UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

Feasibility of Using the Red List of Materials:

A Focus on Avoiding PVC Usage for UBC's SUB Project

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GLOSSARY OF TERMS AND ABBREVIATIONS

Abrasion	The process of wearing away by friction
ANSI/NSF	ANSI stands for: The American National Standards Institute that focuses on enhancing quality of life. NSF International, The Public Health and Safety Company, is the world leader in standards development, committed to public health, safety and protection of the environment. ANSI/NSF is a standard proposed by ANSI and NSF to check chemical contaminants and impurities that are associated to the delivery of drinking water.
ASTM	ASTM International develops international standards for materials and systems used in construction and manufacturing.
ASTM F876	A standard set by ASTM that applies to PEX tubing. Highlights of the standard include testing for dimensions and tolerances, density, sustained pressure, burst pressure, environmental stress cracking, degree of crosslinking and stabilizer functionality
AWWA C904	Stands for American Water Works Association. The C904 standard includes criteria for classifying PEX plastic pipe materials and evaluates the dangers.
CSA B137.5	CSA stands for the Canadian Standards Association. Standard B137.5 provides requirements for PEX pressure tubing systems in the following areas: materials, quality of work, tubing, fittings, interior liners, dimensions and hydrostatic capability.
ASTM F877	Another standard for PEX with criteria for the following: materials, workmanship, dimensions, tolerances, burst pressure, sustained pressure, excessive temperature/pressure, temperature cycling tests, and bend strength. Also included are tests for system malfunctions.
Fittings	Used in pipe/plumbing systems to connect straight pipe or to join different tubing sections
HDPE	High Density Polyethylene
LEED	Stands for Leadership in Energy and Environmental Design. It is an ecology-oriented building certification program, which concentrates on the following: energy efficiency, indoor environmental quality, materials selection, sustainable site development and water savings.
PEX	Cross-linked Polyethylene
Plasticizer	An industrial compound that when added, affects the physical properties of a substance, making it more plastic

Propylene Monomer	A colorless gas with melting point of − 185.2 °C and boiling point of − 47.6 °C. It's molecular formula is C_3H_6
Stabilizer	A chemical compound added to another substance to make it resistant to change
Tensile Strength	The maximum stretching force that a material can withstand before breaking
Thermosetting	Describes a plastic that sets permanently when heated

1.0 INTRODUCTION

The University of British Columbia (UBC) has stated that they would like to apply the Cascadia Living Building Challenge's Red List of Materials in the construction of the new Student Union Building (SUB) at the Vancouver campus. The red list comprises of building materials that throughout their lifecycle may pose significant health or environmental concerns. Although highly popular among the construction community, Polyvinylchloride (PVC) has landed on Cascadia's red list. PVC reduction and elimination has become a priority for many government institutions, healthcare organizations, and design firms due to the serious environmental health impacts in every stage of the PVC lifecycle. Recent Olympic venues such as the Sydney Olympic Stadium and the Olympic Village constructed for the Sydney 2000 Olympic Games, made a huge undertaking to insure that no PVC was used in any of the permanent fixtures within the building. However, the Center for Interactive Research on Sustainability (CIRS) building that is to serve as a model for UBC's sustainability measures, has not made the same effort for eliminating the use of this harmful material. We believe that the new student union building could do better than this, and since the pipe market represents more than half of total PVC use in the United States (Harvie, 2002), the focus will be on eliminating PVC used for interior plumbing. This paper will examine plastic, metal, and natural pipe options by assessing the combined economic, social, and environmental impact of each material (Figure 1) to suggest the best replacement for PVC plumbing to the designers of the SUB.

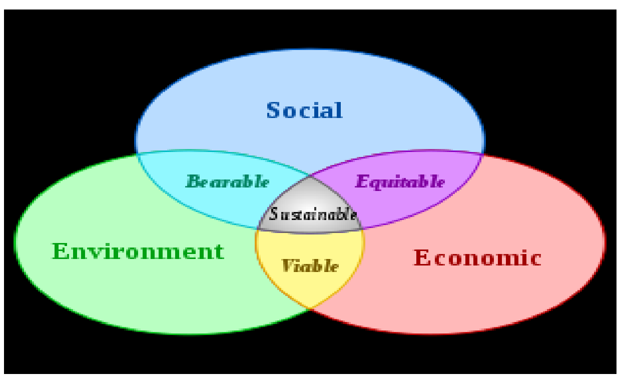

Figure 1: Triple Bottom Line Assessment
Source: (Wikipedia, 2010)

2.0 AN OVERVIEW OF PVC

2.1 The PVC Issue

Due to the overwhelming flexibility of PVC, its low cost and durability, it is obvious why PVC is the industry standard. Through interviews conducted by Professor Meg Calkins for an article in the March 2006 edition of the Landscape Architecture Magazine, it is revealed from contacting various landscape architects and engineers that more than half were unaware of the problems caused by PVC. Most admitted that PVC is their material of choice for construction. Calkins also quotes from Steve Benz, a ***LEED*** accredited professional, that "[Engineers] don't hear much in the trenches about the pitfalls of PVC use. The average civil engineer probably doesn't even know it's an issue." (Calkins, 2006) So why is PVC considered a product of choice by so many engineers without a second thought for its environmentally damaging potential? Calkins explains that "PVC is a good product for water lines that are pressurized; it has good ***tensile strength***, it is rigid, but when flexibility is needed, ***plasticizers*** or various other additives can be added to create a flexible pipe." (Calkins, 2006) Compared to many alternatives, PVC piping is lightweight compared to cast iron and many PVC ***fittings*** are readily available.

2.2 Health and Environmental Effects

The issues caused by PVC are extensively studied by scientists, currently with emphasis making engineers aware of the issue. In "Environmental Impacts of Polyvinyl Chloride Building Materials," a report published by Dr. Joe Thornton, a research scientist at Columbia University, it is revealed that PVC is environmentally damaging in every stage of its lifecycle. Thornton explains that PVC, unlike other plastics, contains 57% chlorine, consuming about 40% of total worldwide chlorine production. (Thornton, 2002) Chlorine gas is classified on the Environment Protection Agency's (EPA) list of extremely hazardous substances as it is highly dangerous when inhaled.

In addition, standalone PVC is known to be rigid and brittle, useless in the sense of construction. It is through adding large amounts of plasticizers and additives that PVC can be enhanced into something useful. However, adding these additives lead to health and environmental issues, as these additives are not bound to the plastic and are known to leach out. One type of plasticizer, phthalate, is a known carcinogen, mimicking human hormones and causing infertility and abnormal development. In support, Calkins reveals that plasticizers are added in amounts of up to 60% of the product's weight in order to make flexible hosing for piping applications (Calkins, 2006).This large amount and the fact that phthalate plasticizers are not chemically bonded to PVC means the plasticizer will leach into the air or water, causing adverse environmental effects.

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*__Note:__ *Glossary terms* **are bolded and italicized on their first appearance in the report**

Other additives, such as lead and heavy metal ***stabilizers*** are often added to PVC to extend its life. Common PVC additives added are lead, cadmium and organotins, each proving to be particularly hazardous. In Dr. Thornton's analysis of metal stabilizers, he lists the following impacts:

1. Metals do not degrade in the environment, often resisting environmental breakdown.
2. Metal stabilizers are highly toxic: lead damages human cognitive ability with small doses, cadmium is a neurotoxin and carcinogen, and organotins degrades human immunity while disturbing the endocrine system.
3. Most importantly, metal stabilizers are released throughout the PVC lifecycle.

In support of point 3, Wikipedia states that metal stabilizers are released from vinyl products during the formulation, use and disposal stages of its lifecycle—metals cannot be incinerated, they can be emitted into the air through air emissions or ash residues (Wikipedia, 2010). It is also known that with accidental fires in buildings and landfills, excessive amounts of pollutants can be released into the environment. Figure 2 below, from Greenpeace, outlines some dangers associated with the PVC lifecycle.

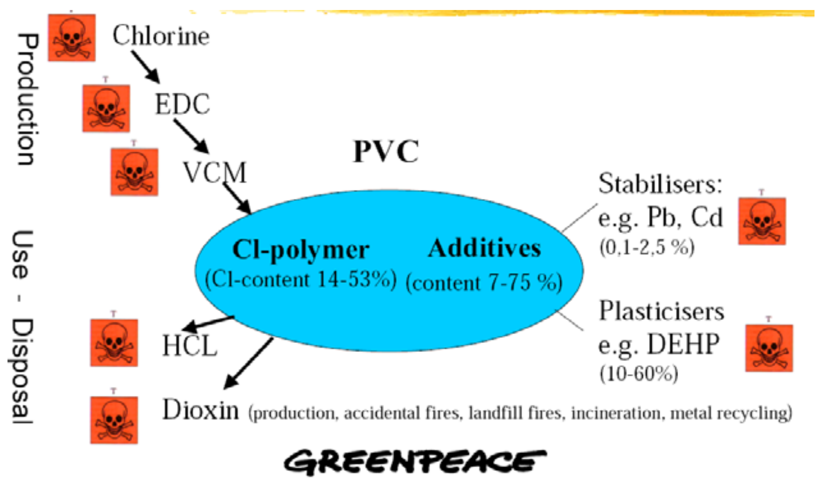

Figure 2: PVC Lifecycle Dangers
Source: (Greenpeace, 2000)

To summarize, PVC is known for its high chlorine and additives content, which makes it an environmental poison throughout its life cycle. It is a human carcinogen, is known to leach additives and is known to release dioxins during manufacture and disposal. The list presented above is not an exhaustive list of PVC impacts (for a complete list, refer to (Thornton, 2002)). The point of this section is only to provide a brief overview of the dangers of using PVC, and to encourage a mindset into switching to greener alternatives. The subsequent sections will highlight more sustainable plastic, metal and natural alternatives to PVC plumbing.

2.3 Efforts to Reduce PVC Usage

In an effort to reduce PVC usage, one prime example would be the Sydney 2000 Olympic Games. For the Olympic village and the Sydney Olympic stadium, all building material options have been assessed using lifecycle costing analysis, selecting materials for their contribution in minimizing pollution and conserving resources. The rationale was that if it can be done at the Olympics, it can be done anywhere. In a book published by the Centre for Olympic Studies at The University of New South Wales, it is outlined that lifecycle costing analysis consists of the following considerations.

1. Energy used in manufacture, maintenance and disposal
2. Use of recycled materials in their manufacture/fabrication
3. Their ability to be recycled/reused
4. Toxicity of the material and by-products from manufacture
5. The effect of the material on the environment
6. Maintenance required
7. Thermal capabilities

The book also highlights that the principal initiative of designing the Olympic village was to reduce PVC use by 40%. The Olympic village was therefore constructed using PVC free electrical cabling, alternative floor finishes (such as timber) and alternative piping materials to PVC (such as vitreous clay, fibre cement and ***high density polyethylene (HDPE)***) (Centre for Olympic Studies, 1998). In a report compiled by Greenpeace International, it is shown that in completing the Olympic Athlete's Village, builders managed to reduce PVC use by 80% compared to regular housing construction (Greenpeace, 2003). The other 20%, as the report unveils is due to outdated government and health regulations, which only specify PVC for use. If these regulations are updated, almost all of the PVC in the village can be avoided. In the Sydney Olympic stadium, polyethylene was used for plumbing, drainage and seating, completely avoiding PVC. In addition, Teflon coated glass fibre was used in the main arch shading membrane instead of PVC while the roof was constructed using translucent polycarbonate.

In building projects, many safe alternatives can be considered. However, governments are regulated differently in different countries, some with outdated policies on PVC. For instance, the SMZ Ost Hospital in Vienna is almost entirely PVC free due to the Austrian government's PVC Working Group placing strict policies on construction with PVC. According to the Greenpeace list of PVC Policies Worldwide, Canada currently has no policies or restrictions on PVC construction (Greenpeace, 2003). This means that the University of British Columbia's new SUB building can be constructed virtually PVC free, setting a prime example for the world as one of Canada's leading institutions. In addition, Canada should consider establishing PVC construction laws, like Austria, by setting up community based committees to manage local construction projects. UBC's SUB project can contribute to promoting the idea, by setting up student teams to ensure that the recommendations of UBC's

APSC 262 projects are considered. These efforts should also be made publicly aware, such that similar efforts can be in place for the Canadian government.

3.0 METAL ALTERNATIVES

3.1 Copper

Copper has a long history of being used for pipes and the practice of using copper plumbing systems is well known by plumbers. Assembly of even the most complicated copper plumbing designs can be implemented due to the large variety of copper fittings available on the market (Figure 3).

Figure 3: Copper Fittings
Source: ("Copper fitting," 2008)

Copper is an essential mineral in the diet and to be beneficial for human health, The National Academy of Science recommends 2-3 mg of copper in the daily diet. Too much copper, however, can cause serious health problems including nausea, vomiting, diarrhea, and intestinal cramps. Corrosion of copper pipes used for supplying water leads to leaching from the copper pipes into water supplies and can be harmful to human and aquatic life. “Health studies have found that copper in drinking water can add 4 to 45 percent more copper to a person’s diet than what is in food sources” (Washington State Department of Health, 2006). Although residential copper plumbing systems have been shown to last for many years under certain conditions, if the pH of the water to be run through it is lower than 6.5, acidic and otherwise aggressive water deteriorates copper from the inside out while adding copper to the contained water. A study conducted by an American home inspection company has also found that the orientation (Figure 4) and temperature of the water carried (Figure 5) also affect the corrosion resistance of the copper plumbing (Walker).

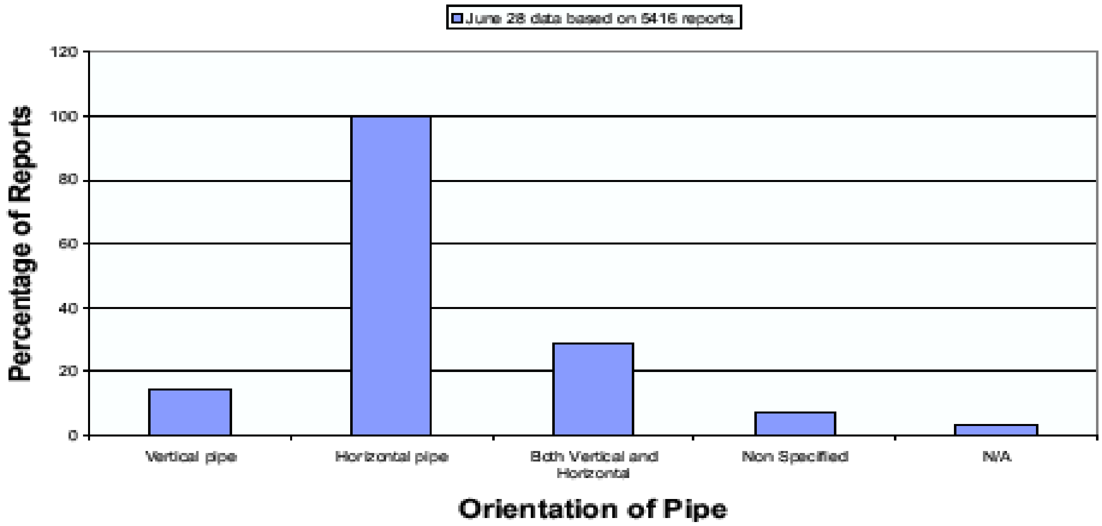

Figure 4: Orientation of Copper Pipe in House Where Pinhole Leaks Were Found Source: (Walker)

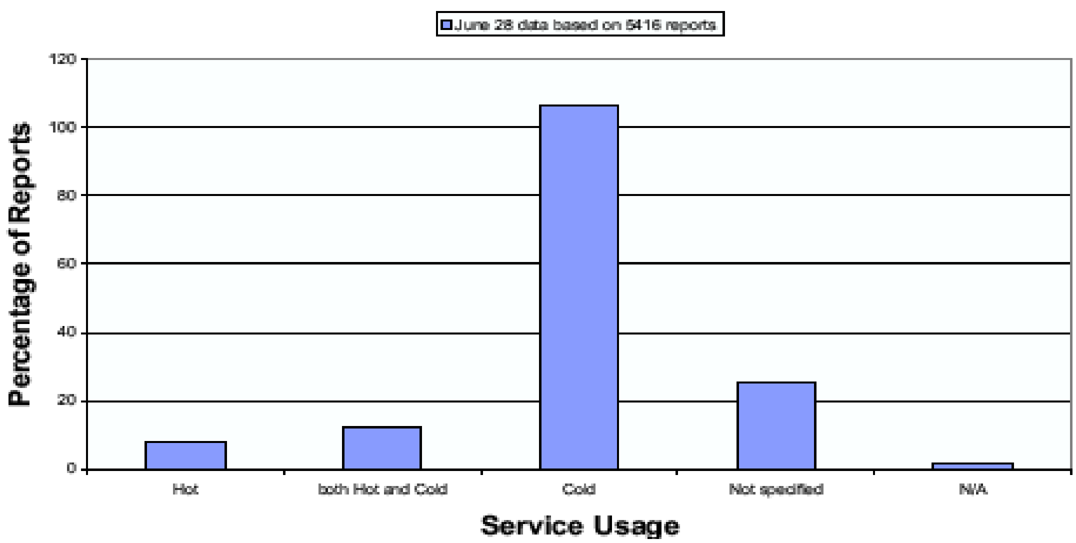

Figure 5: Copper Pipe Service (Hot or Cold Water) Where Pinhole Leaks Were Found Source: (Walker)

Despite the fact that copper is highly recyclable, to meet the market demand for new copper pipes, copper ore needs to be extracted and refined from mining the earth using environmentally destructive procedures. Therefore, due to the detrimental effects that corroding copper pipe has on the environment as well as on human and aquatic health, it is recommended that when using copper pipes, one should avoid long horizontal pipe sections containing cold water and they should not be used to deliver drinking water.

4.0 PLASTIC ALTERNATIVES

PVC is perhaps the most popular and widely used of all plastics for piping and plumbing applications today. As a plastic, PVC is known for its light weight, high strength and low reactivity for piping applications. According to Greenpeace's Pyramid of Plastics (Figure 6), PVC is the most environmentally damaging.

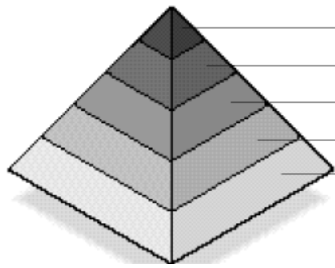

Figure 6: Greenpeace's Pyramid of Plastics
Source: ("Building the Future")

However, Greenpeace also states that "the addition of toxic additives can significantly change the environmental impacts of a plastic, which would significantly increase the plastic's hazard level and change its position in the pyramid." ("Building the Future"). In the following subsections, we will propose two alternatives to PVC, polyethylene and polypropylene, which are identified by PE and PP on the pyramid, respectively. As seen in the pyramid, both these alternatives are more sustainable.

4.1 Polyethylene

4.1.1 High Density Polyethylene (HDPE)

Unlike PVC, HDPE is non-chlorinated, requiring fewer additives and therefore resulting in a higher recycling rate. HDPE is also classified as not ***thermosetting***, therefore it is easily recyclable. Intrinsically, HDPE is highly resistant to many different solvents, making it a perfect alternative for piping. HDPE is also able to withstand temperatures of up to 120 °C for short periods and 110 °C continuously, while inversely, the material gets stronger the colder it gets. HDPE is more durable, usually lasting much longer than PVC. In addition, HDPE is also very flexible, where it is as simple as bending the pipe to fit the twists and turns of a piping system—this also reduces the number of fittings. Equally resistant to chemical corrosion compared to metal or concrete, HDPE is highly ***abrasion*** resistant, while PVC is not as resistant to abrasion. In contrast, PVC is generally stiffer than HDPE pipe, making it more brittle and vulnerable to shipping and handling damage. Moreover, HDPE's flexibility makes it less likely to rupture from construction and freezing around the pipes. Oxford Plastics Inc, a company stationed in Ontario compared the properties of PVC vs HDPE in figure 7 (Oxford Plastics, 2003).

	PVC	HDPE
Durability	Decades	Decades
Joining	Solvent	Fusion
Joint Integrity	Leak Free	Leak Free
Weight	Light	Lighter than PVC
Flexibility	flexible	flexible
Internal Wall Smoothness	Good	Good
Tensile Strength	Fair	Fair
Abrasion Resistance	Fair	High
Chemical Resistance	Fair	High
Impact Resistance	Fair	High
Fire Resistance	Fair	Fair
Operating Temperature	-40°C to +65°C	0°C to +60°C

Figure 7: Oxford Plastic Inc's Comparison of HDPE with PVC
Source: (Oxford Plastics, 2003)

One downside to HDPE is that it is generally more expensive than PVC, however this is not always the case. Professor Calkins cites a study for the city of Seattle, in that the city's irrigation project saved $2,170 for 31,000 feet of pipe, with the PVC cost being $.76 per foot and the HDPE cost being $.69 per foot (Calkins 2002). An irrigation company stationed in Alberta, compared PVC and HDPE piping systems on golf courses and summarized their advantages/disadvantages (BlueGrass Irrigation Consulting).The company's results are outlined in figure 8.

PVC PIPE		HD POLY PIPE
	(1) Design Characteristics	
100%	Same Size Pipe Flow @ 4 fps Water Velocity	80% of PVC flow
Same	Timed Static Pressure Rating (no surge or flow in pipe)	Same
Less than Static	Working Pressure Rating (surge & flow events in pipe)	Greater than Static
More	Availability of Pipe / Fittings	Less
	(2) Installation Characteristics	
Shorter	Time to Install Mainline (4" & Larger size)	Longer
Longer	Time to Install Laterals (2" – 3" size)	Shorter
Mechanical	Mainline Pipe Joining Method	Butt Fusion
Saddle	Mainline to Lateral Connection Method	Side Wall Fusion
Glue - Gasket	Fittings Used on Laterals to Sprinklers	Saddle
Required	Thrust Restraints / Thrust Blocks	Not Required
Yes	Need for Proper Alignment of Pipes	No, Able to Curve
Yes	Need for Proper Backfill Material Around Pipes	No
	(3) Maintenance Characteristics	
Breaks	Durability (Ice In or Around Pipe / Soil Movement)	Will not Break
30 Years	Life Expectancy of Pipe & Fittings	50 Years Minimum
Difficult	Repairing Leaks / Breaks on Mainline	More Difficult
Easy	Repairing Leaks / Breaks on Laterals	Easy
	(4) Cost	
Less	Initial – Capital Cost	More
More	Long Term – Operating Costs	Less
	(5) Overall Rating	
Good	Evaluation Over Time	Best

Figure 8: BlueGrass Company's Comparison of HDPE and PVC Pipe
Source: (BlueGrass Irrigation Consulting)

From the figure, it is clear that HDPE is the better alternative. That, and the fact that HDPE is more environmentally friendly, cheaper and more durable justifies a cause for using HDPE for piping in UBC's new SUB building.

4.1.2 Cross-linked Polyethylene (PEX)

PEX has many characteristics similar to HDPE, with the difference being that its molecules are cross-linked to improve its ability to withstand high temperatures. Like HDPE, PEX is flexible, making it easy to install and service. PEX is also able to withstand high and low temperatures, and is highly resistant to chemicals found in plumbing applications. Unlike copper, the smooth interior of PEX systems will not corrode, and unlike PVC, additives injected into PEX are less likely to leach due to stronger chemical bonds. In addition, PEX is manufactured and tested according to strict national standards ***F 877, AWWA, C904, CSA B137.5*** and ***ASTM F 876***, while going through required routine quality control and quality assurance evaluations to ensure the product meets ***ASTM, ANSI/NSF*** International and ***CSA*** standards before being marketed (PPFA). PEX is expected to perform as long as copper and longer than PVC, however, it is not designed to be exposed to direct sunlight. Therefore PEX is not intended for outdoor applications and must be stored in a sheltered environment. In addition, PEX is significantly cheaper than copper pipe, but fittings, especially larger ones can get expensive. However, due to PEX being very flexible, fewer fittings are needed because PEX is able to bend and twist anyway to route, saving labor. Therefore, in sheltered applications requiring easy installation and material characteristics most like PVC, it is recommended that PEX be used.

4.2 Polypropylene

Polypropylene is currently titled the "material of the future" by many notable articles due to its ecologically clean reprocessing of greenhouse gases, the fact that it is one of the most neutral plastics, and that it is 100% recyclable. Polypropylene is manufactured using ***propylene monomer***, a relatively safe gas, which is a waste product of the petroleum industry that gets burned off into the atmosphere to contribute to greenhouse gas emissions. As a result, the production of polypropylene contributes to minimizing greenhouse gas emissions. When polypropylene is combusted, the only byproducts are carbon dioxide and water, making it dramatically more environmentally friendly than PVC (Albox, 2008). In addition, polypropylene is able to withstand high temperatures, with a melting point between 130–171 °C (Wikipedia, 2010). However, it is also known to be less sturdy compared to polyethylene, making it less applicable to piping applications requiring high tensile strength. It is also known that polypropylene experiences degradation with exposure to UV radiation (ie: sunlight). Such degradation usually shows up as fine cracks and crazes which becomes more severe depending on time of exposure (Wikipedia, 2010).

In the November edition of Engineered Systems magazine, polypropylene was used by Westbrook Service Corporation to repair the piping system of a Florida retirement community. Westbrook's general manager, Don Hammond, proclaimed "Using the polypropylene made everything go super quick—we just fused it and let it set for a few minutes, where with the PVC, we had to let the glue set for 24 hours, and that alone saved a day on the job." According to Hammond, the estimation of savings was 11 man days per riser, with 40 risers on the job, saving roughly 10-15% in first costs ("What to Do," 2009). In sheltered piping applications that does not require high tensile strength, it is highly recommended that polypropylene be used because polypropylene is flexible, saving installation time/costs and is very environmentally friendly compared to PVC.

5.0 NATURAL ALTERNATIVES

5.1 Bamboo

The natural tubular shape of bamboo makes it stand out as an abundant natural and renewable resource that could be used for plumbing purposes. Depending on the species of bamboo, some bamboo are known to develop within 3 years, growing in excess of 50 feet and having up to a 6 inch diameter (Figure 9).

Figure 9: Bamboo Plants
Source: ("Clumping bamboo")

A difficulty with bamboo is that they are subject to attack by rot fungi and wood-eating insects. Bamboos with higher moisture and starch content are found to be more prone to attack, and insect pests (US Department of Agriculture, 1963). A test of mechanical and physico-chemical properties of bamboos carried out by the aerospace engineering department at the Indian Institute of Technology found that Phyllostacys Bambusoides (Japanese Timber) was lowest in both moisture and starch, followed by Dendrocalamus Giganteus (Giant Bamboo) (Naik). Since the bamboo is intended to hold water, the only currently recommended treatment is that the bamboo be immersed in a borax-boric acid solution (US Department of Agriculture, 1963).

According to a report from the United Nations Environment Program on bamboo water supply systems in Nepal, "Because bamboo decays as a result of its exposure to the weather and the scouring effect of the flowing water, all of the bamboo components have to be replaced each year." ("Bamboo pipe water"). Although any intended implementation of bamboo pipes would not incur the same harsh environmental condition as in Nepal, the report does provide an idea of an approximate lifetime for bamboo plumbing. Manufacturing and joining of bamboo pipe sections can be a very straightforward process and carried out using simple carving tools (Figure 10), though specialized equipment could be utilized if manufacturing required large quantities of bamboo piping.

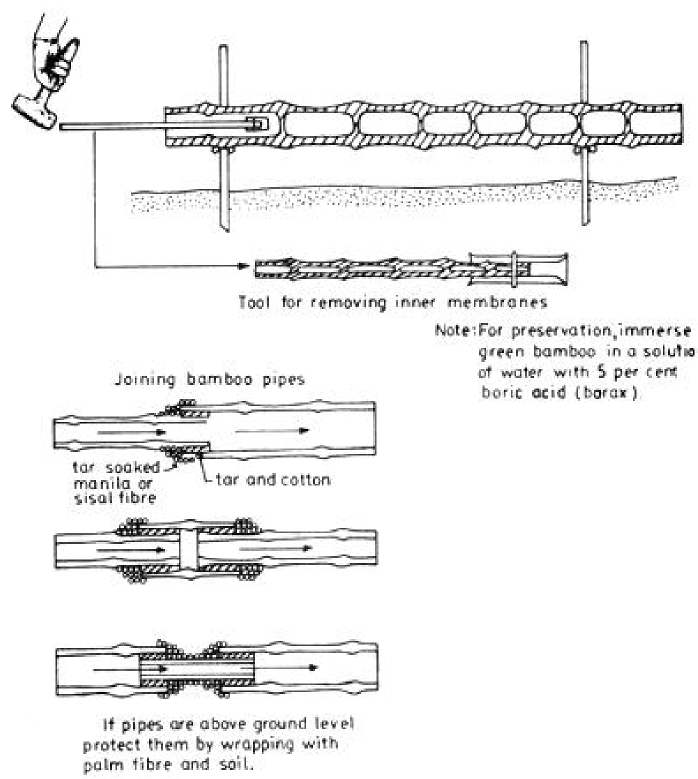

Figure 10: Manufacturing of Bamboo Pipe
Source: ("Bamboo piping and")

Although bamboo appears to be an exceptional substitute for PVC piping based on its minimal environmental impact, the large economic cost of the labor required to replace decaying pipes makes bamboo an unviable option for plumbing throughout the UBC Student Union Building. However, bamboo still remains a practical alternative plumbing material in smaller projects such as one of the building's gardens, if a community is in place to maintain the bamboo pipe sections.

6.0 COMPARISON OF ALTERNATIVES AND RECOMMENDATIONS

Due to the detrimental effects of PVC on the environment, it is advised that PVC be avoided whenever possible. PVC is on the red list for a reason; with its use, both humanity and the environment suffer equally from the release of toxic additives. Referring to figure 1, the insane environmental impacts of PVC shifts the recommendations to the far left, making PVC a very unviable choice. Socially, PVC is easier to install compared to bamboo and copper, but such convenience can be outweighed using any of the greener plastic alternatives presented. In addition, this convenience also decreases the number of trucks needed to haul additional piping and equipment to mold material to fit special plumbing segments. However, the savings in transportation and energy is only trivial compared to the after-effects of using PVC piping for extended periods of time. Sure, PVC is light and inexpensive compared to copper, but its 'full' cost is usually masked—that the full cost of the environment and social impacts and for the cleanup are not paid for by the manufacturer. These costs are usually covered by tax payers, the community and the environment, which contributes to a downfall of global economy and environmental deterioration.

As of now, PVC is in high demand due to its applicability to many plumbing applications. However as presented above, HDPE, PEX and polypropylene also share most of the characteristics evident in PVC, with the addition of enhanced durability in HDPE without the environmental impacts. In small scale purchases, HDPE and PEX are proven to be slightly more expensive than PVC; however, when purchased in bulk, all three plastic alternatives are proven to be more financially beneficial. This is partly due to the much smaller demand of HDPE, PEX and polypropylene in the market, leading to the production of these plastics in smaller volumes. Economically, producing products in small volumes result in higher per-unit price, however, these prices will eventually drop as the demand for the products increase. Therefore, we should initiate the shift away from PVC as soon as possible and by using these materials in one of the centerpiece buildings at UBC, we can contribute to the initiative, much like the awareness derived from the Sydney 2000 Olympic Games.

As shown in figure 7 and 8, HDPE is a superior alternative to PVC and is highly recommended for use in the SUB project. In sheltered applications involving higher temperatures, PEX and polypropylene should be considered, depending on the sturdiness required. In applications where sturdiness is not needed, we highly recommend the use of polypropylene due to its contribution to decreasing greenhouse gases in its manufacture. Copper is also a viable alternative to PVC because though it is environmentally damaging in its manufacture, its long life, durability and minimal environmental effects is sufficient to outweigh the negativity involved in its production. However because corroding copper pipes are known to affect human health, it is recommended that copper pipes be considered for drainage applications in the new SUB with various vertical and horizontal pipe sections, carrying both hot and cold drainage water, to prevent leaks. In addition, wherever possible, the SUB should also contain small scale bamboo pipes for gutter applications, due to bamboo having no environmental effects. Because bamboo involves a high initial manufacturing cost, the cost can be cut down with the manufacture of smaller bamboo sections.

This report has presented various alternatives to replace the red list poison plastic, PVC. Structurally, any of the alternatives are proven to be just as strong or stronger than PVC, sometimes with added benefits in durability and resistance.

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