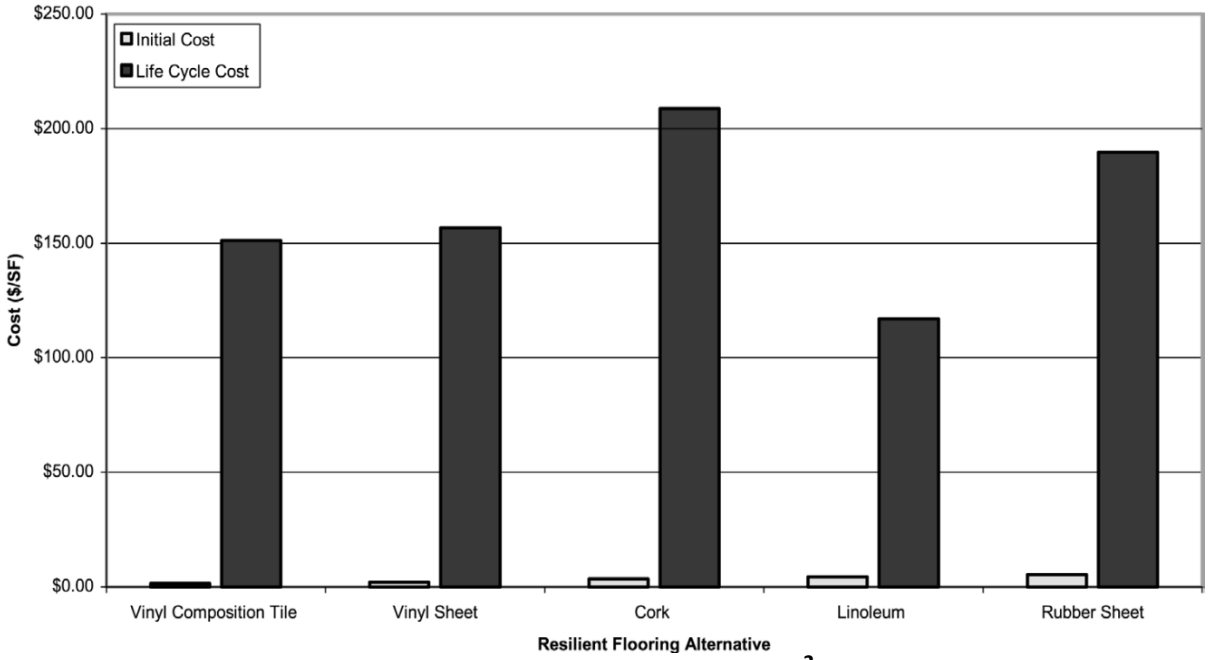

Figure 1: Initial and life cycle cost of resilient flooring (per ft^2)
Adapted: Moussatche et al., 2001, p. 336

2.4 Economic Possibility off Recycling PVC and Linoleum

After the materials have gone through their useful phase, the recycling possibilities with the used materials are considered. Unfortunately for PVC, the additives in PVC make PVC flooring very difficult to recycle and the so economic possibilities of PVC in its post-life are extremely limited (Jones, 1999). On the other hand, the natural material in linoleum, such as linseed oil, limestone, and wood powder, make it highly renewable. One economic possibility of used linoleum making it compost. There are some pilot projects in North America that gather linoleum for composting (Loomans, 2013). Another economic possibility of used linoleum is converting it into energy. Because of the natural materials, linoleum can be safely incinerated so it can be brought to waste-to-energy facilities and can yield approximately 186 Mj/kg (Jones, 1999).

In summary, linoleum may have the higher initial cost than PVC, but the lifecycle cost, the lifetime of linoleum and the possibilities for recycling linoleum make it a better economic choice in the long-term. In the next sections, the environmental and social impacts of PVC and linoleum will be examined.

3.0 ENVIRONMENTAL IMPACTS OF PVC AND LINOLEUM

In this section, the impact of PVC flooring and linoleum flooring are examined from the environmental perspective. The focus is mainly on the production and the waste management of these two materials and also a detailed investigation on the harmful aspect of each material to the environment. This section is going to narrow down into four sections: production, additives in flooring, recyclability for each flooring, and the production origin of each flooring.

3.1 Production

3.1.1 PVC

Before the production of PVC, the manufacturers first need to create vinyl chloride monomer (VCM). There are several methods of producing VCM but the main two production ways are: direct chlorination or combining acetylene with chlorine. Direct chlorination requires ethylene to react with chlorine gas directly to make ethylene dichloride (EDC). Then at high a temperature and pressure, it decomposed into VCM. Direct chlorination is much cleaner when compared with the acetylene- based production method. The main concern with the acetylene method is that it required the use of a mercuric chloride catalyst during the chemical reaction. Because it is an exothermic reaction process, the mercuric chloride tends to sublime and thus can result in severe environmental pollution problems (Zhang, Liu, Li, Dai, 2011).

Apparently, PVC production in China has been higher than USA; however, China still uses acetylene-based technique because it boosts the coal industry. Because of this, about 70% of the total PVC production in China still uses such techniques (Zhang, et al., 2011). This is definitely a big concern in the PVC production industry.

3.1.2 Linoleum

Linoleum was invented in 1960, and was the dominant flooring before vinyl flooring came out. It is a mixture of linseed oil, powdered wood, cork, and limestone. After mixing all the raw materials together, a homogeneous mass is obtained. The mass then is converted into granules and fused with jute under pressure and heat. The entire process of making linoleum flooring involves using materials that are not harmful to the environment. Comparing the production of both floorings, linoleum is obviously a more favorable choice in the environmental aspect. A detailed life-cycle flow chart of linoleum is shown below (Figure 2).

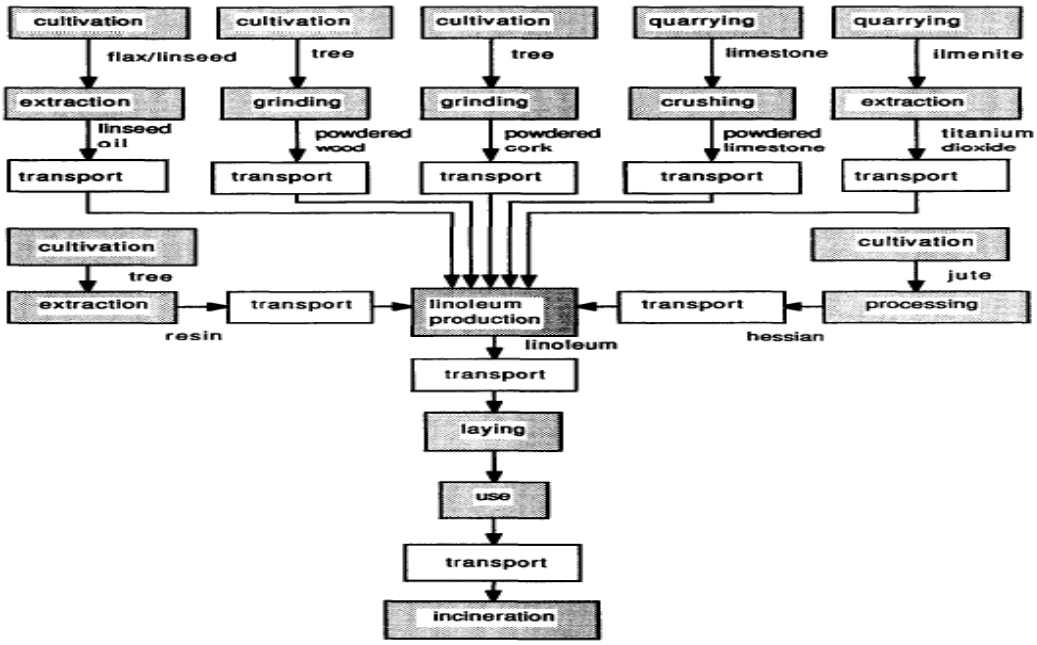

Figure 2: Flowchart of the Life-Span of Linoleum
Adapted: Jonsson, Tillman, Svensson, 1996, p. 247

3.2 Additives in Flooring

3.2.1 PVC

PVC needs to mix with stabilizers and plasticizers, in order to make it flexible, water proved and heat resilient. However, some of the additives in PVC flooring, such as the plasticizer phthalate, can cause health issues among people. Phthalate has been proved as harmful to the reproduction and development of people and it is also a possible carcinogen (Lowell Center for sustainable Production, 2011). Moreover, most of the stabilizers used in PVC flooring are heavy metals such as lead and cadmium. Lead is a carcinogen, endocrine disruptor and a reproductive and neurodevelopmental toxic. Cadmium is also a carcinogen, a

developmental and reproductive toxic and an aquatic toxic (Lowell Center for sustainable Production, 2011). A possible leakage of these two heavy metals would lead to serious social issues and environmental pollution.

3.2.2 Linoleum

Linoleum on the other hand, does not have nearly as much toxic additives as PVC throughout its production except carbon black or titanium dioxide. These are used in pigments and both are considered as potential carcinogen. Nonetheless, another downside of the production of the raw materials, such as linseed, is that the modern agriculture practices can lead to significant eutrophication (Gorree, Guinee, Huppes, Oers, 2001). Farmers tend to use too much fertilizer to grow its crops in order to mass produce them. After using them, these fertilizers will eventually wash into a body of water. They can oversaturate the nutrients in a body of water; thus, interrupt the life-cycle within it and lead to an uninhabitable water environment for organism to live in. (Gorree, Guinee, Huppes, Oers, 2001). This phenomenon can be prevented if farmers pay attention to the amount of fertilizers they use.

3.3 Recycling

3.3.1 PVC

It is hard to recycle PVC floorings because the multitude of additives used to make PVC useful. This makes large scale post-consumer recycling nearly impossible. According to Resilient Flooring & Chemical Hazard report directed by faculty of the University of Illinois at Chicago

School of Public Health, of 2.9 billion pounds of PVC that was discarded in the U.S. in 1999, only 18 million pounds was recycled. Unless the government really puts efforts and funding in recycling PVC products, it seems nearly impossible to get PVC recycled in an efficient way.

3.3.2 Linoleum

Because linoleum flooring is all made from natural materials, technically, it is biodegradable. Some investigations shown that incineration seems can be another option rather than putting linoleum waste in landfill (Gorree, Guinee, Huppes, Oers, 2001). However, this conclusion still needs to be considered with more care. Some pilot project in North America has successfully converted 20 tons of solid waste per month from landfills. Such good news show a good sign on recycling linoleum in the future and we should expect more from these projects to eventually perform commercially (Lowell Center for sustainable Production, 2011).

4.0 SOCIAL IMPACTS OF PVC AND LINOLEUM

The third category in the triple bottom line analysis is the impact of flooring on our society. In this section PVC flooring will be compared to the alternate linoleum flooring in the social aspects. This includes many un-quantifiable issues such as health risks, maintenance and ease of the construction of the floor.

4.1 Health Risks

4.1.1 PVC Health Risks

There are many known health risks as associated with PVC. The plasticizer, phthalate, that is added to PVC has been known to be carcinogenic as well as been known to damage development in children (Health Canada, 2011). Because of this, in the Europe Union, Phthalates have been banned in children's toys since 1999. In Canada there can be a maximum of 0.1% phthalates that are allowed to be in children's toys (Health Canada, 2011). Although there is no bans on PVC flooring, it is disconcerting that children will also be in contact with these floors. Another potential health issue associated with PVC is that in the event of a fire. When burned PVC releases hydrogen chloride. Hydrogen chloride is known to cause many unwanted health problems such as coughing and skin rashes.

4.1.2 Linoleum Health Risks

Linoleum is made mostly from natural products and therefore contains mostly organic materials. Because of this, there are not any known health risks due to installation or production of linoleum flooring.

4.1.3 Residential and Commercial Health Risks

When comparing the health risks in residential and commercial applications, most health risks are similar in both settings. In addition to this, children are more likely to be exposed to longer periods of time in residential applications.

4.2 Construction Impacts and Building Codes

4.2.1 PVC

Construction on UBC requires materials to abide by the BC building code and UBC technical guidelines (UBC, 2013). PVC does work with both guidelines. However it is not an ideal material because the technical guidelines recommend that materials with recycled and recyclable content are used. PVC flooring does not meet this requirement.

4.2.2 Linoleum

Linoleum also does meet the requirements of the UBC technical guidelines as well as the BC building code. Because linoleum can be easily recycled, it is a more preferable choice than PVC while abiding to the UBC technical guidelines.

4.2.3 Residential and Commercial Construction Impacts:

A property that must be considered when installing PVC or linoleum flooring is its resistance to water damage. PVC is completely waterproof. Linoleum is just water resistant. In the case of flooding or a large water spill, linoleum may absorb water and then ruin the floor. In accordance with A-9.30.1.(1) of the building code, if linoleum is used in these areas prone to water there must be a waterproof sub layer underneath the linoleum and the linoleum must not be glued or nailed down. In residential areas such as laundry rooms, bathrooms or any other room that may be prone to water leaks, linoleum floors should be avoided. PVC may be a better option in these rooms.

5.0 CONCLUSION

This report has thoroughly reviewed materials, PVC and linoleum, in an effort to choose a sustainable and clear cut choice for UBC to use in the future.

In the environment section, it is shown that PVC contributes heavily to environmental pollution due to the use of mercuric chloride catalyst and other heavy metals such as cadmium and lead. The materials for linoleum are all natural ingredients so it leaves a very small environmental impact when compared to PVC. The biodegradable property of linoleum as outweighs the difficult and inefficient recycling property of PVC.

In the economic section, PVC has lost its charm as a low cost material. The initial low cost of PVC compared to linoleum can be offset by the operation and maintenance cost of the material throughout its lifecycle. Also, depending on usage, linoleum can last up to 15 more years than PVC. Not only can that, but the potential use of waste linoleum as a fuel source for waste to energy plants generate some revenue when it needs replacing.

In the social section, health problems associated with the mixture of carcinogenic additives in PVC makes it unsafe around children as it causes development problems. On the other hand, linoleum is allergen free and safe to be used around all age groups. Also, according to the UBC technical guidelines, both materials pass the minimum requirements but linoleum offers better recycling options.

In conclusion, PVC proves to be a less desirable flooring product to be used when compared to linoleum. Through the environmental and social aspects, linoleum stands out as a better alternative. The main attraction of PVC flooring is its low initial cost but that can get

offset by operation and lifecycle cost of linoleum flooring. Although linoleum flooring can't be used in areas prone to water leakage, it is suggested that linoleum be used as the main flooring material in place of PVC in future UBC building projects in support of becoming a sustainable campus.

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