UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into Alternatives to PVC Flooring in UBC Food Service Areas

Ben Mattison, Kai Godfrey, Rojin Nazari, Shayan Rezaiezadeh

University of British Columbia

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Ben Mattison
Shayan Rezaiezadeh
Kai Godfrey
Rojin Nazari
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Dr. Carla Paterson

ABSTRACT

UBC Food Services uses polyvinyl chloride (PVC) tiles for many of the floors in their cafeterias across the UBC Vancouver Campus. Development of sustainability regulations has led to inquiries over the environment and health effects of PVC, and whether its usage should be discontinued, as it has been identified a "Red List" material. As UBC moves towards building new buildings across campus, alternatives to PVC flooring have the possibility of being implemented.

This report investigates and compares two alternatives to PVC, linoleum and ceramic tiles, for usage in the food service areas around UBC Vancouver Campus. Important factors investigated include the life cycle effects on the environment, health concerns and overall cost for a building's lifespan.

Using a triple bottom line assessment of each of the three materials, it was found that linoleum could match the performance of PVC in a food service area, with an overall lower cost over an entire life span, and lower environmental impact and without the release of toxins associated with PVC. However, ease of installation for PVC is a major factor in the limitation to implement alternatives. It is recommended that UBC considers linoleum as a serious alternative to PVC flooring in food service areas.

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GLOSSARY

Acidification:	The process of becoming an acid or being converted to an acid.
Acrylate:	A salt or ester of acrylic acid.
Carcinogen:	A substance capable of causing cancer in living tissue.
Earthenware:	Pottery made of clay fired to a porous state which can be made impervious to liquids by the use of a glaze.
Formaldehydes:	A colorless poisonous gas; made by the oxidation of methanol.
Granular:	Resembling or consisting of small grains and particles.
Impervious:	Not allowing fluid to pass through.
Organotins:	Chemical compounds based on tin with hydrocarbon substituents
Phthalate:	A salt or ester of phthalic acid.
Thermoforming:	The process of heating a thermoplastic material and shaping it in a mould

LIST OF ABBREVIATIONS

ADA – Americans with Disabilities Act
COF – Coefficient of Friction
CO2 – Carbon Dioxide
DEHP – Di-ethylhexyl phthalate (found in PVC)
DINP – Di-isononyl phthalate (found in PVC)
DBT – Dibutyltin
KWh – Kilowatt-Hours
LBC – Living Building Challenge
MJ – Mega-Joules (measure of Energy)
PVC – Polyvinyl Chloride
SO2 – Sulfur Dioxide
TVOC – Total Volatile Organic Compounds
UBC – University of British Columbia
USDA – United States Department of Agriculture
UV – Ultraviolet
VCH – Vancouver Coastal Health
VCT – Vinyl Composite Flooring (composed of PVC)
VOC – Volatile Organic Compound

1.0 INTRODUCTION

UBC currently has many food service areas around campus, and with the UBC Food Services meal plan, they are an integral component of student life. In fact, first years in residence are required to spend a minimum of $2513 on their meal plan (2013, UBC Student Housing). Currently, the cafeterias in Vanier and Totem use PVC tiles as their primary surface. The Vancouver Coastal Health's requirements for Food Safety (2012) requires floors that are subject to moisture, as is the case for kitchens and dishwashing areas, to be made of impervious materials. This requirement is met by ceramic tiling, however PVC is used in the main cafeteria area. As seen in Figure 1, the layout of the cafeteria changes from PVC to ceramic tiles for the preparation areas.

FIGURE 1: PVC tiles used in main cafeteria area, and the ceramic tiles required for the preparation area. (Photo by Ben Mattison)

Concern from the Living Building Challenge, based in Seattle WA, has identified PVC as a "Red List" material. These are materials that demonstrate negative health and toxicity concerns and in order to meet the Living Building Challenge, cannot be included in a project without an exception (LBC, 2013). The main concern in food services areas is the inclusion of phthalates used in the plasticizers of the PVC flooring. The three most common phthalates are harmful to the endocrine, reproductive and development systems (Pharos Project, 2013). Further, PVC includes stabilizers that have the potential to leach out heavy metals such as lead (Ackerman and Massey, 2003). Food service areas are places where food is being served and ingested therefore the use of PVC is of specific concern due to the presence of these toxins.

The alternatives this report will investigate are linoleum and ceramic tiles. Advice from our stakeholder and communication with UBC Campus Sustainability staff led us to choose linoleum. The initial interest came from the fact it has similar performance when compared with PVC flooring, however could reduce not only the impact of recycling and disposal, as well as the embodied energy, but the concerns of toxins are removed as well since linoleum is manufactured from linseed oil, a renewable resource (Carter et al., 2008). Further, UBC Campus Sustainability staff told Ceramic tiles were chosen due to the fact they are required for the preparation area (VCH, 2013) and could be extended into the cafeteria itself.

When considering the removal of PVC from future use there are major limitations and logistics in place. When travelling to Home Depot to acquire samples flooring for our investigation we encountered the flooring expert, Norm, who provided some insight into these limitations from a manufacturing industry point of view. Rather than interest himself with our investigation, he was more curious as to the size of flooring space we needed. Realizing we were considering the cafeteria space he was surprised we were even considering alternatives. PVC's ease of installation was the dominant factor for him, where no matter what environmental or social impacts could be uncovered that would favour alternatives, installation costs of the PVC outweighed all of it. Linoleum and ceramic tiles would require hiring of professionals to install and would lead to large difficulties for the university. In fact, Home Depot only had one flooring product from linoleum, and it has been shown that building supply stores have been replacing pure linoleum products for vinyl imitations for over a decade (Ackerman and Massey, 2003). Norm's story is important for our investigation because it outlines the difficulty of influencing decisions on alternatives for people who have been involved in flooring for some time.

The primary research conducted in this survey reached out to UBC Student Housing & Hospitality Services, as well as UBC Campus Sustainability. Unfortunately, this was met with difficult results. Appendix A outlines questions we proposed, which are challenging to answer and due to time constraints this report is unable to include answers to some of them. This again shows the difficulty in implementing PVC for future use, even on the UBC Vancouver Campus. Decisions take time to be considered by the many staff who overview not only food service areas, but also sustainability operations. This report hopes to overcome these challenges by presenting a triple bottom line assessment that will compare PVC to the chosen alternatives using not only the economic impact that seems to be the dominant discourse at the time, but also the environmental and social impact of these alternatives to best determine the possibility of implementation for future use at UBC.

2.0 PVC

Polyvinyl Chloride is a widely used plastic with applications in flooring, furniture, pipes, and window frames. One of the major issues with regards to PVC is the potential leaching of the substances, including lead, cadmium, organotins, and phthalate plasticizers, added to its composition in order to enhance its properties. In addition to these problems, there are also concerns regarding the environmental impacts of the hazardous chemicals used in the manufacturing stage of PVC. Vinyl building materials release hydrochloric acid fumes once they catch fire, and burning PVC produces dangerous chemicals such as dioxin, a strong carcinogen. The hazardous chemicals associated with the production, use, and disposal of PVC are avoidable for the most part, but there are alternatives that have fewer environmental and health related risks. What makes PVC an appealing flooring option for most buildings is the low production and installation costs and simple installation and cleaning procedures and high accessibility, which make it a practical for kitchen surfaces and flooring. In this section of the paper, the environmental, economic, and social aspects of PVC are discussed and further analyzed. PVC flooring is created from soft PVC that is plasticized to increase its flexibility.

2.1 ENVIRONMENTAL IMPACT

PVC is initially a powder derived from salt, chlorine component, and fossil fuel, ethylene component. Approximately 90% of PVC is produced by suspension polymerization, where the monomer is suspended in an aqueous mixture that contains buffers, reaction initiators, and colloid-forming agents to produce material with desired molecular weight distribution, particle size, and particle morphology (Whitfield & Associates, 2008). The final product is PVC resin in powdered form. Emulsion polymerization is another polymerization technique used to make plastisols, which are fluid components of PVC in plasticizers (Whitfield & Associates, 2008). Non-aqueous polymerization is used to produce special polymers and copolymers for floor tiling purposes in organic solvents. Finally, bulk polymerization is used to produce high clarity resins for products such as bottles and floor tiles. In later stages, phthalates such as DEHP are added for heat stabilization, UV absorption, flame avoidance, flexibility, and lubrication. PVC processing techniques consist of five different methods: extrusion, injection molding, calendaring, coating, and thermoforming. PVC floor tiles are produced through calendaring, a process in which the PVC resin is heated and kneaded as it passes through pairs of rollers that press it to the desired thickness, thus creating wide flat products with various flexibilities. Ethylene production during the initial stages of PVC production emits ethylene and propylene to air, and methanol and propane or butane emissions to water and other emissions such as Total Organic Compound and Sodium Hypochlorite to both water and air. During chlorine production, chlorine, hydrogen, mercury, and asbestos fibres are released into the environment. Asbestos is chemically inert and has no major environmental impacts. The on-site mercury disposal can contaminate the water, air, and soil in the neighbouring plants and endanger the nearby ecosystem. Furthermore, chlorine can have potential environmental impacts once released as a toxic gas. The electrolysis process to produce chlorine consumes a great deal of electricity, causing CO_2 and SO_2 emissions, resulting in high global warming potential and acidification potential (Baitz, Kreissig, and Byrne, 2004). Vinyl chloride monomer is produced after thermal decomposition of ethylene dichloride and processes several chlorinated hydrocarbon byproducts. These byproducts are not only carcinogenic, but and components are unstable in the environment even when the amount of emissions are low. Advanced wastewater treatment prevents emissions of these hydrocarbons from entering the water system and capture possible contaminants. Proper emission reduction plans can also ensure that contaminants are below the risk level. The risk associated with lead and tin organic stabilizers is the exposure to and ingestion of dust through air, food, or water. Emissions of plasticizers during calendaring process is the highest, 0.02 - 0.07% of the total mass of the plasticizer used (Cadogen, 1994). Most of these emissions are released to the air. Furthermore, calendaring process for every kilogram of PVC is 6 MJ. Air emissions are mainly due to energy use and are also produced during end-of-life stage. The PVC recovery process is a hydrolysis reaction separating inorganic and organic parts and is followed by post-heating of organic fractions (Kreissig, Baitz, and Schmid, 2003). Sodium Chloride, oil fraction, solid residue, polyethylene, and metal scrap are the reclaimable outputs of this process and sodium hydroxide, hydrochloric acid, and electrical energy are the inputs of this reaction. No water is required. The inorganic material is used as feedstock and the organic content is used for energy input to heat the sandblasting process.

Recycling rates are very low for PVC, only 3% of the available post-consumer waste (Makishi and Kupfer 2003). Some life cycle analyses investigating the environmental impacts of a substance from production through use and disposal have given PVC good ratings; however, they often ignore its toxic and carcinogenic emissions (Ackerman and Massey, 2003). Waste incineration consists of combustion, heat recovery, and gas and liquid effluent treatment. This causes chlorine, carbon dioxide, and cadmium to enter the environment and pollute the area even further. Overall, the fumes produced during the production, use, recycling, and waste management of PVC flooring can have significant effects on the environment.

2.2 ECONOMIC IMPACT

PVC sales reached 14.4 billion pounds in the United States and Canada in 2002 (Ackerman and Massey, 2003). This means that 5% of the world's population consumed 24% of the world's PVC. This amount reduced in 2007, when consumption of PVC amounted to 14.2 billion pounds. As mentioned before, one of the benefits of PVC is its low cost, which is achieved through its mass production and the advancing technologies used to produce it. While PVC flooring has the lowest initial costs among its competitors for commercial and industrial uses, but its short lifetime and frequent maintenance requirements cause its eventual costs to increase. In other words, on a life-cycle basis, reflecting durability and ease of maintenance, it is the most expensive flooring option (Ackerman and Massey, 2003). Even though PVC has higher life cycle costs compared to other alternatives, it is still selected by most of the consumers due to its low installation costs, as well as ease in installation. As mentioned previously, the requirements to lay PVC are much less rigorous than for linoleum or ceramic tiles. Therefore, the institution does not have to hire a professional to install the flooring, and the installation costs remain low.

2.3 SOCIAL IMPACT

The released phthalates from PVC contaminate water, air, and food, hence exposing humans to these chemicals. The greatest intake of this chemical was found to be through food consumption, sometimes as high as 0.25 mg per day, and inhalation of particulate matter containing di-ethylhexyl phthalate (DEHP) found in the air and house dust. DEHP may in turn cause inflammation of the lung airways and increase the risk of asthma. Recently, the most commonly used chemical to soften PVC is di-isononyl phthalate (DINP), which does not bind to PVC chemically and is mobile and prone to leaching in the plastic matrix. As a result of this phthalates are released into the air over time by the volatilization of the air. Jaakkola, Oie, Botten, Samuelsen and Magnus (1999) demonstrated that phthalates transfer from PVC floor to sediment house dust. Allsopp, Santillo, and Johnston (2000) measured the amount of chemicals present in 5 different PVC flooring samples, and the amount of DEHP was found to be below the detection limit, but several organotins were identified. Dibutyltin (DBT) compounds, the most commonly used stabilizer/phthalate in PVC, were found to be present in high concentrations in four out of give of the samples and DINP was found to be in all samples in relatively high concentrations. This may reflect the growing market of DINP and a reduction in demands for DEHP (Allsopp, Santillo, and Johnston 2000). Despite the lack of evidence regarding the risks of DINP, it has exhibited various toxic effects in laboratory animals and does not have any less potential hazards to human health than DEHP. In conclusion, these hazardous chemicals have the potential to leach into the environment from PVC flooring and resulting in human exposure, causing PVC flooring to have a negative social side effect and be criticized by most of the residents and users of the buildings.

PVC flooring requires cleaners with toxins and hazardous chemicals to keep it shiny and functional. Carcinogens such as formaldehydes are common in these cleaners and waxes. Formaldehyde affects the immune, respiratory, and central nervous systems and sense organs. Currently, there are PVC flooring products that offer a no wax finish, thus reducing the exposure to volatile organic compounds (VOCs). A study showed that the amount of the VOCs emitted throughout the life cycle of PVC flooring is lower that the VOCs emitted from one waxing session. Young children and fetus are the groups that are mainly threatened by the toxins found in these cleaners, by affecting their physical and mental development. A common chemical used in floor finish products is Styrene, which is a suspected carcinogen, and has negative effects on cardiovascular, endocrine, developmental, immunological, central nervous, respiratory, and reproductive systems. Another common chemical in shineline floor finish is Tributoxyethyl Phosphate, which may cause ataxia, breathing problems, and tremors through repeated contact. Lent, Silas, and Vallette (2009) showed that janitors and firefighters experience the highest rate of occupational asthma. Overall, the chemicals in cleaners influence the health of the students, the food produced in the kitchen, and the workers and janitors who are mainly in contact with the cleaning products.

3.0 CERAMIC TILE

Ceramic tiles have vast usage in construction industry and are almost being used in all buildings. Ceramic industry plays a crucial role in preserving sustainability by saving biodiversity and restoring clay extraction sites. These tiles are produced to be durable due to high temperature firing of various ranges of minerals. The minerals can range from clay to synthetic industrial minerals. This industry is committed to recover and recycle its materials, reduce CO_2 emissions and cut down its water wastes.

3.1 ENVIRONMENTAL IMPACT

3.1.1 Carbon Footprints and CO_2 emissions

In order to quantify the carbon footprints of ceramic, the CO_2 emission and Energy consumption of a ceramic piece during production of is being studied. The piece is a cubic vessel with the mass of 0.417 kg and dimensions of 10cm x 10cm x 10cm (Quinteiro et al., 2012). Given the average thickness of ceramic tiles, 1/3 of an inch, the cubic vessel would be enough to cover 1 square feet (0.1 square meter) of floor.

The carbon footprint to produce the above mentioned ornamental earthenware is 1.22 Kg CO_2 per unit. Manufacturing stage is the major contributor to the greenhouse gas emissions with almost 88% of total carbon footprints. The raw and supplementary materials has a 10% share in CO_2 emissions while distribution and disposal stages are responsible for 1% and 1% of respectively (Quinteiro et al., 2012).

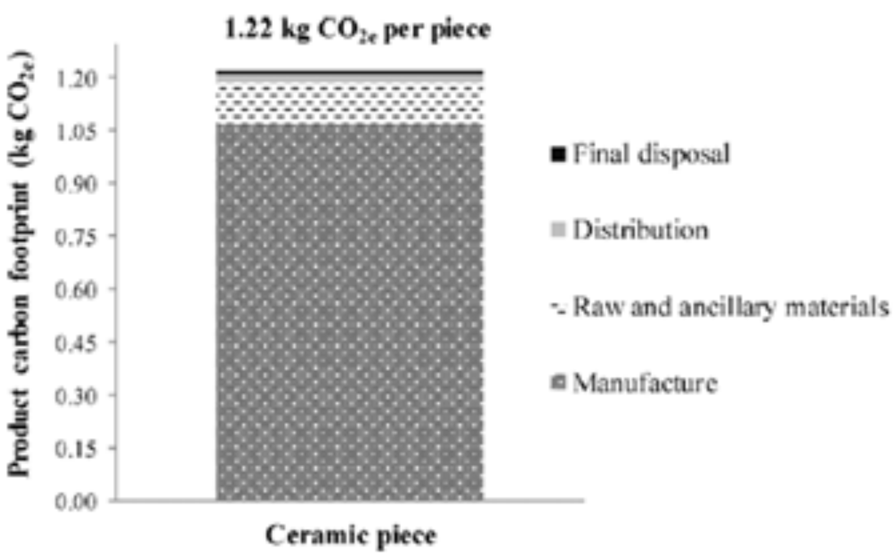

FIGURE 2: Contribution of each production stage to the total CO_2 emission (Source: Quinteiro et al., 2012)

About 90% of the entire carbon footprint is produced during energy consumption and the rest comes from the process emissions (Quinteiro et al., 2012).

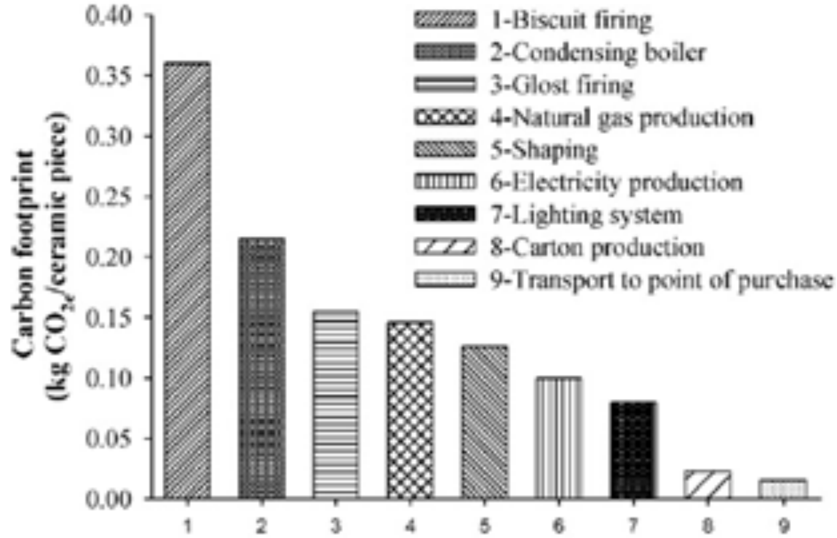

FIGURE 3: CO_2 emissions during different stages of unit processes (Source: Quinteiro et al., 2012)

3.1.2 Energy Consumption

The ceramic piece consumes a total of 8.19 KWh energy during its lifecycle. Figure 3 breaks down the energy consumption during different stages of unit process.

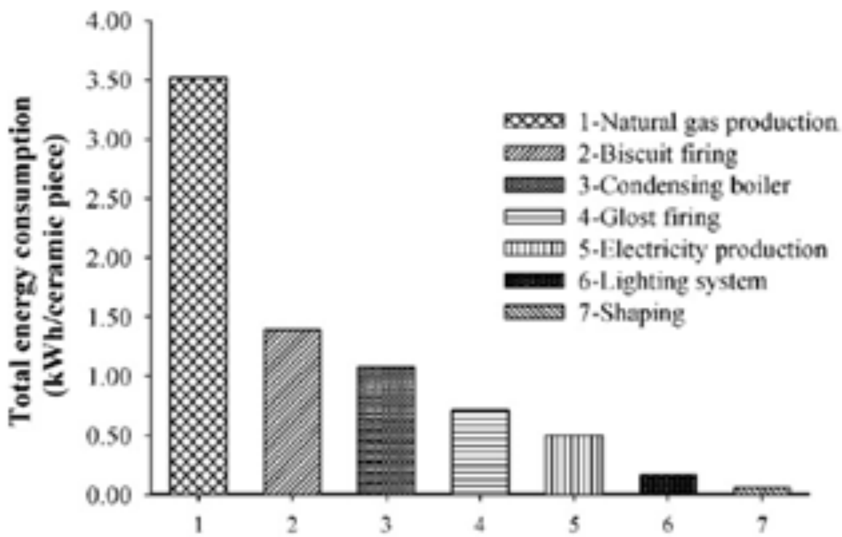

FIGURE 4: Energy consumption in unit processes (Source: Quinteiro et al., 2012)

3.1.3 Recycling

In the production of the ceramic tiles some companies use even up to 20% from alternative, recycled and secondary sources materials. As an example even the waste mud from ceramic tile production as the main component in paving blocks (Wattanasiriwech et al., 2009).

3.1.4 Lifespan

When evaluating the impact of ceramic tiles we need to look beyond the production phase. The long life span of the ceramic tiles is a great indicator of their durability. Ceramic average lifetime is around 50 years which make this type of flooring long lasting and robust (Aksamija, 2010).

3.2 ECONOMIC IMPACT

3.2.1 Purchase and Installation Cost

There are many factors affecting the final price of installing ceramic tiles. The difference in material prices, tile sizes and installation patterns (straight or diagonal) are some of the biggest aspects that drive the price.

In Table 1, the different prices of various types of ceramic tile flooring needed to cover 1000 square feet (almost 100 square meter) are compared. 100 square meters is the estimated size of the cafeterias in Totem and Vanier. This data is based on the average price of ceramic tiles in 2013 in Seattle, WA, which is almost identical to the prices in Vancouver.

	Basic	Better	Best
Material prices	$1,250-$2,825	$2,600-$4,400	$4,175-$5,750
Installation Cost	$3,381 -$5,265	$5,001 -$6,761	$6,463 -$8,747
Total cost	$4,631 -$8,090	$7,601 -$11,161	$10,638 -$14,497
Total Average Cost per square foot	$6.36	$9.38	$12.57

TABLE 1: Average prices of ceramic tiles per square foot. (Calculated using: HomeWyse)

For a medium quality ceramic tile, the total cost of installing for 1000 square feet is going to be between $7,601 and $11,161.

3.2.2 Lifecycle cost

The tile council of North America conducted a life cycle cost study comparing various kind of flooring including ceramic tiles. The study showed that ceramic tiles cost less than $0.40 per square foot per year. However, vinyl flooring with the lifecycle cost of $1.83, is significantly more expensive due to its shorter lifetime span. Since this study was conducted in 2005, in order to get the up to date price we have to take into account the inflation rate between then and 2013. After calculating the new prices, the lifecycle cost of ceramic tile ended up being $0.5 per square foot while vinyl flooring is $2.20.

Based on this study, the lifecycle cost represent the installation cost, maintenance costs and removal cost of each material over each product's lifespan (Floor Covering Comparison, 2005).

3.3 SOCIAL IMPACT

3.3.1 Slipping Factor

Slip resistance is an important factor to reduce the accident rates. Since there are high standards for hygienic environment in food services areas, floors might be wet constantly due to the regular cleaning schedule. Coefficient of friction is a metric value used to gauge the slipperiness of a surface. The bigger the coefficient of friction, the harder it is to slipp. "Smooth glazed tiles offer little slip resistance when wet. With grit, ceramic tile offers COFs of 0.62 when dry and 0.34 when wet. Without grit, ceramic tile measures 0.7 when dry and 0.1 when wet" (Nick Gromicko, par. 4).

3.3.2 Silicon Dust

Ceramic tiles can contain up to 14 to 18 percent silicon dioxide dust that can be harmful and a health hazards. Cutting tiles can release this dust into the air causing lung cancer.

3.3.3 Mold

Mold and mildew can be formed around ceramic tile, especially in wet locations as would be found in food service areas like kitchen floors. Mold spores can be harmful to one's health and cause issues like asthma and skin rashes.

3.3.4 Indoor Air Quality

Most exposure to environmental pollutants is through breathing. Aksamija (2010) measures the TVOC of ceramic tiles versus vinyl flooring and found that the TVOC grams in use of ceramic tiles are significantly less than vinyl flooring. The linoleum section of this report will give a further comparison between different flooring types.

4.0 LINOLEUM

Linoleum is a floor covering that was invented in 1860 and has been in continuous use since 1864. It consists of a binder made from linseed oil and/or vegetable drying oils and rosin mixed with wood flour and/or cork, inorganic filler and pigments, on a carrier of jute or canvas.

4.1 OVERVIEW OF PRODUCTION

Linseed oil is derived from the flax plant. The oil is used as the binder in linoleum. It is catalytically oxidized and polymerized with air which produces an elastic mass that is mixed with colophonium, a resin derived from pine trees. This forms a cement mixture that is first matured and then mixed with powdered cork, powdered wood, powdered limestone and pigment. The wood and cork provide resilience and the limestone acts as mineral filler. Traditionally titanium oxide has been used as the main source of pigmentation in linoleum processes. After the mixing process the mass is made granular and then fused to a backing of jute or canvas using pressure and heat. The resulting sheets require two to three weeks drying time after which they are coated with a thin layer, usually acrylate, and then prepared for sale by trimming and rolling (Jonsson & Tillman & Svensson, 1996).

4.1 ENVIRONMENTAL IMPACT

4.2.1 Life Cycle

The growing of linseed, transport and energy used for production are the primary factors impacting an environmental assessment of linoleum. It is classified by the USDA as a 100% Bio-based product so consideration of factors like pesticide and fertilizer use are included in its environmental impact.

One significant variable in the environmental assessment of linoleum is the use of titanium oxide as a pigment. This was considered to have a significant impact on the environmental profile of linoleum (Jonsson & Tillman & Svensson, 199\). However, they also state that manufacturers have provided information on use and impact and there have been moves to use alternative pigments with less impact.

4.2.2 Global Warming Impact

The global warming impact of linoleum as assessed in Figure 6 is 576g of CO2 per unit. This provides the lowest global warming impact of the floor coverings examined in this report. Linoleum also provides the best profile for fossil fuel depletion, 1.92MJ/Unit, Figure 7 and it's 40% use of renewables in the embodied energy analysis, Figure 8, provides a superior energy profile although it's overall usage is slightly higher than VCT, at 25.64 MJ/Unit compared to 22.75 MJ/ Unit.

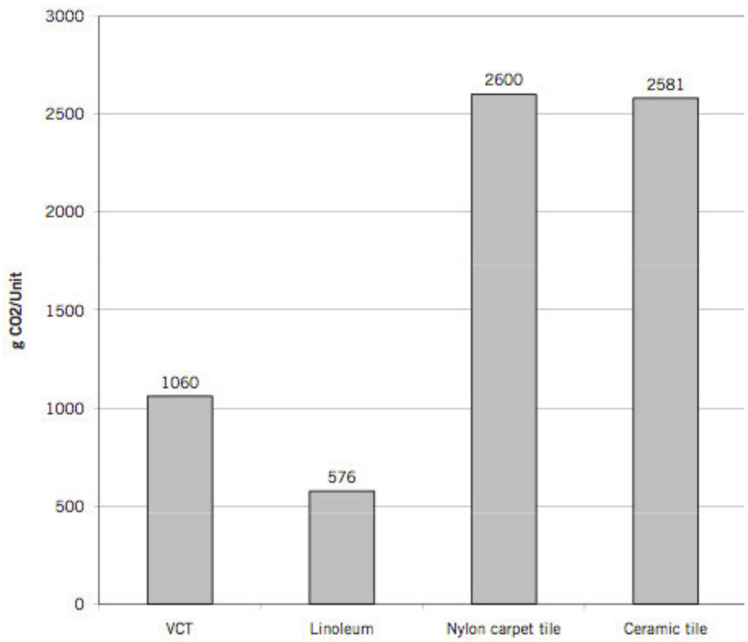

FIGURE 5: Grams of Carbon Dioxide released per Unit during manufacturing process. (Source: Aksamija, 2010)

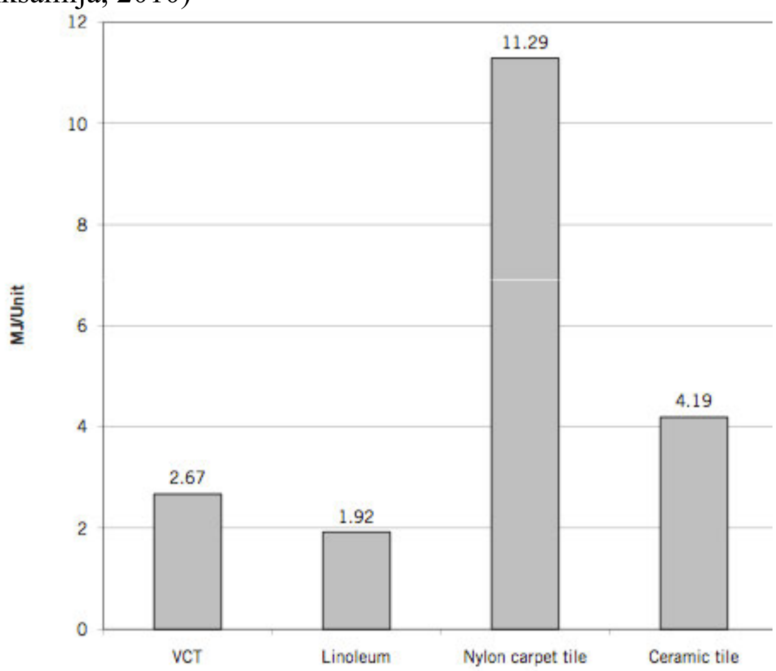

FIGURE 6: Fossil Fuel Depletion in Mega-Joules per Unit of production. (Source: Aksamija, 2010)

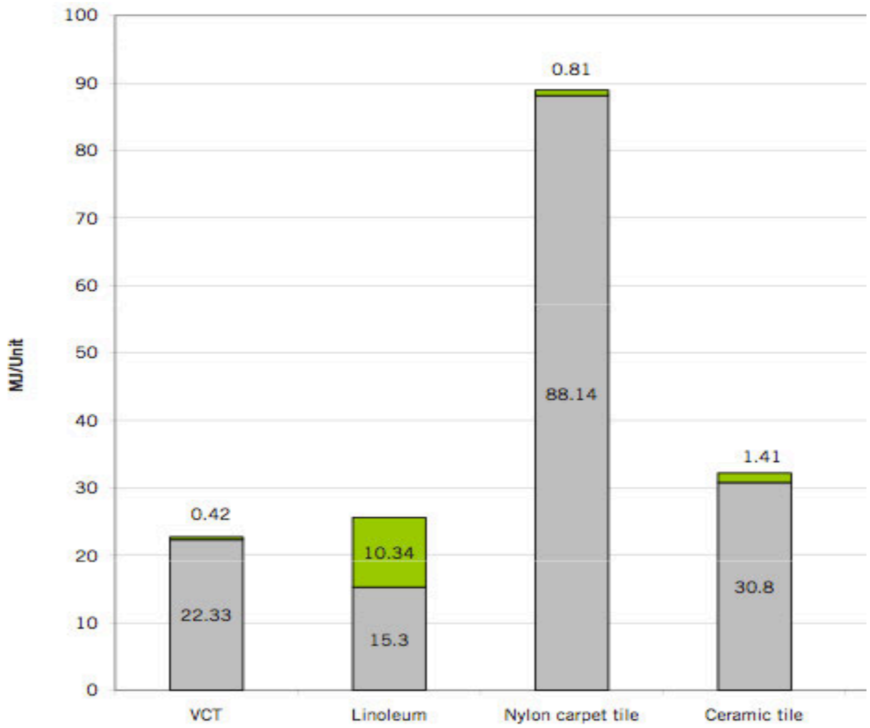

FIGURE 7: Embodied energy of the materials measured in Mega-Joules per Unit of production. Green bar indicates renewable energy of the material. (Source: Askamija, 2010)

Linoleum also has the best profile for acidification during production, Figure 9, with 530.79 mg H+/ Unit. Another important contributor to environmental impact, as acidification is another indicator of the level of CO2 emissions.

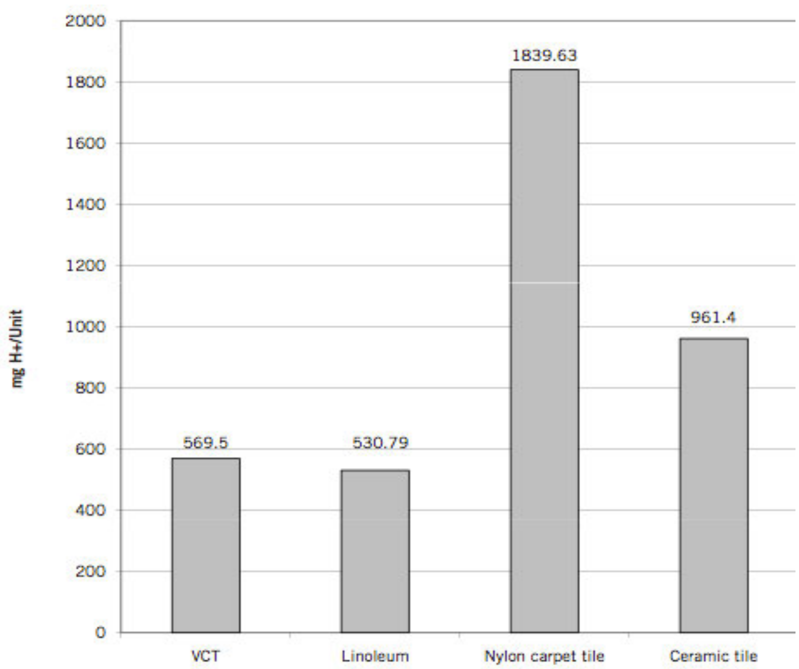

FIGURE 8: Acidification during manufacturing given by mg H+ per Unit. (Source: Aksamija, 2010)

4.2.3 Post Life and Disposal

Forbo-Krommenie B.V, the largest manufacturer of linoleum in the world claim a 100% incineration capacity for the product which would give a zero emission profile and offer potential energy source in a waste incinerator designed for energy production, although Gorree et al. (2000) point out that the figure may be optimistic and it is not independently verified. Because of its high renewable content (80%) linoleum also has the potential for composting (Lent, 2009). Both options provide significant post-use benefits over PVC flooring.

4.3 ECONOMIC IMPACT

4.3.1 Purchase Cost

Linoleum is more costly to purchase and install than Vinyl flooring. The costs relate to the raw materials used, which are currently more expensive based upon agricultural production of raw materials, and the requirement for professional installation, which requires heat bonding on site. The representative cost for installed linoleum quoted by HomeWyse is $2.73 per square foot.

4.3.2 Maintenance Costs

Linoleum is a low maintenance product but due to the long lifespan of the product small variations in maintenance patterns can have significant impact on the economic analysis of the product. A comparison between Dutch and Swedish maintenance programmes in (Gorree et al., 2000) reveals entirely different methodologies that would result in significantly different lifetime costs. For the purposes of this assessment we were not able to discover how the flooring would be maintained at UBC so were unable to determine exact costs. However, assuming a maintenance programme as recommended by North American suppliers, Linoleum is likely to be cheaper than vinyl flooring to maintain.

4.3.3 Lifespan

The expected lifespan of linoleum is 30-40 years. Assuming an average building lifetime of 50 years this would require one full replacement of the flooring. This would require a cost between $4100-$7684 for an area of 100 square meters. Table 2 outlines the overall cost comparison for the 3 materials this report concerns. The last line takes into account the total cost per square foot over 50 years, given that linoleum would need to be re-installed twice, PVC four times, and ceramic tiles would not need to be re-installed.

	Linoleum	PVC	Ceramic tile
Material Prices ($/sq ft)	1.408	2.208333	2.0375
Installation Costs ($/sq ft)	1.324	0.195833	3.70833333
Total Cost per square foot ($/sq ft)	2.73	2.4	5.75
Average Life Time (years)	35	15	50
Cost per square foot per year ($/sq ft * year)	0.078	0.16	0.115
Cost per square foot for 50 years ($/sq ft)	5.46	9.6	5.75

TABLE 2: Overall cost comparison for the 3 materials in this report. (Calculated using: HomeWyse)

4.4 SOCIAL IMPACT

4.4.1 Health Concerns

In modern building designed for energy conservation the circulation of air is an important social factor. Volatile organic compounds are known to have significant health impacts and it is important to minimize public exposure from building materials. Linoleum has the best profile of Total volatile organic compounds on air quality in this comparison; releasing 0.0037 g tvoc/Unit, Figure 10.

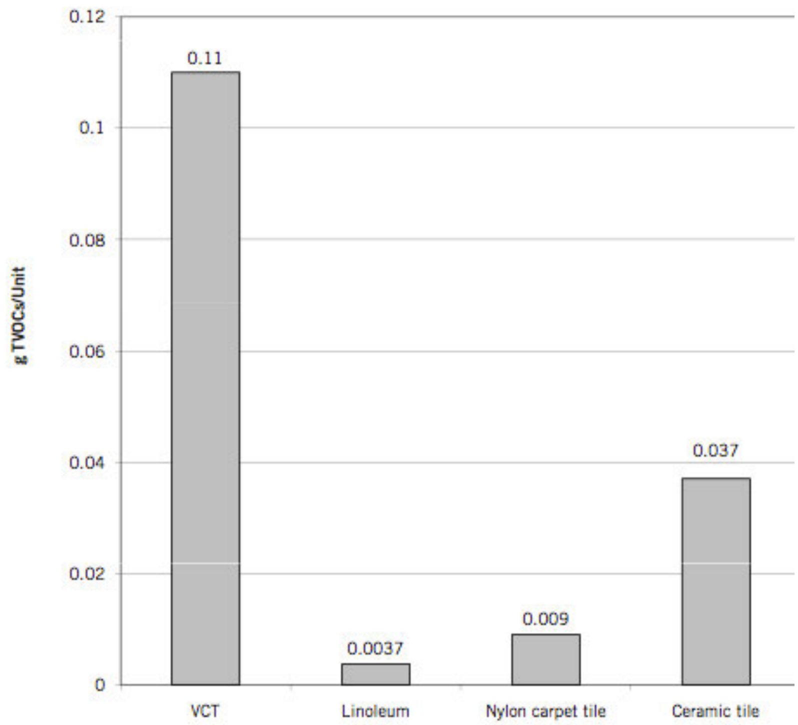

FIGURE 9: Indoor air quality measured by grams of total volatile organic compounds released during life span. (Source: Aksamija, 2010)

According to Forbo-Krommenie B.V Marmoleum sheet technical data, their linoleum meets or exceeds A.D.A recommendation of 0.6 for slip resistance for flat surfaces, has an Impact Sound Reduction of 6db, is naturally resistant to bacteria and has anti-static properties.

4.4.2 Labour Effects

With most linoleum being produced in either Europe or North America there are few concerns for social and labour factors regarding the entire lifecycle. Armstrong in the US has a strong corporate responsibility strategy, and published environmental goals. Forbo-Krommenie B.V, the world's largest manufacturer, has an extensive social and environmental impact programme that demonstrates a commitment to improving the sustainability of their product throughout the lifecycle.

5.0 CONCLUSION AND RECOMMENDATIONS

After examining the social, environmental and economic impacts of PVC as well as the alternatives linoleum and ceramic tiles for use in food service areas on the UBC campus, it is difficult to determine if alternatives to PVC flooring are realistic to implement.

Environmentally, PVC was found to have higher impact on global warming, and it is only 3% recyclable as opposed to linoleum, which can be up to 80% recyclable. PVC was outperformed slightly in all environmental measures touched on in this report.

Socially, raising awareness about the hazards of PVC toxins both in manufacturing as well as use in food service areas will lead to change. The health concerns of PVC include the many gases and toxins released during its life cycle are impacts that should not be included in any food service area.

Economically, it was found that the initial installation costs of PVC are very attractive, however when we take into account the re-installation over an average building lifespan of 50 years, PVC would need to be re-installed 3-4 times. This actually leads to an overall life cycle cost for PVC that is in fact greater than those of the linoleum and ceramic tile alternatives.

It has been shown, however, that the long decision making process in place, as well as the ease of installation for PVC are obstacles that are hard to overcome when considering realistic implementation of any alternatives. It is hoped that this report can provide information on the alternatives available through a triple bottom line assessment of both linoleum and ceramic tiles. Our best recommendation is that linoleum be considered as the primary possible alternative to PVC in future food service areas on the UBC Vancouver campus.

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APPENDIX A

Questions asked during primary investigation: (challenging questions we have determined that are important for future investigation to determine whether implementation on UBC Vancouver Campus is feasible)

1) Are there specific criteria for UBC food services flooring? We know about the BC building code and UBC technical guidelines; are there other guidelines that you follow?
2) Have you thought about using alternatives to PVC flooring? If so, which ones?
3) Is there any way that we can have an estimate about how much PVC is being used in UBC food service areas?
4) Who is in charge in deciding what materials to use for floors in food service areas?
5) What cleaning criteria do you have while cleaning the floor? (What chemicals?)
6) How often do you clean the floor? (Preparation and serving areas)
7) Any reported accidents due to the flooring?
8) What does UBC consider important for flooring in kitchen and food service areas? (Safety, how it feels, cleaning, installation, etc.)