An Investigation Into Alternatives to PVC Flooring at the University of British Columbia

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ABSTRACT

The University of British Columbia (UBC) is well known for its commitment to innovation and environmental stewardship. UBC has consistently been one of the most sustainable Universities in Canada over the last 5 years, lacking only in the shareholder engagement category (The Sustainable Endowments Institute). The UBC Social, Ecological, Economic, and Development Studies program (SEEDS) is part of UBCs plan to address this issue and continue to lead sustainability initiatives on other fronts.

This report addresses the possibility of using flooring materials that do not contain Poly Vinyl Chloride (PVC) within UBC buildings. PVC has been a common choice for flooring material around North America because it has a low initial cost as was originally believed to be a safe option. Over the years it has become more apparent that PVC is not the miracle material it was hailed as. We now know that the production and disposal of PVC releases a large amount of Green House Gasses (GHG) into the atmosphere, along with many other harmful chemicals such as NO_2, and SO_2. The epoxies used to install PVC flooring in buildings is also a source of carcinogens.

This report focused on alternative flooring types that are both more sustainable than PVC, and practical for use in UBC's public buildings. All the alternative flooring options were compared using a Triple Bottom Line analysis. The options of cork and polished concrete were determined to be the most sustainable, although each of the two options are better in certain circumstances. In new buildings that are constructed with minimal concrete, cork flooring would be ideal. Buildings that contain concrete sub floors should use polished concrete as their finishing option.

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GLOSSARY

Stabilizers:	A substance added to prevent unwanted change in state of another substance
Plasticizers:	Additives that increase the plasticity or fluidity of a material
Phthalates:	Esters of phthalic acid and are mainly used as plasticizers

ABBREVIATIONS

CO_2	Carbon Dioxide
EVA	Ethylene Vinyl Acetate
GHG	Green House Gasses
NO_2	Nitrogen Dioxide
PVC	Poly Vinyl Chloride
SEEDS	Social, Ecological, Economic, and Development Studies
SO_2	Sulphur Dioxide
UBC	University of British Columbia
VCM	Vinyl Chloride Monomers
VOC	Volatile Organic Compounds

1.0 INTRODUCTION

In accordance with the University of British Columbia (UBC) sustainability policy, campus sustainability is interested in reducing the environmental impact of buildings at UBC. One of the ways UBC sustainability plans to do this is to avoid using building materials that are harmful to the environment. It is now known that Poly Vinyl Chloride (PVC) produces a large amount of greenhouse gasses (GHGs), is expensive to maintain, and environmentally damaging to dispose of. This report will focus on the alternative flooring options and analyze each one using a triple bottom line analysis. This analysis will examine the flooring types from a social, environmental, and economic point of view.

2.0 SOCIAL IMPACTS OF ALTERNATIVE FLOORING OPTIONS

To determine the social impact of alternative flooring types at UBC, we looked a few factors. These factors include the health impacts of PVC and other flooring on factory workers, manufacturers, and people exposed to the flooring, what alternatives are used in other countries, which countries have banned PVC, how safe are different flooring types, the preferences of UBC students, and the accessibility of each flooring type.

2.1 HEALTH IMPACTS OF DIFFERENT FLOORING TYPES

All flooring types have some negative impact on people during some stage of production or installation. Some of these flooring materials also provide positive benefits. Through our research, we have determined that PVC flooring is the worst in terms of health impact.

2.1.1 HEALTH EFFECTTSOF PVC FLOORING

Vinyl chloride monomers (VCM) which are the main components of PVC are a known human carcinogen for a very long time. In addition to the VCM in PVC, many additives are added to PVC. These plasticizers and phthalates are used to make PVC less brittle, and they are also toxic to humans. Workers that work in factories that manufacture PVC are the most susceptible to developing a rare liver cancer because they are exposed to larger amounts of the additives in the form of dust (Karstadt, 1976). Stabilizers and plasticizers have also been shown to leach out of PVC over time or if the PVC is exposed to heat in excess of 70 degrees Celsius (Ackerman, Massey, 2003). Flooring that is exposed to the sun in the summer can become hot enough to start this process.

2.1.2 HEALTH EFFECTS OF OTHER FLOORING OPTIONS

Comparing concrete, cork, linoleum, rubber, tile, and wood flooring to PVC flooring shows significant improvements for both workers and students and staff that are in UBC buildings. After the installation of each type of flooring, the floor

does not release any dust or any other chemicals. They are also easily cleaned with either a broom or mop. This reduces the amount of dust and allergens in the building and improves the overall air quality. The only exception to this is rubber flooring. It may have a strong odour, which may not be very good for people who are more sensitive.

During the installation process of cork, linoleum, rubber, tile, and wood flooring, there can be dust from cutting the materials. Also, the mining of limestone for concrete can send dust flying into the air. These can negatively impact workers if they are breathing in too much of this dust. However, these can be easily prevented if workers wear protective gear, like masks, and cut the flooring materials in an open and well ventilated area. In terms of comfort, the best choices would be linoleum and cork. These two flooring materials are softer the others and offer less fatigue when people are standing on it for extended periods of time.

2.2 ALTERNATIVE FLOORING IN EUROPE

In Europe, the flooring options are identical to what is available to us in North America. By quickly browsing some online hardware store site, we can see wood, ceramic tile, and cork flooring for sale. Instead of PVC, It is also possible to install marble flooring, and concrete can be used in public buildings. The options that are available in Europe are easily obtainable in North America. However, it may be better to use a more local option to reduce greenhouse gas emissions caused by transporting the materials.

2.3 STEPS TO REDUCING PVC

PVC is currently banned in many countries, and many companies are trying to reduce the use of PVC and phthalate in their products. Countries that have banned the use of PVC and phthalate in some products, like packaging and toys, include the EU, Japan, Iceland, Mexico, Norway, Canada, the United States, and South Korea. Hospitals and large companies in many sectors are trying to phase out the use of PVC in their products. These include shoemakers, like Nike and Adidas, automobile makers, like Ford and Honda, and electronics makers, such as Apple and Samsung.

Some alternative PVC free products that are being used in the medical scene in Europe are bags made from ethylene vinyl acetate (EVA), multilayer polyethylene, or polypropylene, tubing made from silicone or polyurethane, and gloves made from nitrile. This is an important change because the liquid in the bags and tubing used in IV drips can leach out some of the harmful chemicals and directly enter the patients' body.

2.4 UBC STUDENT FLOORING PREFERENCES

To determine if students at UBC have a preference when it comes to floors in UBC buildings, we conducted a survey. This survey consists of one question asking which type of flooring they preferred. This survey was intended to gather the students' preferences based purely on aesthetics. For each option, the participants were shown a picture to give them an example of how the floor may look like. The options to the survey were the alternative flooring types - rubber, cork, linoleum, tile, wood, and polished concrete - that we are looking into.

After surveying 81 students, the results showed that most of the students preferred cork flooring, and concrete flooring was the second most preferred. During this survey, one person did not choose a flooring type because she preferred whatever was the most practical and wouldn't cause students to slip when wet. Another chose cork because it was environmentally friendly. This shows that some of the students may have taken other information into account when making their decision, as opposed to our intended purpose of basing the choice on aesthetics alone.

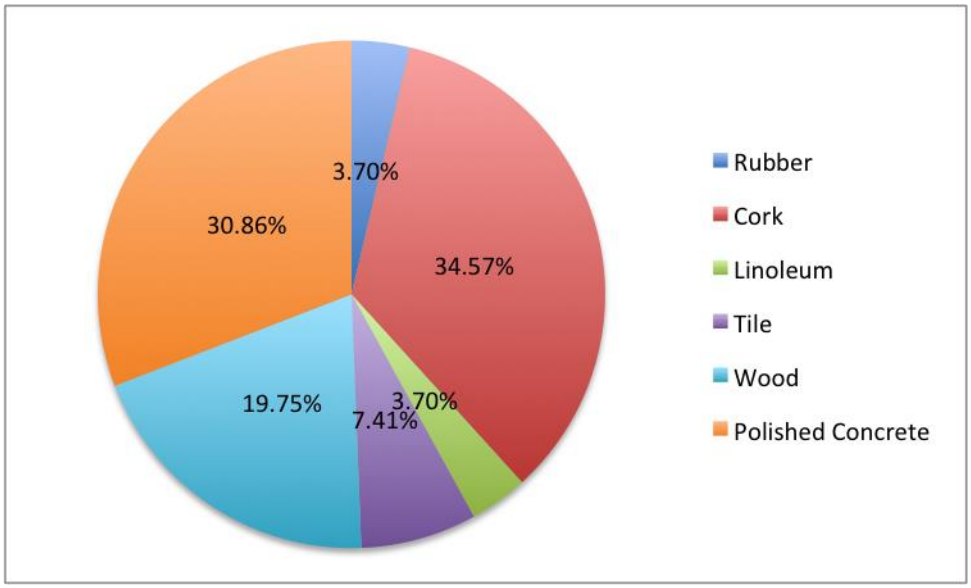

Figure 1: Results From Our Flooring Prefernce Survey (81 Students Surveyed)

2.5 ACCESSIBILITY OF ALTERNATIVE FLOORING TYPES

All the alternative options that we looked at in our research are accessible to UBC. All the flooring types, with the possible exception of cork and wood floor are already in UBC buildings. Cork and wood are purchasable from vendors in Vancouver. All flooring types except concrete would not affect construction of a building in development. Although the installation may be slightly different for each material, the structure of the building does not need to be altered. These flooring types can also be used to replace the flooring in old buildings provided the height difference of the materials is not too large.

Concrete is the only material that requires structural modifications if it is chosen part way through a building construction. The structure needs to be strengthen to hold the concrete if it is used on any floor besides the ground floor. However, in old buildings with a concrete subfloor, concrete can be a good choice when replacing the flooring. After removing the old flooring, it is possible to polish the concrete to minimize the material needed to be bought. This option only requires hiring people and is not dependent on the ability to acquire the flooring material.

2.6 SAFETY

As far as can be determined, the alternative flooring materials met the requirements in the BC building code. As long as each flooring options is properly installed, it will meet the building code. The building code does say that flooring must have waterproofing from moisture in the ground, so as long as proper water barriers are put in place and proper coatings are applied to each material; the floor should not suffer water damage.

The friction of each flooring type is dependent on the coating applied to the flooring. Also different tiles may slip less than others, so it is possible select the material to meet the required amount of friction. In the case where slipping is a major issue, a non-slip coating can be applied to the floor for extra friction.

3.0 THE ECONOMIC IMPACT OF PVC AND ALTERNATIVE FLOORING OPTIONS

PVC (poly-vinyl chloride) is mainly used because of its low cost of installation, however maintenance and replacement costs over the years makes it one of the most expensive options in the long term for flooring. A large portion of the expense is due to the use of toxic cleaning products and strippers to maintain the flooring.

3.1 COST OF ALTERNATIVES TO PVC FLOORING

PVC is also water and stain resistant, which is the other main reason why it is so prevalent. There are several alternatives to PVC which are commonly used including linoleum, cork, rubber and wood. Linoleum is produced from linseed, so it's environment friendly and is also anti-static and anti-bacterial. Linoleum has a lifespan of approximately 35 years, whereas PVC will only last about 15 years. Stratica, a non-vinyl polymer flooring type, is non-allergenic, mildew-resistant and odour-resistant. It is also easily recyclable. In the figure below, we can see the overall maintenance cost of each square foot of PVC is over $1000 over a period of 20 years, whereas for cork it is about $518. The life span of cork based flooring is also higher than that of PVC at around 40 years. While the flooring alternatives mentioned below may have a higher initial cost than PVC flooring, their lower maintenance cost makes them uniformly cheaper over their life span.

Table 1: Cost and life span of flooring types

Material	Brand, type	Initial cost: material and installation	Expect life span (years)	Initial cost per year of life span	Maintenance cost per year	Total cost over 20 years
Vinyl	Armstrong, Sold Vinyl	$9.70	25	$0.39	$52.00	$1,048
	Armstrong, VCT	$2.65	15	$0.18	$52.00	$1,044
Cork	Dodge, Regupol	$7.25	40	$0.18	$25.70	$518
	Expanko	$10.30	30	$0.34	$25.70	$521
Linoleum	Armstrong	$6.30	25	$0.25	$40.00	$805
	Forbo, Sheet	$5.50	35	$0.16	$33.30	$669
	Forbo, Tile	$6.42	25	$0.26	$33.30	$671
Non-chlorinated polymer	Amtico, Stratica	$6.75	40	$0.17	$32.00	$643
Rubber	Dodge, Regupol, Econights	$6.50	30	$0.22	$40.00	$804
	Dodge, Regupo, Ecostone	$7.75	30	$0.26	$40.00	$805
	Expanko, Treadmaster	$7.50	30	$0.25	$32.00	$645
	Flexco, Radial I, II	$11.70	35	$0.33	$24.00	$487

3.2 THE COST OF REPLACING PVC FLOORING

Of all the uses of PVC, 3.2% of it is used in flooring. Environment Canada published a report in 1997 on options for replacing PVC based products. Although they are somewhat outdated now it does provide us an idea about it. Environment Canada used two sets of price comparisons: a low case looking at the cheapest alternative and a high case looking at the expensive alternatives used in canada. The figure below describes the result of the study along with two other similar environment conscious organisations.

Table 2: Cost of replacing PVC

Table 2: Cost of Replacing PVC

US dollars per pound of PVC (2002 prices)

	CRA (industry)	Hickling (for IJC)	Environment Canada Low	High
Pipes	$1.43	$1.03	$0.15	$0.33
All other uses	$0.87	$1.10	$0.94	$3.84
Average	$1.15	$1.07	$0.55	$2.08

Average is the unweighted average of pipes and "all other uses" estimates
Hickling data excludes windows

The study conducted by Environment Canada revealed that the use of alternatives to PVC in all types of construction materials wo\uld raise the cost of new residential construction by 0.4% in the low case and 2.4% in the high case. Even though flooring represented about 3% of all PVC usage in Canada it accounted for over half of the cost of the entire low cost PVC replacement procedure. If the above figure still applied it would cost about $4 billion per year for Canada and the United States to replace all the PVC flooring (about $12 per capita).

3.3 BEST ALTERNATIVE TO PVC FLOORING

According to figures and the survey conducted, UBC students prefer polished concrete and cork over all of the suggested alternative flooring types. After considering all the economic factors of different flooring types cork seems to be the most ideal choice for flooring at UBC and is also aproved by our stakeholder Ms. Penny Martin. Cork is said to be 50% air, reduces noise, is impact resistant and insulates against heat and cold. Cork flooring resists scuffs and its textured pattern disguises dust, thus, making it an ideal choice for labs and classrooms at UBC. It comes from cork tree and so is environmental friendly and renewable. All in all it seems that being the least expensive in overall cost over 20 years including maintenance costs and durability cork is the most suitable option available for UBC flooring.

4.0 ENVIRONMENTAL IMPACT

The environmental impact of each flooring option will be assessed by the following factors:

- Renewability of the materials required to produce the flooring.
- Greenhouse gas emissions during the life cycle of the flooring.
- Toxins released during the life cycle of the flooring.
- Energy consumption during the production of the flooring.
- Recycling cost/availability of the flooring.
- Biodegradability of the flooring.

Polished concrete will be excluded from the analysis as it is only recommended for buildings with a concrete sub-floor and therefore the only environmental impact would be the negligible amount of energy used to polish the floor. Rubber will also be excluded from the environmental analysis because of insufficient data and by the fact that there are many types of rubber with a wide range of environmental impacts.

4.1 RENEWABILITY OF THE MATERIAL REQUIRED TO MANUFACTURE FLOORING

- **Vinyl** – Vinyl or PVC Is a non-renewable resource created from sodium chloride (salt), ethylene (a crude oil product) and plasticizers.
- **Tile** – Ceramic tiles are made from clay which a non-renewable but incredibly abundant material.
- **Linoleum** – Linoleum is a mostly renewable resource created primarily from linseed oil. Linseed oil is oxidized and mixed with powdered cork, powdered wood, limestone and titanium dioxide (Jönsson et al. 1997).
- **Wood** – Wood is a renewable resource that can be harvested every 25-80 years with replanting (Teara.govt.nz 2013).

- **Cork** – Cork is a renewable resource harvested from the back of the Cork Oak tree. Harvesting cork does not kill the Cork Oak tree and it can be harvested every nine years (Leal et al. 2008).

Cork is the most renewable flooring option as it requires only nine years to regrow.

4.2 GREEN HOUSE GAS EMISSIONS

The carbon dioxide (CO_2) emissions of the flooring types can be seen in Table 3. Tile flooring has by far the highest CO_2 emissions with nearly four times the CO_2 of vinyl and 39 times the carbon dioxide emissions of wood flooring. The high levels of CO_2 emission from tile flooring is due to the large amounts of fossil fuels required to fire the clay (Peng et al. 2012). Wood and cork flooring are clearly the best options in terms of greenhouse gas emissions.

Table 3: Carbon Dioxide Emissions during the Life-Cycle of 1 m^2 of Flooring

	Vinyl	Linoleum	Tile	Wood	Cork
CO_2 Emissions (kg)	4.14(Jönsson et al. 1997)	1.6(Jönsson et al. 1997)	16.4(Peng et al. 2012)	0.424(Jönsson et al. 1997)	0.66(Rives et al. 2011)

4.3 ENVIRONMENTAL TOXINS

Table 4 shows the amount of prevalent toxins in the flooring options. As the table shows PVC releases very high amounts of VOC (volatile organic compounds), HCl (hydrogen chloride) which is a strong acid, and mercury. Some of the VOC in PVC and mercury have been shown to accumulate in living organisms (Heathybuilding.net 2013). Wood had the lowest amount of each type toxic emission except for NO_x (the sum of nitrogen dioxide and nitrogen monoxide) emissions in which it was the highest. NO_x and SO_x (Sulfur dioxide and Sulfur Monoxide) has been related to acid rain and is regulated

by the Canadian government (Eg.gc.ca 2013). Although ceramic tiles do not contain any VOC, they release large amount of NO_x, SO_x, mercury and lead. It should also be noted that many heavy metals not listed on this table are released in the production of ceramic tiles (Edo et al. 2011).

Table 4: Various Toxins Released during the life-cycle of 1 m^2 of flooring.

	VOC (mg)	SO_x (g)	NO_x (g)	Mercury (mg)	Lead (mg)	HCl (g)
Vinyl (Jönsson et al. 1997)	1950	4.87	8.36	0.081	-	23.4
Ceramic Tile (Edo et al. 2011)	-	7.7	20.9	0.039	350	-
Linoleum(Jönsson et al. 1997)	5.87	4.3	12.8	-	-	-
Wood (Jönsson et al. 1997)	-	1.89	31.6	-	-	-
Cork(Rives et al. 2011)	-	6.1	(no data)	-	-	-

4.4 ENERGY CONSUMTION

The energy consumption of the flooring options can be found in Table 5. With the exception of tile, which has a much higher energy consumption than any other flooring option, all the flooring options have comparable total energy consumption. Cork was excluded from the table due to a lack of data on the energy consumption of cork flooring however, since the process of producing cork flooring is similar to wood flooring it can be assumed that they will have similar energy consumption (Knapic et al. 2012). While the total energy consumption of the flooring types may be similar wood uses far less non-renewable energy that the other flooring options.

Table 5: Energy Consumption during the production of 1m² of flooring

	Vinyl (Jönsson et al. 1997)	Linoleum (Jönsson et al. 1997)	Tile (Edo et al. 2011)	Wood (Jönsson et al. 1997)
Fossil Fuels (MJ)	26.4	25	148	5.39
Electricity (MJ)	18.2	16.3	Negligible	8.37
Renewable Fuels (MJ)	0	0	0	35.4
Total (MJ)	44.7	41.3	148	49.16

4.5 RECYCLING

The recyclability of each to the flooring options is listed below:

- **PVC –** Is extremely costly to recycle and is sometimes incinerated as a way to reclaim energy which results in large emissions of greenhouse gasses, harmful chlorine compounds and heavy metals (Braun, 2002).
- **Tile** – Ceramic tiles can be recycled into a rock base for paths or driveways (businessrecyling.com.au 2013).
- **Linoleum** – The disposal of linoleum is manly accomplished by incineration which releases large amounts of greenhouse gases and a significant amount of heavy metals (Gorrée et al. 2002).
- **Wood –** Wood can be recycled into a variety of products or used as a fuel source (miragefloors.com 2013).
- **Cork –** Cork Is the most easily recycled flooring option and is often recycled into cork boards or insulation. Cork flooring is also often made of recycled cork (Putacorkinit.ca 2013).

4.6 BIODEGRADIBILITY

Wood and Cork are completely organic and biodegradable. Linoleum is completely biodegradable. The majority of the components of linoleum are organic with the exception of titanium dioxide and the thin coating of acrylate applied to the surface (Nussbaumerm, 2013). PVC is not biodegradable and there is reported to be no loss of certain plasticisers when observed for 50 months in a landfill (Mersiowsky et al. 2001). Ceramic tiles are natural and will erode over time but are not biodegradable (Nussbaumerm, 2013).

4.7 ENVIRONMENTAL CONCLUSIONS

According to our environmental factors wood flooring appears to have the lowest environmental impact. Wood flooring released the least CO_2 and released no VOC or heavy metals. Wood flooring is also renewable, biodegradable and recyclable. The only environmental factor in which wood flooring performed poorly was in NO_x emissions. With timber being one of B.C.'s top economies wood flooring is also the most local flooring option. Cork is a close second based on the factors we have explored and it had very similar results to wood. Other factors such cork being naturally very insulating could potentially place it ahead of wood. The levels of damage to the natural environment in the harvesting area could also be a factor worth considering. The insulation provide by cork flooring could reduce the amount of greenhouse gas emissions from heating. It is unclear which of PVC or ceramic tiles has the greater environmental impact. PVC contains large releases large amounts of VOC while ceramic tiles require extremely large amounts of fossil fuels and therefore release large amounts of CO_2. The environmental impact of linoleum is somewhere between that of cork and that of PVC or ceramic tiles. It has a greater environmental impact than cork and a lesser environmental impact than PVC or ceramic tiles. Linoleum is notable as the only flooring with VOC besides PVC and the flooring with the lowest total energy consumption.

5.0 CONCLUSION

In all aspects of the triple bottom line analysis, PVC flooring was the worst option for flooring at UBC. The best flooring option for retrofitting older buildings is polished concrete. Many existing buildings at UBC have concrete sub floors already. Therefore when the existing floor covering needs replacement, the best option is to polish the sub floor rather than install a new floor covering. Using a polished concrete floor avoids all the pollution associated with manufacturing and transporting a new floor to place over it. Concrete floors also do not require environmentally harmful chemicals to clean, and can be safely disposed of at the end of the building's life span.

In new buildings, or buildings that have been constructed without concrete subfloors, cork is the best flooring option. Cork is a natural and renewable flooring material with minimal environmental impact during manufacturing. It also has a long life span of approximately 40 years, and is easily recyclable at the end of its lifecycle. Cork also requires a relatively small amount of maintenance, leading to costs of only $518 per square foot over 20 years.

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