End-of-Life Options for Waste Paint In Australia

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## Abbreviations

<table>
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>A&amp;D</td>
<td>Architectural and Decorative</td>
</tr>
<tr>
<td>ASLP</td>
<td>Australian Standard Leaching Procedure</td>
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<tr>
<td>APMF</td>
<td>Australian Paint Manufacturers Federation</td>
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<tr>
<td>BTU</td>
<td>British Thermal Unit</td>
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<tr>
<td>CCAA</td>
<td>Cement Concrete &amp; Aggregates Australia</td>
</tr>
<tr>
<td>DYH</td>
<td>Detox Your Home</td>
</tr>
<tr>
<td>HHC</td>
<td>Hazardous Household Chemical</td>
</tr>
<tr>
<td>HDPE</td>
<td>High Density Poly Ethylene</td>
</tr>
<tr>
<td>HVLT</td>
<td>High Volume Low Toxicity</td>
</tr>
<tr>
<td>LMC</td>
<td>Latex Modified Concrete</td>
</tr>
<tr>
<td>LVHT</td>
<td>Low Volume High Toxicity</td>
</tr>
<tr>
<td>OH&amp;S</td>
<td>Occupational Health and Safety</td>
</tr>
<tr>
<td>PMMA</td>
<td>Poly Methyl Meth Acrylate</td>
</tr>
<tr>
<td>PMB</td>
<td>Polymer Modified Binder</td>
</tr>
<tr>
<td>PMC</td>
<td>Polymer Modified Concrete</td>
</tr>
<tr>
<td>SBR</td>
<td>Styrene Butadiene Rubber</td>
</tr>
<tr>
<td>SV</td>
<td>Sustainability Victoria</td>
</tr>
<tr>
<td>SUT</td>
<td>Swinburne University of Technology</td>
</tr>
<tr>
<td>TCLP</td>
<td>Toxicity Characteristic Leaching Procedure</td>
</tr>
<tr>
<td>WLP</td>
<td>Waste Latex Paint</td>
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In this document waste paint refers to waste A&D paint.
Executive Summary

Swinburne University of Technology (SUT) was commissioned by Sustainability Victoria (SV) to undertake a research review into “End of Life Options for Waste Paint in Australia”. This report specifically looks into options for Architectural and Decorative (A&D) waste paint (including wood care paint). Industry, marine, automotive paint and other industry paint applications are not within the scope of this report. The following options have been identified: Replacement for water in concrete, replacement for polymer in polymer modified concrete (PMC) and replacement for polymer in asphalt sealants.

The objectives of this research study was to complete a literature review including current options and solutions for waste paint along with failed approaches to waste paint both domestically and internationally. The literature review revealed three potential options and the next phase was to conduct an economic feasibility, risk management, environmental impacts, volume considerations and technical feasibility criteria for all options. SUT was also to summarise findings and submit recommendations for waste paint in Australia that details the next stage to pursue these recommendations.

This report provides and discusses the following items:

1- Current situation for A&D waste paint in Victoria
2- A literature review on waste paint management solutions globally and locally
3- Recommendations for sustainable waste paint management in Victoria and Australia
4- Technical feasibility, volume considerations, environmental impact assessment, cost analysis and risk assessment of reusing waste paint as water replacement in concrete, polymer replacement in PMC and polymer replacement in asphalt sealant and Polymer Modified Binders (PMB).

The following recommendations have been made considering all criteria influencing waste paint management solutions:

1- Further research using waste paint as a water and polymer replacement is recommended.
2- Due to limited research on using WLP in asphalt sealants and PMB and also potential environmental risks of this application it is recommended to first start with use of WLP as a polymer and water replacement in PMC and in the next stage move toward the other option.
3- Conduct trials on concrete with lower performance requirements (such as curb side concrete, pedestrian walk and bike trails for PMC and low volume traffic roads and pedestrian walks for PMB option).
4- A framework for the introduction of new incentives for industries in reusing WLP in construction activities need to be developed by interested stakeholders such as state and local governments, industry representatives and research institutions.

5- Raising consumer awareness to improve consumers’ participation in collection programs and also to increase market share for recycled products.
1 Architectural and Decorative Waste Paint

This report specifically looks into end of life options for A&D waste paint (including wood care) and does not include industrial, marine, automotive and any other industrial paint.

Current options and solutions for waste paint in Australia and internationally along with failed approaches to waste paint will be reviewed and discussed. Viable end of life options for A&D waste paint considering economic feasibility, risk management, environmental impacts, volume considerations and technical feasibility criteria are presented and discussed.

1.1 Introduction

According to the Australian Paint Manufacturer’s Federation (APMF), Victoria sells approximately 16.5 million litres of paint each year through retail outlets of which about 11% (with current estimate around 3%) is unused (Responsible Resource Recovery Ltd., 2006). Since paint contains substances such as suspended solids, stable emulsions, dyes, acids, alkalis and organic solvents which can potentially impose a risk to environment and human health, illegal disposal (disposal in landfill) or storage of waste architectural and decorative (A&D) paint threatens our environment (APMF, 2011).

Paints can be generally grouped into two categories; latex paint (water based paint) and solvent-based paint. The current manufacturing trend of paint is changing from solvent to latex paint rapidly since latex paint contains 50% to 90% water and has a lower impact on the human health and environment. Latex paint accounts for a majority of A&D paint production in Australia. Similarly in New Zealand there is a clear trend in manufacturing of paint away, from solvent-based paints and towards latex paints. A majority of companies have their products as latex paints (Responsible Resource Recovery Ltd., 2006).

Solvent-based paint is made of several chemical components including, resin, pigment, solvent, additives and extenders. Resin (binder) is used for film-forming. Pigments comprise of solid particulates which provide certain characteristics such as colour, opacity, durability, and mechanical strength. Solvent is the liquid used to make the paint flowable prior to use. Solvents are chemical substances that make it possible to process, apply, clean, dissolve or disperse the film-forming constituent. Additives are chemical components applied to obtain special effects in paints (Talbert, 2007).

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1 Further study is required to find a more accurate percentage. At the moment the unused paint lies between 3 to 11% of A&D paint production in Australia.

2 Latex paint, water-borne paint and water-based paint are equivalent terms. Since 1950’s, plastic (vinyl and acrylic) is used in latex paint instead of latex from rubber trees (Greiner et al, 2004).
Latex paint typically consists of approximately 50% water, 25% acrylic binder, 15% TiO₂ (Titanium Dioxide) and 10% extender and additives. Solvent-based paint, on the other hand typically consists of approximately 20% hydrocarbon solvent, 40% alkyd binder, 20% TiO₂ and 20% extender and additives (Greiner et al., 2004).

1.2 Waste Paint

Paint contains material which is categorized as Household Hazardous Chemicals (HHC) as they can adversely affect human health and pose environmental risks (Sustainability Victoria, 2011). For instance Alkyd solvents, release Volatile Organic Compounds (VOC’s) into the atmosphere which present some degree of hazard (McMaster, 2003).

Waste paint is considered one of the most problematic household chemical waste due to negative environmental impacts of improper disposal as well as its considerable volume. Sustainability Victoria (SV) has identified unwanted paint as the largest component of residential household hazardous chemicals (HHC) in Victoria. Based on data obtained from a five year HHC collection program in Victoria, waste paint constitutes 68% of total collected HHC.

To reduce these risks, management solutions need to be in place to collect, recycle or dispose paint in sustainable ways.

1.2.1 Existing Collection System in Victoria

The “Detox Your Home” (DYH) program commissioned by Sustainability Victoria (SV) collects and manages HHC through two methods: Firstly; a network of 13 permanent drop-off facilities for low toxicity chemicals including waste paint and secondly; through a mobile collection service for disposal of a wider range of household chemical products, including more hazardous chemicals which may require expert identification and management (Sustainability Victoria, 2011). The main goal of DYH is to provide Victorian householders the ability to dispose HHC products in a free, safe, accessible and environmentally responsible way through permanent drop-off facilities and mobile collection services (Sustainability Victoria, 2011). Figure 1 shows waste paint bins at a permanent collection centre in City of Monash, Victoria.
HHC are referred to by SV as either of two categories: high volume low toxicity (HVLT) materials or low volume high toxicity (LVHT) materials. Waste paint falls in category of HVLT which implies that the toxicity level of waste paint is low but there is a significant volume requiring management.

Over a five year period from 2005/06 to 2009/10, 2812 tonnes of unwanted paint, averaging over 562 tonnes per year, was collected in Victoria through Detox Your Home (DHY) program (Table 1). This amount represents 68% of total HHC (Sustainability Victoria, 2011).

Table 1  Waste paint collection over five year period in Victoria (tonnes) (Sustainability Victoria, 2011)

<table>
<thead>
<tr>
<th>Collection system</th>
<th>2005/06 (t)</th>
<th>2006/07 (t)</th>
<th>2007/08 (t)</th>
<th>2008/09 (t)</th>
<th>2009/10 (t)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent</td>
<td>51</td>
<td>211</td>
<td>462</td>
<td>425</td>
<td>537</td>
<td>1,686</td>
</tr>
<tr>
<td>Mobile</td>
<td>359</td>
<td>183</td>
<td>242</td>
<td>186</td>
<td>157</td>
<td>1,126</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>410</strong></td>
<td><strong>393</strong></td>
<td><strong>704</strong></td>
<td><strong>611</strong></td>
<td><strong>694</strong></td>
<td><strong>2,812</strong></td>
</tr>
</tbody>
</table>

SV records show that the mobile services collected over 2,100 tonnes of material during the five-year period of program with paint making the highest percentage and more than half of the collected materials by 53.5% (Sustainability Victoria, 2011). As with the mobile collections, the bulk of the material collected at the permanent sites for treatment was waste paint. “Over the five-year period, paint represented around 83% of the total material collected at the permanent sites, and in the 2007/08, 2008/09 and 2009/10 period it has reached almost 90%” (Sustainability Victoria, 2011).

The quantities of all materials collected declined over the five year period (except for four types of material), however, as Figure 2 suggests, “the reductions have been overwhelmed by the increase in these four types of material especially paint” (Sustainability Victoria, 2011).
For implementing the DYH program, the range of contributing costs are collection, transport, treatment, disposal, advertising and promotion of the mobile collection services.

Figure 3 shows the total costs of DYH program which has increased from $1,529,242 for 2007/8 period to $1,623,570 for 2009/10 period.

Table 2 shows the cost of this program per kilogram of collected material. According to Table 2 in 2009/10 period, SV has paid over $1.6m in support of the program. A third of this is related to infrastructure, staging, auditing and promotion. The remaining two thirds was the cost of treatment and disposal, and two thirds of this was for waste paint (Sustainability Victoria, 2011). Compared with the limited available data from other jurisdictions, the program appears to be “financially effective”. There is insufficient data to accurately differentiate between costs for metropolitan and regional collections. However there would appear to be a significant expenditure of funds on some rural programs that collect small quantities of HHC. The data suggests that it is much more cost-effective per unit to recover material at a permanent site than a mobile site (Sustainability Victoria, 2011).
Table 2  Program cost per kilogram collected from 2005/6 to 2009/10 (Sustainability Victoria, 2011)

<table>
<thead>
<tr>
<th>Year Period</th>
<th>2005/06</th>
<th>2006/07</th>
<th>2007/08</th>
<th>2008/09</th>
<th>2009/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile collection (cost kg)</td>
<td>$1.57</td>
<td>$2.17</td>
<td>$2.08</td>
<td>$3.00</td>
<td>$3.07</td>
</tr>
<tr>
<td>Permanent site (cost kg)</td>
<td>$1.88</td>
<td>$1.38</td>
<td>$1.18</td>
<td>$1.21</td>
<td>$1.30</td>
</tr>
<tr>
<td>Total DYH program (cost kg)</td>
<td>$1.63</td>
<td>$1.85</td>
<td>$1.59</td>
<td>$1.94</td>
<td>$1.84</td>
</tr>
</tbody>
</table>

In South Australia, the review of a comparable program revealed the overall average cost of the collections was $3.50 per kg (compared to a reported $2.90 in Victoria); although there were some differences between the programs which make direct cost comparison difficult (Sustainability Victoria, 2011).

The SV report of DYH program recommends that there is a need for “continuation and/or establishment of product stewardship for collected HHC, starting with HVLT materials” while at the same time there is a need to collect reliable data on “chemical contamination of sewage” caused by HHC. Point-of-sale return where feasible (e.g. depleted household batteries and potentially paint) is a recommendation which needs fully engagement of industry for a successful product stewardship solution (Sustainability Victoria, 2011).

A comparable program has been running in NSW since 2003 which shows paint (oil and latex) makes up to 58% of collected chemicals in NSW for 2009/10 period as shown in Figure 4.

In South Australia findings show that waste paint was also one of the main HHC materials collected through similar comparable programs making up to 18.6% of total collected material (Sustainability Victoria, 2011).

![Figure 4 NSW Household Chemical Cleanout Program results (Sustainability Victoria, 2011)](image-url)
1.2.2 Existing Waste Paint Solution in Victoria

The waste paint management in Victoria has advanced significantly toward sustainability since 2003. However, illegal disposal of waste paint in Victoria is still very common and significant volumes end up in landfills or are illegally poured into the sewerage system (APMF, 2011). APMF estimates less than 15% of all waste A&D paint and paint cans are recovered for recycling in Victoria, with much of the rest disposed to landfills (APMF, 2011). In 2003, it was estimated that over 12 kg of paint is stored per household in Australia (Clay et al., 2006) with a majority of it eventually being disposed illegally in landfills or ending up in the sewerage system.

To reduce illegal disposal of waste paint, some end-of-life options have been tried in Victoria, with energy recovery being the most commonly used option. In Victoria waste paint is predominantly sent to Geocycle where it is turned into a fuel blend suitable for use in approved cement kilns (Western Australia Waste Authority, 2010).

Besides energy recovery, not many other end-of-life options for waste paint have been explored in Australia. In 2003 paint-back (Paintback™) stewardship program was an attempt towards remanufacturing paint which unfortunately faced technical and financial challenges and as such did not continue successfully.

In 2011, Toxfree (Chemsal) produced Paintcrete, which was a successful application for waste paint done in small scale as an initial trial. Paintcrete is a type of concrete in which water is partially replaced by waste paint (EPA Victoria, 2011)

Despite several research works and trials carried out about potential solutions to reuse and recycle waste paint, energy recovery is still the only option being practically used in Victoria.

1.3 Summary

Managing waste paint sustainably is critical due to relatively high volume of waste paint, expensive disposal process, and chemical constituents with high recycling potential. It is not only a cost effective solution for conserving energy and reducing the cost of disposal but also to assist the community and the environment through the reduction of greenhouse gas emissions. Several studies have been conducted globally to investigate recycling options for waste paint. Recycling waste paint will furthermore support the “Toward Zero Waste” program developed by SV.

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3 Paintbak is a registered Trademark (Paintback™)
2 Waste Paint Management Solutions

In the *Environment Protection Act 1970*, the waste hierarchy is one of eleven principles of environment protection which provides a framework for EPA’s decision making to benefit the Victorian environment and community (EPA Victoria, 2013).

The waste hierarchy is shown in Figure 5. It defines a general order of preference for waste management options in order to minimize adverse effects of waste (EPA Victoria, 2013).

![Waste Hierarchy Diagram](image)

**Figure 5 Waste Hierarchy according to EPA Victoria**

Waste hierarchy can be applied to waste paint to prioritise potential options and solutions for waste paint management.

Modern waste management is moving towards material recycling. Similarly many researchers in waste paint management are also turning their research focus to identify solutions for recycling or reusing waste paint. In this research review study, existing practices and proposed solutions for waste paint management are categorised into three groups reflecting different levels of waste management hierarchy; Paint Reuse, Paint Recycle and Energy Recovery. Figure 6 illustrates how the hierarchy applies to waste paint solutions.
2.1 Paint Reuse

The most environmentally sustainable option for waste materials is to reuse them in their original application. There are a number of organisations around the world that reuse latex paint. However, this is not always possible due to associated technical restrictions and financial viability issues. Paint reuse can be achieved in four ways: paint swap, consolidation, remanufacturing and re-blending.

2.1.1 Paint Swap or Exchange

Excess paint from households can be reused by the community. However, considerations pertaining to storage, manual sorting and collection procedure must be carefully planned and managed appropriately. Councils can achieve a sustainable paint reuse program in their wards by using collected waste paint for graffiti abatement or in other council projects, or alternatively by providing it back to the community if all considerations are managed properly.

Solvent-based paint as with latex paint can be exchanged and reused within community. However, because of the special materials in solvent-based paints, special measures should be taken to prevent fire hazards during collection and storage (Quiroz, 2011; McMaster, 2003).

There are several examples of exchange programs in the world. Paint Recyclers is one which was founded in 2009 and operates in Western Australia. It provides low price paint exchange services to customers (Paint Recyclers, 2012). In 2011, PaintWise product stewardship scheme was started in
New Zealand, in which good condition paint is returned back to the community for use by non-profit community groups free of charge (Resene, 2011).

On average about 8% of waste paint cans are nearly full or full and in good condition for exchange (based on stewardship program in other countries (New Zealand, Manitoba, Massachusetts) (McMaster, 2003, Greiner et al., 2004) which potentially can be reused by community or community groups.

This can theoretically become a highly efficient solution for waste paint management since it doesn’t involve major transportation and does not require energy use for reprocessing. However diversity in types and colours of collected waste paint, specific and limited demand, serious occupational and health risks associate with storage and handling, lack of warranty implications and uncertainty with size of demand makes it quite difficult to match demand and supply.

With the current surge in usage of internet and social media, it will be certainly beneficial to investigate ways by which this media channel can be used as a platform for implementing such programs and also to raise public awareness around benefits of paint swap and exchange. Local governments are a major player in this scheme.

2.1.2 Paint Consolidation

In this method, good quality paint is sorted based on the type of paint and other characteristics such as colour (e.g. light, medium, dark, and green-yellow-blue). It is then filtered, poured into large containers, and mixed (manually in most cases). This process does not require special machinery or trained labour. Furthermore, it is usually undertaken on the collection site so the storage and transportation costs are dropped which can make the process more cost effective (McMaster, 2003).

The final product in this scenario will not have the same quality as the original paint but potentially it can still be used for specific applications such as graffiti abatement or warehouse painting. An example of this approach is Snohomish County in USA which uses this approach and produces a very low cost latex paint. Volunteer labour is used for mixing paints, (Greiner et al., 2004; McMaster, 2003).

Some of the technical issues related to this solution are the solids existing in waste paint which can potentially block the nozzle of the spray gun and also the adverse effect of solid particles on the finished surface of work. This process is labour intensive and there are occupational health and safety issues associated with volunteers working with hazardous material. Risk issues associated with storage facilities add up to the obstacles in front of this approach.
2.1.3 Remanufacturing Paint

In paint remanufacturing or reprocessing, WLP is converted to recycled-content paint. Replacement of reprocessed paint for virgin paint is a cost effective approach at first glance; however having limited available colours is a disadvantage which gets more complicated when market demand is taken into account. Customer concerns regarding the quality of this paint are another serious drawback (McMaster, 2003; Greiner et al., 2004). The process of remanufacturing paint is similar to consolidation; except testing and mixing additives, pigments, and virgin paint is required to achieve a better quality and performance which add up to the costs of final product. This approach also requires special equipment and a trained workforce which increase the costs of this solution.

Microorganisms grow well in latex paint by consuming the available oxygen quickly (Dey et al. 2002) which raises a concern on possible bacterial contamination of paint production lines. Accidental cross contamination of latex with oil paint (Mugabe, 1998) and solid contamination in leftover paint are further challenges to this approach. If the cost of collection, sorting, filtering and removing bacteria from waste paint goes beyond the production cost for virgin paint, there would be significant challenges in the application of this solution. Another barrier for this solution is the low market demand which can potentially be overcome by putting in place new regulations by government to encourage councils or individuals towards use of reprocessed paint.

According to the Department of Ecology, State of Washington (USA), using recycled paint helps to conserve energy and resources. Approximate calculations indicated that one gallon (3.78 litre) of recycled paint conserves approximately 100 kilowatt hours of energy compared to a new paint which provides the opportunity of a 115 pounds (70 kg) carbon savings (Department of Ecology State of Washington, 2013).

Remanufactured paint can be used for application where quality is not critical and high volume of paint is required. Local councils and road authorities can be amongst major users for paint produced using this approach.

Paint remanufacturing was attempted in Victoria for the first time in Australia in 2003 (Figure 7). The Paintback™ partnership targeted safe paint collection and remanufacturing it to Dulux Walpamur™ fence paint. As illustrated in Figure 8, the cost per unit of collected paint in this one month pilot program reduced from $8.67 per kg in the first phase to a more sustainable $0.74 per kg in the latest phase. 10% of the paint collected during these phases was reprocessed into a fence paint product (Sustainability Victoria, 2007).

Dulux Walpamur™ fence paint is made by substituting 60% recycled paint for virgin material which ultimately reduces greenhouse gas emission. Dulux estimated that manufacture of 10,000
litres of Walpamur™ fence paint is equivalent to saving around 10,000 kg of carbon dioxide (Sustainability Victoria, 2007).

This program was a noble demonstration of collaboration between government, retailers and industry. However due to technical difficulties such as risks associated with bacterial contamination of production lines, diversity of collected waste paint, warranty issues with final products and financial barriers associated with market demand, it was not pursued and was therefore never transformed into a permanent practice.

Figure 7 Victoria recycled paint product in 2004 (Sustainability Victoria, 2007)

Figure 8 Comparison costs per kg for all phases of paint remanufacturing trial in Victoria (Sustainability Victoria, 2007)
2.1.4 Paint Re-Blending

In this method post-consumer leftover paint can be used as a minor constituent (less than 20 %) in the manufacture of “virgin” paint. The unusable paints are screened out and then sorted by characteristics such as type, colour, and sheen (Greiner et al., 2004). Consolidated paint can be used as a virgin paint replacement. The main advantage in this approach is that re-blending paint has the same consistency of colour, sheen, and performance as the virgin paint because of small amount of leftover paint used. Issues such as possible bacteria contamination, intensive labour demand and quality assurance of final product exist for this approach, similar to remanufacturing paint option. Also ongoing quality control is required for consolidated paint before blending it which adds up to the cost of this solution.

2.1.5 Summary

Paint reuse, based on the waste hierarchy, has the highest priority amongst other solutions and is considered as the best potential end-of-life option for waste paint. It has great environmental benefits as it results in reduction of illegal disposal of waste paint and also reduces the need for new paint manufacturing. However it has several disadvantages:

- Paint reuse may not always be possible due to the unsuitable quality of leftover paint.
- The reuse process is often not simple. WLP contains volatile organic compounds (VOC), which makes it difficult and expensive to reuse (Quiroz, 2011).
- Bacterial growth in waste paint can potentially infect the paint production line.
- Diversity of paints both in terms of type and colour also add to difficulties.
- Paint produced through re-blending and remanufacturing lacks the quality of original paint. As such the costumer warranty based on quality assurance remains a challenge in this option.
- Ongoing quality control of extracted and consolidated waste paint before adding to the production line is required which adds up to the costs.
- There is a limited market for recycled paint and low demand for specific colours (MMSB, 1996).
- In “paint reuse” (swap) approaches practiced with community involvement OH&S issues needs to be thoroughly investigated and monitored.

On the other hand, the advantages of paint reuse are as follows:

- Paint reuse has great environmental benefits.
- For some applications such as graffiti abatement or warehouse painting where the paint quality is not very important, use of waste paint can be more appropriate.
• Improvements in consumer awareness and moves toward green building practices are also other factors creating a potential market growth for reprocessed paint.

• Government initiatives (for example councils promoting using recycled paint in graffiti abatement) can play a positive direct impact in this approach.

Currently a number of paint companies around the world, are reprocessing or re-blending paint. For instance Table 3 illustrates that in Canada, 18 paint products are reproduced by 11 companies (CalRecycle, 2010).

### Table 3 Recycled paint products in Canada

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Company Name</th>
<th>Total recycled content</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Coat Recycled Paint - Flat</td>
<td>BFJ Company</td>
<td>100%</td>
</tr>
<tr>
<td>E-Coat Recycled paint - Semi-Gloss</td>
<td>BFJ Company</td>
<td>100%</td>
</tr>
<tr>
<td>Paint</td>
<td>Cal Western Paints, Inc.</td>
<td>100%</td>
</tr>
<tr>
<td>Paint-semi-gloss interior/exterior latex recycled paint</td>
<td>E-Coat, Kelly-Moore Company</td>
<td>100%</td>
</tr>
<tr>
<td>Paint - flat interior/exterior latex recycled paint</td>
<td>E-Coat, Kelly-Moore Company</td>
<td>100%</td>
</tr>
<tr>
<td>ECOating Paint</td>
<td>Kathleen and Company</td>
<td>100%</td>
</tr>
<tr>
<td>EcoPaint -- Paint</td>
<td>Atlantic County Utilities Authority</td>
<td>95%</td>
</tr>
<tr>
<td>Amazon Select latex Paint</td>
<td>Amazon Paint</td>
<td>90%</td>
</tr>
<tr>
<td>Cal Trans Graffiti Blocker</td>
<td>Acrylatex Coatings &amp; Recycling, Inc.</td>
<td>60%</td>
</tr>
<tr>
<td>TAG-OUT Graffiti Abatement Paint</td>
<td>Acrylatex Coatings &amp; Recycling, Inc.</td>
<td>60%</td>
</tr>
<tr>
<td>Metal Primers (Maint. Grade)</td>
<td>Acrylatex Coatings &amp; Recycling, Inc.</td>
<td>60%</td>
</tr>
<tr>
<td>Global Green</td>
<td>California Paint Recycling, Inc.</td>
<td>50%</td>
</tr>
<tr>
<td>Interior Paint</td>
<td>California Paint Recycling, Inc.</td>
<td>50%</td>
</tr>
<tr>
<td>Exterior Paint</td>
<td>California Paint Recycling, Inc.</td>
<td>50%</td>
</tr>
<tr>
<td>Recover -- Paint</td>
<td>Dunn-Edwards Corporation</td>
<td>50%</td>
</tr>
<tr>
<td>Caltrans Recycled Graffiti Cover Up Latex Paint</td>
<td>Regal Hue Coatings, Inc.</td>
<td>50%</td>
</tr>
<tr>
<td>Paint - Interior &amp; Exterior</td>
<td>Visions Paint Recycling, Inc.</td>
<td>50%</td>
</tr>
<tr>
<td>Life Cycle Coatings</td>
<td>Acrylatex Coatings &amp; Recycling, Inc.</td>
<td>30%</td>
</tr>
</tbody>
</table>

#### 2.2 Paint Recycling

Waste paint recycling refers to solutions where waste paint is used as a raw material for other products. Many waste paint recycling options have been attempted in the past which will be reviewed in this section. Although some of these options may look attractive at first, environmental
impact and also financial viability and volume considerations of these options need to be assessed properly.

2.2.1 Concrete

One of the most commonly practiced options for WLP is its application in the production of concrete. Generally WLP can be used in the production of concrete in two ways; as a partial replacement for water or as a partial or full replacement of polymers used in certain types of concrete.

WLP can be used as a replacement for water in concrete, to reduce water consumption in producing concrete. It is often reported that the end-product concrete exhibits superior properties, such as smoother finish (Nehdi and Sumner, 2003; EPA Victoria, 2011).

Polymer admixtures in concrete are not new. Polymer Modified Concrete (PMC) dates back to 1920’s (Ismail et al, 2011). Polymeric admixtures are used in concrete production by mixing either a polymer in dispersed, powdery, or liquid form with fresh cement mortar and concrete mixtures to increase the matrix bond between cement and aggregates to improve workability and flow of cementitious materials (Ismail et al., 2011).

Natural rubber was the first polymer used in PMC. In the 1960’s the use of synthetic polymers such as Styrene Butadiene Rubber (SBR) was common (Clear and Chollar, 1978). Despite many advances in polymer admixture, the finished cost of produced concrete was still expensive and therefore its use was limited to certain applications (Almesfer et al., 2012). Such applications include but are not limited to bridge overlays, anti-corrosive linings, waterproofing, parking decks, and patching deteriorating concrete (Quiroz, 2011).

Recycling waste paint as a replacement for polymer in PMC can potentially make this product more cost effective and also preserves and improves the positive properties of PMC (Quiroz, 2011). The first application of waste paint in the concrete industry was reported in 1993 (Amazon Environmental Inc., 2013). This topic seems to have been neglected for few years after that. But recently it has become more attractive and many researchers and industries have turned their attention to this approach. In the following sections a number of researches and applications related to use of waste paint in concrete are reviewed.

- Overlay, Rigid Pavement, Pervious Concrete

Quiroz (2011) investigated two applications of WLP: firstly the use of WLP as a replacement for virgin latex in Latex Modified Concrete (LMC) and secondly, the possibility of improving properties of standard Portland concrete by using WLP. Extensive series of tests have been carried out to evaluate
quality and properties of WLP concrete and compare it with those of standard concrete and SBR concrete with regards to the following applications:

- **Bridge Overlays**: possible replacement of SBR which is commonly used as an admixture in this application has been investigated. For protecting the bridge super-structure from chemical attacks which may result in corrosion of the reinforcement and surface scaling of concrete, a thin protective layer is used on top of bridge roadway. Using WLP in this application can reduce the cost of LMC enormously (Quiroz, 2011).

- **Rigid pavement**: high durability requirements are vital for rigid pavements and research has been conducted to investigate possible improvements of standard concrete properties using WLP. Rigid pavements are used for places with constant traffic loading such as airports and highways (Quiroz, 2011).

- **Pervious concrete**: as demonstrated by Huang et al. (2009), latex additive improves tensile and compressive strength of pervious concrete. The possible use of WLP as latex replacement was examined in Huang et al. (2009) work. Pervious concrete contains 15% to 25% air voids and is able to capture and reduce stormwater, and recharge groundwater (Quiroz, 2011).

Quiroz (2011) concluded that in all cases concrete produced by replacing WLP succeeds to meet requirements and specifications. However, in some stages of the tests, concrete performance was found to decrease with addition of more WLP which dictates proper investigation in mixture blending ratios.

- **Masonry Blockfill**

  In a study carried out in New Zealand (Haigh, 2007), the application of WLP in masonry blockfill mix was investigated, both as water replacement and standard polymer admixture replacement. Several tests were carried out on fresh and hardened blockfill mix to compare its properties with conventional blockfill mixes.

  Polymer admixtures increase the workability and flow of cementitious materials and increase the matrix bond between cement and aggregate. These materials, however, are often too expensive (Haigh, 2007).

  According to this study, Pozzolith 370C and Micro Air are standard chemical currently used in concrete masonry blockfill by a ready mix concrete supplier in the production of standard 17.5 MPa blockfill in New Zealand. The chemical components in waste paint are comparable to the chemicals currently used as admixtures in blockfill and can be used as air entrainers and water reducers.

  In the research study conducted by Haigh (2007), following standard NZS 3112:1986 tests such as, compressive strength, elastic modulus, drying shrinkage, change in workability over time,
paintcrete rheology, full scale seismic testing, and scanning electron microscope were undertaken. To assure the feasibility of implementation in an industrial scale, properties of blockfill mix with use of WLP was confirmed during industrial trials (Figure 9).

![Figure 9 Pumping paintcrete into trial wall (Haigh, 2007)](image)

The waste paint was sampled and tested at the paint collection factory to determine the variability of water content, pigment content and polymer content. It was established that using WLP in blockfill mix can maintain the strength and improve the workability and can be used as a substitute for chemical polymeric admixtures currently used in the manufacture of concrete to attain similar results (Haigh, 2007).

Figure 10 represent the blockfill compressive strength with addition of WLP. The water content of waste paint (~47.6%) replaced the water content of the mix.

This study shows the optimum WLP ratio is between 8-12% for replacement of water to achieve the required 17.5 MPa compressive strength, while maintaining workability and drying shrinkage.

![Figure 10 28 day compressive strength (Haigh, 2007)](image)
Considering the amount of blockfill mix produced and used in New Zealand, this method can potentially recycle 3.6 million litters of WLP per year at 10% replacement for water by mass which is far above the projected volume of WLP collected in New Zealand based on 2003-05 data (Haigh, 2007).

- **Non-Structural Concrete Elements**

  Nehdi and Sumner (2003) have investigated recycling WLP as both a partial replacement for virgin latex in Latex Modified Concrete (LMC) as well as a partial replacement for mixing water in footpath concrete. They concluded that use of WLP results in comparative advantages such as increased flexural strength and decreased chloride ion penetrability. Nehdi and Sumner (2003) reported some observations about concrete produced for footpath (with 50% mixing water replaced with WLP) constructed in 1998 and monitored till 2003 in Ontario, Canada. The ease of construction, enhanced workability and finishing, distinctly lighter and more reflective colour, not exhibiting coarse pop-outs, and no signs of surface scaling were amongst the advantages of this experimental sidewalk compared to a reference sidewalk. However they have suggested that more research is required before WLP can be used in large scale industrial production of concrete for sidewalks (Nehdi and Sumner, 2003).

  Mohammed et al. (2008) studied the use of WLP as a partial water replacement in concrete. Different proportions of WLP were added to concrete and were compared to virgin latex concrete. Results indicated that by adding WLP, the properties of ordinary concrete improved and was comparable to regular LMC. WLP was able to form a polymer film in concrete and its pigments and extenders fill additional porosity, which improves the long-term durability of concrete. Moreover, WLP had improved properties over the control mixture in compressive strength, flexural strength, and chloride penetrability. It was concluded that 15% WLP partial replacement for water in concrete could be used in non-structural concrete elements such as sidewalks, highway median barriers, and concrete blocks (Figure 11). Since WLP can add beneficial properties to concrete compared to LMC, it can be used in special applications with greater economic benefit (Mohammed et al., 2008).

![Figure 11 Stamped deck; and (b) stamped sidewalk with concrete incorporating 15% WLP (Mohammad et al. 2008)](image-url)
Concrete Car Park

Toxfree (Chemsal) in Victoria, Australia has used waste latex paint as partial water replacement for concrete in a trial in their Victorian factory in Laverton North (EPA Victoria, 2011). The concrete produced passed all manufacturing tests and even showed superior properties compared to existing products in some aspects, such as in the final finish. Other benefits included 10% reduction in water consumption as well as saving 2% of natural resources used as composite material. WLP used for this purpose is separated from a mixed waste stream containing both latex and solvent-based paints which otherwise would be sent to concrete producers to be used as a fuel for cement kilns. This application alone is estimated to be able to consume 1,700 tonnes of waste paint per year (EPA Victoria, 2011). This method was successfully tested and used by Chemsal (toxfree) in the construction of a car park project shown in Figure 12.

![Figure 12 Chemsal's car park concrete trial (EPA Victoria, 2011)](image)

Processed Latex Pigment (PLP)

A USA paint recycling company (Amazon Environmental Inc.) has patented a process for recycling non-usable waste paint into "Processed Latex Pigment" (PLP) which is used in Portland cement as an additive for special cements or as a raw material for the kiln feedstock. PLP can be used in replacement of shale, clay, limestone, and other materials to manufacture cement (Segala, 2003).

Portland cement is one of the important materials in construction. In the production of Portland cement, various proportions of raw materials such as aggregate, stone, and clays containing calcium, aluminium, iron, and silica are blended to obtain a particular concentration and subsequently transferred to kilns. A new substance called clinker will be added from the lower end of the kiln. Clinker is a pebble size stone material which is grounded in ball mills to a very fine powder with specific additives such as fly ash, gypsum, fumed silica, or PLP. The proportion of the additives
depends on desired properties of final product. PLP can be used as a grinding aid, air-entraining additive, or to improve adhesion and/or setting times. Cement may have up to 5% PLP (Segala, 2003).

Segala (2003) introduced a technique to produce PLP by combining recyclable materials such as industrial paint sludge, water-treatment sediment, leftover latex paint, and agglomeration agents.

PLP can be used as a replacement for 0.5% of the raw material of cement manufacturers. In US, since 1995, by using the PLP manufacturing process, 25 thousand tons of materials have been recycled (Segala, 2003).

According to Australian Bureau of Statistics (ABS), Portland cement manufactures produced 8.8 million tonnes in 2008-9. By replacing 0.5% of raw material with PLP in manufacturing cement, the potential need for WLP would be about 44 thousand tonnes in Australia per annum according to 2008/09 figures.

In a recent study by Ismail et al. (2011), attempts have been made to identify properties of cements when semi-solid WLP is added to it and also finding optimum polymer to cement ratio. Results of this work show the optimum quantity of polymer content is 2% of cement weight, which improves the strength of final product. However, in some tests such as initial and final setting time test, slump test, Vebe test, and water absorption test, this 2% polymer content does not offer a significant improvement to the concrete properties. These tests have been done by polymer-by-product as the additives of concrete which is produced in paint factory. The WLP was not used as direct additives in this study.

- **Summary**

Concrete is one of the key materials in construction. According to Cement Concrete & Aggregates Australia (CCAA, 2013) approximately 2,200 quarries operate around Australia and subsequently produce 150 million tonnes of rock, limestone, gravel and sand. This industry produces 8.9 million tonnes of cement and 24 million m³ of pre-mixed concrete per year. Cement and concrete are the most consumed material on the planet (CCAA, 2013).

With current water shortages in Australia, there is also a need to identify alternative sources of water in concrete production. Experiments and trials have shown that WLP can replace water in concrete. This is not only beneficial in terms of saving water, but also adds desirable benefits to the final concrete product.

Chemical admixtures in premixed concrete are important and are an increasingly-used component to impart desirable properties in concrete as well as economic benefits. Since latex can

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4 The data for 2009-10 has not been completed in ABS website
improve some key properties of concrete, WLP are potentially a good replacement for chemical additives in concrete both from economic and environmental aspects. By replacing even a very small percentage of chemical additives with an alternative green material such as WLP, savings in resources and energy and reduction in carbon footprint can be achieved in the concrete industry.

Table 4 summarises some of works undertaken on using waste paint in concrete, the intended application, and how it has been used (as water replacement or chemical admixture replacement).

There are still challenges in front of the large scale use of waste paint in concrete. Additional local laboratory and industrial tests are required to assure that the final concrete product complies with the required standards for specific applications. Inconsistency in waste paint mixtures presents another challenge as it results in variability in properties of produced concrete. As such continuous quality monitoring of WLP in terms of percentage of water, pigment and polymer is required which is not complicated and costly. Despite these challenges, use of WLP as water replacement in concrete for non-structural applications seems to be a viable end-of-life option.

<table>
<thead>
<tr>
<th>Researchers</th>
<th>Applications</th>
<th>Replacement of water</th>
<th>Replacement of chemical additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiroz (2011)</td>
<td>Rigid pavement</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Quiroz (2011)</td>
<td>pervious concrete</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Quiroz (2011)</td>
<td>Bridge overlay</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Haigh (2007)</td>
<td>Masonry Block fill</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>toxfree (2011)</td>
<td>Non-structural concrete element (car-park)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ismail (2011)</td>
<td>Raw material (Chemical additives) for cement manufacturing</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Mohammad et al. (2008)</td>
<td>Non-structural concrete element (sidewalk, highway median barriers, concrete blocks)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Nehdi and Sumner (2003)</td>
<td>Non-structural concrete element (sidewalk)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Amazon Environmental Inc. (2013)</td>
<td>raw material (Processed Latex Pigment ) in Portland cement manufacturing</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* the percentage of WLP varies according to the properties of collected WLP
2.2.2 Use as Polymer Feedstock Materials

The idea of recycling waste paints as a component of an immiscible polymer blend has been recently patented\(^5\) in the USA (Lynch et al., 2011). However, this application of waste paint has had limited research. In this innovation, paint is used as one of the polymer components of pigmented immiscible polymer blends. In particular the available research focuses on introducing new mixes for High Density Poly Ethylene (HDPE) or Poly Methyl Meth Acrylate (PMMA).

HDPE is a plastic commodity with a wide variety of applications including pipe fittings, trays, tanks, and cutting boards. PMMA can be used as a glass alternative which is marketed as Plexiglas and Lucite and it is ideal for use in skylights and aircraft (Lynch et al., 2011). Chemical characteristics of PMMA are very similar to many of the polymers used in latex paints. Both HDPE and PMMA are easy to process and are fairly inexpensive.

The polymer phase of paint is typically made from one or more polymers including acrylates, vinyl acrylates, vinyl acetates, styrene acrylates, polyurethanes, epoxies, neoprenes, polyesters, and alkyd polyesters. Paint containing acrylate and/or polyester polymers are preferred in this application (Lynch et al., 2011).

In this solution dried latex paint is melt-blended with HDPE or PMMA and injection moulded into specimens used for testing mechanical properties of the mix (Lynch et al, 2011).

The limited available results show that using latex paint as a polymer feedstock with HDPE and PMMA enhances the mechanical properties of neat HDPE or neat PMMA (Lynch et al., 2011).

2.2.3 Using in Landfill

Using WLP as a daily cover or biodegradation enhancement in landfills are two options toward managing waste paint. Each of these options is explained below.

- **Alternative Daily Cover (ADC) For Landfill**

Alternative daily cover is applied in landfills to control disease vectors, fires, odours, blowing litter, and scavenging. In Florida, USA, latex paint is used as a landfill cover. In this method, the latex is mixed with an equal part of water and then sprayed over landfill. Another example of this is a public service authority regional landfill in Virginia, USA, which used WLP as 10% mix for its alternative daily cover. In 2002 this approach led to use of over 30 tonnes of WLP, saving over $27,000 (US Dollars) disposal fees. In addition; this alternative daily cover takes less landfill space compared to mixture previously used (Greiner et al. 2004; Quiroz, 2011).

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\(^5\) Intellectual Property & Development Status: Patent applications have been filed in: the United States, Canada, Europe, Israel, Japan, China, India, South Africa (Submitted), North Korea, Brazil, and Mexico. The inventor has made samples based on the technology for mechanical properties testing.
The main concern with this approach is the potential hazard posed to groundwater tables and water streams due to leachate containing waste paint.

- **Enhance Landfill Biodegradation**
  Columbia Ridge Landfill in Oregon, USA at 2011 embarked on a research study on biodegradation technology of WLP. In this application, WLP is added to the landfill to increase the biological activity. Improved biodegradation reduces the height of landfill, thereby making more space available for in the same cell of the landfill and furthermore makes it more economical to extract the gas produced for energy production (Keane, 2011). This can be a useful solution for WLP in climates without sufficient precipitation (Zarrehparvar, 2012). However it should be noted that WLP is not classified as a hazardous waste in Oregon, USA (Keane, 2011).

- **Summary**
  WLP can be used as an alternative daily cover for landfill. Furthermore mixing WLP within landfills accelerates the degradation process. However by using these options, WLP ends up being used inevitably in landfills which may lead to adverse environmental impacts. Rainfall can potentially wash the leachate containing waste paint into water streams and subsequently into ground water tables. In Victoria WLP is considered as a HHC and therefore as a result this approach is not recommended.

### 2.2.4 Alternative Products
Several other applications for WLP have been investigated which are explained in this section.

- **Use in Roof Membrane System**
  Using waste latex paint in roof membranes is a novel solution towards reducing this waste. Nehdi and Soliman (2012) investigated key properties of a new roofing system with the use of waste latex paint and then compared it with existing low-slope roofing membrane systems. The overall performance of WLP based composite over layer in low slope roofing membranes has been enhanced considerably compared to the existing membrane. This new method can increase the puncture resistance and as a result reduce the risk of roof leakage and also increase the fire resistance (Nehdi and Soliman, 2012).

- **Asphalt Sealant**
  Sealant helps maintain and increase the life of asphalt. To form a homogeneous compound and increase the performance of sealants, a combination of polymeric materials is needed (Johnson, 2000). Polymers enhance aggregate retention, prevent drain-down, improves binder performance at
high and low temperature extremes, and retards asphalt pavement oxidation in non-structural maintenance applications (BASF, 1998).

Latex asphalt sealant is used to renew the asphalt surface and prevent erosion, cracking and chipping. It can be made of post-manufactured by-products and post-consumer latex paints. Acrylatex Coatings & Recycling Inc. founded in 2008 is a company in the U.S which produces this latex asphalt sealant using waste paint. Figure 13 shows an application of this product in a field trial.

![Figure 13 Asphalt sealant (Acrylatex Coatings & Recycling Inc., 2013)](image)

- **Decorative Ground Cover**

  Decorative ground landscape cover is produced by collected Latex Paint Aggregate (LPA). LPA is comprised of the dried and hardened material found at the bottom of paint cans and crushed into decorative ground landscape cover. Calibre Environmental Ltd. Founded in 2003 and Acrylatex Coatings & Recycling are two companies in USA that manufacture this product (Figure 14).

![Figure 14 Decorative Ground Cover (Calibre Environmental Ltd., 2003; Acrylatex Coatings & Recycling, 2008)](image)

- **Asphalt Concrete**

  WLP has been unsuccessfully trialled for use in asphalt concrete (Earth-Tec Canada, 2001). Despite initial laboratory successes of the experimented mixture, during the field trial phase it was
observed that unpleasant smells emitted from the mixture and the impact of released vapours on air quality makes it impracticable to use WLP in this application. It was suggested that further testing is needed to confirm this research and to refine proportioning (Earth-Tec Canada, 2001).

- **Summary**

A number of different applications for waste paint have been reviewed in this section. These solutions represent innovative and novel end-of-life options for waste paint but are often in research and laboratory testing stages or only implemented in small scale and limited trials. Feasibility of implementing such options in Victoria requires more detailed investigations and is likely to need complimentary research to address local factors such as local authorities’ specifications for each application (e.g. VicRoads Specification for Asphalt Sealant), market demand and environmental impact.

Difference in waste management policy and regulations in Australia and countries were these research studies originate from is another issue which needs to be addressed properly for each application. As an example, considering the hazardous classification of waste paint in Australia, applications such as Decorative Ground Cover which can potentially pose risks to the environment and also occupational health and safety risks to people in contact will face several challenges in Australia.

### 2.3 Energy Recovery

According to the EPA’s waste hierarchy; energy recovery is the second least preferred option for waste handling after disposal to landfills. Fuel blending and incineration, which are discussed below, are two common approaches to recover energy from waste paint.

#### 2.3.1 Fuel Blending

Because of the high British thermal unit (BTU) value of Solvent-based paint, it can be used as a fuel blend in energy recovery systems, such as cement kilns. Fuel blending is a cost effective waste management method. The advantage of this option is potential reduction of waste disposal costs, and decrease in fuel costs for cement plant (Centre for Sustainable Resource Processing, 2007).

Toxfree (Chemsal) and GeoCycle in Victoria run a program to recover energy through using waste paint as a fuel. Waste paint used for this purpose comes from a mixed waste stream comprising both latex and solvent-based paints. Waste paint is separated from metal containers and then sent to concrete producers to be used as fuel for concrete kilns.

Figure 15 shows a diagram of this process.
2.3.2 Incineration

Solvent-based paint can provide the necessary BTUs to produce required temperature for destruction of hazardous waste. According to Paint Stewardship; USA, this option is less cost effective compared to fuel blending and is only used when Solvent-based paint fails EPA Toxicity Characteristic Leaching Procedure (TCLP) (Greiner et al., 2004).

2.3.3 Biomass Fuel

WLP is reported to be used by Amazon Environmental; USA, in the process of making PWP. PWP is a biomass fuel product which is made by using waste paint as a binder for wood dust, chips and other high BTU value materials (Keane et al., 2011).

Biomass is a sustainable and potentially environmentally sound energy source. It already supplies 14% of the world’s primary energy consumption and is expected to increase with depletion of fossil fuel recourses (Keane et al., 2011).

2.3.4 Summary

In most countries with a waste paint collection scheme in place, the sole method of solvent-based paint disposal is using it as an energy source (McMaster, 2003). Higher BTU of solvent-based paint compared to latex paints makes it more attractive for this application. Also costs involved in recycling solvent-based paints are greater than fuel blending costs (Greiner et al., 2004).

On the other hand, for WLP, while the recycling and reuse options are preferable compared to the energy recovery; however due to technical difficulties, volume consideration, intensive labour demand and also environmental risks associated with recycling and reuse options; fuel recovery remains as the commonly practiced methods for dealing with waste paint in many countries. This is
despite the fact that fuel recovery for latex paint is not a the most sustainable solution due to the
greater recycling potential and greater water content of WLP (Greiner et al., 2004).
3 Sustainable Management

The solutions for recycling and reusing waste paint are divided into three main categories according to the waste management hierarchy. These are paint reuse, paint recycling and energy recovery.

Available options for solvent-based waste paint are limited to either reuse through exchange programs or energy recovery. Shortage of research for Solvent-based reuse and recycling options are mainly attributed to the fact that Solvent-based paint constitutes only a small percentage of total A&D paint produced and follows a downward trend in volume. Due to the declining significance of waste Solvent-based paint and also its high BTU value, no further research and investment is recommended at this juncture.

On the other hand, the review carried out in this study shows an increasing interest in introducing new and innovative end-of-life options for WLP.

Paint reuse which includes exchange, consolidation, re-manufacturing and re-blending is the most preferred approach in the life-cycle of waste paint if the technical and financial considerations are satisfied.

Paint exchange in the community results in returning high quality paint to consumers and community.

Technical difficulties in paint re-blending can affect the quality of the final product which will have adverse financial and market impact. Producing low quality paint from waste paint (i.e. consolidation and remanufacturing) seems to be a more reasonable approach and has been tried internationally. However, the cost of recycling, sorting, filtering, removing bacteria, quality control and market development remains a barrier to this approach. As a result, it has been a huge challenge for industry to follow the waste paint reuse program in a sustainable manner.

The second category of end-of-life options for waste latex paint is recycling. Several approaches have been tried in recycling WLP in other products with some proven failures such as using waste paint in asphalt concrete.

In this study a growing interest in applications of waste paint in concrete production has been identified. Replacing water with waste paint in concrete has proven to be a technically and environmentally successful approach while financially the question on how viable it is to replace water with paint remains unanswered. Water restriction regulations play an important role in encouraging industry to take up this approach.

Waste paint is also reported to be used as replacement for polymer and chemical additives in concrete. Although results of such works have been implemented and adopted in some countries, in
Australia there is still a need for further research comprising of additional laboratory and field tests for these options to be used in practice.

As WLP contains a range of polymeric constituents it has been used as polymer feedstock in manufacturing of HDPE and PMMA and also as asphalt sealant. WLP use in the manufacture of HDPE and PMMA is still in its early research phase while its application in asphalt sealant has been commercialised in the USA. There is a patent protection in place for this method in some countries (see section 2.2.2) which needs to be considered.

WLP has been reported to be used to manufacture a puncture resistant roof membrane for low slope roofs. This option is a low priority particularly due to the low market demand in Australia for these types of roof systems.

In another attempt to recycle WLP, dried WLP is crushed and used as decorative ground cover. This is not applicable in Victoria as WLP is classified as HHC and furthermore this method can potentially pose OH&S risks to people in contact with this product.

Using waste paint as alternative daily cover in landfills or for enhancing landfill biodegradation are two other options which fit into the paint recycling category. These options can however have adverse environmental effects if the leachate reaches ground water tables or gets to water streams. Furthermore, as slow landfill biodegradation is not a problem in Victoria there is a big question mark on need for using WLP as a biodegradation enhancer.

The final category of options for waste paint is energy recovery. This option is the least preferred option from an environmental perspective. Waste paint, mainly Solvent-based, can be used as a fuel blend or incineration fuel. In another energy recovery application, WLP has been used as binder for producing biomass fuel.

Currently energy recovery from waste paint is the only option practised in Victoria. All collected waste paints, including solvent and latex based, are transported to Geocycle and used as a fuel blend in cement kilns. This is a global common practice for Solvent-based paint, but as discussed previously there are a range of other end-of-life options for WLP which can be explored.

Table 5 summarises the potential end-of-life options for waste paint that were investigated in this study with qualitative assessment on opportunities and obstacles.
<table>
<thead>
<tr>
<th>Solution</th>
<th>Decision</th>
<th>Application</th>
<th>Obstacles</th>
<th>Opportunities</th>
<th>Comment</th>
</tr>
</thead>
</table>
| Exchange                         | NR*      | paint       | - labour cost (in case of using labour)  
- OH&S of volunteers (in case of using volunteers)  
- OH&S with storage and handling  
- diversity in color and type  
- sorting expenses  
- filtering expenses  
- potential bacterial infection  
- warranty issues  
- low volume of high quality waste paint  
- market demand  
- essential local government involvement  
- requires investment on infrastructure and community education | - reduce transportation cost  
- reduced carbon footprint  
- saving in resources and energy  
- increase the community awareness on importance of recycling | These options need heavy involvement from government to educate community, provide infrastructure and to put in place initiatives to increase market demand (e.g. graffiti abatement contractors being asked to use a certain amount of waste paint, giving credit toward green star building for using waste paint in some applications such as fence painting) |
| Paint consolidation              | NR       | paint       | - labour cost  
- sorting expenses  
- filtering expenses  
- ongoing laboratory testing and costs  
- diversity in color and type  
- need to meet technical requirement (ongoing quality control)  
- difficulty in producing repeatable and uniform product  
- potential bacterial infection  
- no stable market  
- warranty issues | - graffiti abatement applications  
- warehouse painting  
- saving in resources and energy  
- reduced carbon footprint  
- Local government initiatives can potentially make it more attractive |                                                                                                                                                                                                 |
| Paint remanufacturing            | NR       | paint       | - labour cost  
- sorting expenses  
- filtering expenses  
- same price as new paint  
- ongoing laboratory testing and costs  
- potential bacterial infection  
- no stable market  
- warranty issues | - producing high quality paint  
- same performance as new paint  
- saving in resources and energy  
- shifting toward green building |                                                                                                                                                                                                 |
| Paint re-blending                | NR       | paint       | - labour cost  
- sorting expenses  
- filtering expenses  
- same price as new paint  
- ongoing laboratory testing and costs  
- potential bacterial infection  
- no stable market  
- warranty issues | - producing high quality paint  
- same performance as new paint  
- saving in resources and energy  
- shifting toward green building |                                                                                                                                                                                                 |
<table>
<thead>
<tr>
<th>Solution</th>
<th>Decision</th>
<th>Application</th>
<th>Obstacles</th>
<th>Opportunities</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete; WLP as a water replacement</td>
<td>R1*</td>
<td>non-structural concrete</td>
<td>- sorting expenses</td>
<td>- can improve concrete performance</td>
<td>Local research and trials in Victoria with collected WLP is required, initiatives such as providing credit toward green star building can increase the market demand</td>
</tr>
<tr>
<td>Concrete; WLP as polymer replacement</td>
<td>R1</td>
<td>masonry blockfill, overlay, rigid pavement, pervious concrete, cement manufacturing</td>
<td>- sorting expenses</td>
<td>- improves concrete properties</td>
<td></td>
</tr>
<tr>
<td>Polymer feedstock</td>
<td>NR</td>
<td>manufacturing of HDPE, PMMA</td>
<td>- ongoing laboratory testing and costs</td>
<td>- reduced carbon footprint</td>
<td></td>
</tr>
<tr>
<td>decorative cover, roof membrane</td>
<td>NR</td>
<td>decorative cover</td>
<td>- high technical risks</td>
<td>- reduced carbon footprint</td>
<td></td>
</tr>
<tr>
<td>Asphalt sealant</td>
<td>R2*</td>
<td>asphalt sealant, pavement overlay, road overlay</td>
<td>- stringent VicRoads specifications needs</td>
<td>- reduced carbon footprint</td>
<td></td>
</tr>
</tbody>
</table>

Local research and trials in Victoria with collected WLP is required, initiatives such as providing credit toward green star building can increase the market demand.
<table>
<thead>
<tr>
<th>Solution</th>
<th>Decision</th>
<th>Application</th>
<th>Obstacles</th>
<th>Opportunities</th>
<th>Comment</th>
</tr>
</thead>
</table>
| Using in landfill         | NR       | alternative daily cover, water replacement as biodegradation enhancer         | to be met                                                                  | - shifting toward green construction  
                                                                              | - stable on-going market                                                                                                           | since WLP is considered as HHW, it cannot be used in this application in Victoria and there is also enough precipitation in Victoria to provide moisture for landfills |
| Energy Recovery           |          | Fuel Blending                                                                |                                                                            | - enhancing biodegradation in landfills,  
                                                                              | - can reduce odour and dust  
                                                                              | - control disease                                                                                                                 |                                                                                                                                 |
|                           |          | CS*                                                                          | - sorting expenses  
                                                                              | - ongoing laboratory testing and costs  
                                                                              | - waste of valuable WLP components                                                                                                 | - reduce the cost of waste disposal  
                                                                              | - ongoing demand for WLP which cannot be reused or recycled                                                                                                           |
|                           |          | cement kilns                                                                 |                                                                            |                                                                                                                                  |                                                                                                                                 |

* NR : Not Recommended  
R1: Recommendation 1  
R2: Recommendation 2  
CS: Current Situation
3.1 Discussion

To develop a successful waste paint management strategy, it should be noted that the quality, colour, and types of collected waste paint varies significantly from location to location. At the same time in situations that only one end of life solution for WLP is practiced there are higher associated risks (management, market and technology risks) if that solution fails or faces challenges.

These two facts rule out the idea of finding a one-fits-all solution for waste paint management. The optimum solution can be a suite of options appropriately selected based on all influential factors including volume considerations, financial and technical viability, environmental assessments and risk management. In Victoria, part of this context is set out by the ‘waste hierarchy’ that explains the preferences for waste management solutions. Considering all these influential parameters the waste paint management strategy should introduce a set of preferred end-of-life options for waste paint rather than focusing on one option.

Results of this review show a remarkable gap between the research and state of the art globally (and especially in North America) and current practices in Australia in terms of available options for WLP management. The following recommendations are made to narrow this gap:

- Better investment in raising consumer awareness is a key rule regardless of the final practiced solution. This plays an important role in the success of waste paint management programs in two ways. It can potentially improve consumers’ participation in collection programs and it can furthermore, create a bigger market for recycled products by improving consumers’ acceptance.

- Excluding the environmental benefits, can negatively affect financial viability of the waste paint management options. Changes in current regulations might be required in order to incentivise involved parties to invest more in end-of-life options for waste paint.

- Improvement in collection programs by monitoring, evaluating, and collecting data over time of the program. Increasing the collection rate is important to expand the market for potential options of end of life waste paint.

- Shortage of research work in this area is evident in Victoria and more broadly in Australia. Further research on end-of-life options for WLP (with government and industry playing a major role in management and direction of the research) can significantly boost the move towards waste paint management. Research studies can focus on the possibility of local adoption of options currently being practiced in other countries considering technical, socio-economical and environmental aspects.
of WLP management in Australia. Further research can also be initiated to investigate new applications for WLP.

This review study proposes the following solutions as having the ability to provide a viable solution for waste paint in Australia. These solutions have been investigated further in sections 4, 5.2, Error! Reference source not found.5.4 and 5.5 of this report:

- Replacement for water in Concrete
- Replacement for polymer in Polymer Modified Concrete (PMC) along with replacement of water
- WLP in Asphalt sealants (and PMB) as polymer replacement

Making a final decision on the most suitable method to manage the end of life waste depends on technical, environmental, economic factors and also risk assessment along with volume considerations.

The technical, environmental and economic impact of the proposed solutions for the end of life waste paint will be discussed in the following sections.
4 Waste Paint Management Process Overview

There are three main stages in the EOL management: collecting, sorting (processing), and application in final solution (product; e.g. concrete).

The collection process refers to the activities performed to transport waste paint to storage and processing facilities. Once the collected paints reach the storage and processing facilities, they go through a pre-processing stage.

As illustrated in Figure 16, collected waste paints in storage facilities are first sorted to determine the type of paint (latex vs solvent) and condition (solid and liquid). Currently, this process is practiced through Detox program in Victoria. In the next step paints are extracted from the containers and based on the technical evaluation (which depends on final application) they will be sent to the final user.

![Figure 16 Waste paint pre-processing paint](image)

Collection, transport, sorting and paint extraction are the primary steps for managing end of life waste paint which is a current on-going practice in Victoria through DYH program. This study is focused on identifying the proper solutions for end of life waste paint after the collection and pre-processing. So the focus of following chapters is on Steps 5 to 7. Technical evaluation tests need to be done prior to selecting the best possible option. Figure 17 shows the process of selecting possible options for managing end of life waste paint.

![Figure 17 End of life waste paint options](image)
It is recommended that solvent based paint be used for energy recovery and liquid latex paint be used in concrete industry and/or asphalt sealants industry as recommended in section 3.1. These solutions will be discussed with more details in next sections of the report.
5 WLP in Polymer Modified Concrete

This section looks into different aspects of the option of using WLP as a replacement for polymer in PMC and also as a water replacement in concrete.

5.1 Technical Background

Polymer concrete is used for repair, thin overlays for floors and bridges, and for precast components (Fowler, 1999). Using polymer modifier in concrete improves microstructure, enhances the durability of cement mortar and concrete and the physical properties of the concrete such as bond and tensile strength. Higher flexural strengths and lower permeability are other advantages of this type of concrete (Singh et al., 2012). This type of concrete has low permeability and provides greater protection against chloride-induced corrosion and deterioration of bridges decks (Singh et al., 2012).

PMC contains of Portland cement concrete with a polymer modifier such as acrylic or styrene butadiene latex (SBR), polyvinyl acetate, and ethylene vinyl acetate. SBR has been widely used for floor and bridge overlays with a minimum thickness of 30 mm. The amount of polymer is around 10±20% of the Portland cement binder (Fowler, 1999).

Polymer can be mixed in a dispersed, powdery, or liquid form with fresh cement mortar and concrete mixtures before curing. Figure 18 shows the polymers and monomers used as cement modifier (Yoshihiko, 1995).

Figure 19 shows a simplified model for formation of monolithic matrix phase happening by cement hydration and polymer film formation. Formation of such a polymer-cement co-matrix phase results in superior properties for PMC.

![Figure 18 Polymers and monomers for cement modifiers (Yoshihiko, 1995)](image-url)
5.2 Technical Feasibility Study of WLP in Concrete

The research into the mechanical properties of concrete with replacement of polymer and water by WLP is extensive, though there are not many field trials available. The chemical characteristics of paint are very similar to some of polymers which are currently used in concrete. Research studies have shown waste paint constituents are capable of being replaced by conventional chemical admixture.

Researchers have examined the durability and mechanical properties of concrete with replacement of polymer and water by WLP. An industrial trial has also been done in the USA and New Zealand. According to previous research, the optimum WLP in concrete is ranging between 5% to 20% paint replacement of water by mass, however this percentage depends on properties of waste paint.

Most of studies conducted on the use of WLP in concrete focus on low risk implications, such as masonry blockfill, bridge overlay, and non-structural concrete applications, such as side walk track, carpark decks, highway median barriers and concrete blocks. These low risk applications are mainly chosen because using WLP in concrete is in the initial research stages and has not been tried in large scales widely. Table 6 shows the assessment of different stages of using WLP in concrete product looking at stages shown in Figure 16.

Since no local research has been undertaken in Australia, tests based on Australian Standards are strongly recommended. It is suggested that a local laboratory and pilot-scale testing program be conducted to address technical details of WLP use in concrete. The proposed program should produce recommendations on optimum mass ratio of WLP to solid content of concrete for each application. Clearly general physical properties of WLP such as specific gravity, density as well as water content, pigment and polymer content need to be considered in these calculations.
Applications to be investigated in proposed work are recommended to be chosen amongst low risk concrete applications reviewed in the literature such as following applications:

- Applications where SBR is used; such as in bridge overlay
- Applications that require high durability; such as carpark decks and side walk
- Applications that require high workability; such as masonry blockfill

<table>
<thead>
<tr>
<th>Stage</th>
<th>Assessment</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Paint Collection</td>
<td>Similar to current DYH program conducted by toxfree</td>
<td>NA</td>
</tr>
<tr>
<td>Transport to storage and sorting facility</td>
<td>Similar to current DYH program conducted by toxfree</td>
<td>NA</td>
</tr>
<tr>
<td>Sorting Waste Paint</td>
<td>Similar to current DYH program conducted by toxfree</td>
<td>NA</td>
</tr>
<tr>
<td>Paint extraction</td>
<td>Similar to current DYH program conducted by toxfree</td>
<td>NA</td>
</tr>
<tr>
<td>Technical evaluation tests on waste paint</td>
<td>Water content, polymer content and pigment content</td>
<td>Frequency and number of tests depends on volume, final application and outcomes of initial research work</td>
</tr>
<tr>
<td>Transport and handling</td>
<td>Similar to current procedure from toxfree to geocycle</td>
<td>NA</td>
</tr>
<tr>
<td>Production line</td>
<td>Similar to adding water and polymer to concrete</td>
<td>An allocated tank (mixer) with capability of weight and volume measurement will be required (Refer to Figure 22)</td>
</tr>
</tbody>
</table>

5.3 **Volume Considerations for WLP in Concrete**

The percentage of WLP used in concrete varies between 5% and 20% of water used in concrete production which varies based on the concrete application and also WLP water content. As a rough estimation, an average of 50 kg WLP per cubic meter of concrete (according to Quiroz, 2011 and Haigh, 2007) is used. According to CCAA the Victorian premixed concrete industry produced 5.6 million m³ of premixed concrete in 2009/10. Table 7 shows rough estimations on WLP quantity required to replace polymer and water in concrete and. In the replacing polymer and water in PMC option 4.48 thousand tonnes of WLP could be utilised per year in Victoria which is well beyond the current amount of collected WLP in Victoria (i.e. 560 tonnes per year on average).
Table 7 Volume considerations for WLP in concrete

<table>
<thead>
<tr>
<th>Application</th>
<th>Annual production (Victoria)</th>
<th>Replaced polymer</th>
<th>Replaced Water</th>
<th>Required WLP (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>5.6 million m$^3$</td>
<td>-</td>
<td>11 kg/m$^3$</td>
<td>117,600 *</td>
</tr>
<tr>
<td>PMC</td>
<td>0.112 million m$^3$ **</td>
<td>40 kg/m$^3$</td>
<td>11 kg/m$^3$</td>
<td>4,480</td>
</tr>
</tbody>
</table>

* To replace 11 kg of water; 21 kg of WLP is required.
** Based on the assumption of a potential market equivalent to 2% of total concrete market.

5.4 Environment Impact Assessment of WLP in Concrete

This section provides an overview of the major environmental impacts and considerations associated with recycling WLP in concrete and also asphalt sealants. Understanding the environmental impacts of each option helps in making informed decisions on whether or not to proceed with a project.

5.4.1 Positive Environmental Impact of WLP in Concrete

Concrete is one of the most energy consuming materials in the world. Using recycled materials helps to reduce the negative environmental impact of concrete. In the following section the positive impacts of recycling WLP in concrete is discussed.

- Reduce Greenhouse Gases and Aggregate Conservation

Concrete generates a large amount of greenhouse gases and require a large amount of raw materials such as limestone and clay, and fuel such as coal, resulting in deforestation and top-soil loss (Mehta, 2001). In Australia there are approximately 2,200 quarries operating that produce some 130 million tonnes of stone, limestone, gravel and sand used to produce materials, such as cement, concrete, bricks, tiles, pavers and road paving. 580 operating quarries are operating across Victoria (CCAA, 2013).

The worldwide concern and governance on carbon dioxide emissions has encouraged research into the partial replacement of cement, polymer, aggregates with supplementary materials such as WLP, fly ash and slag. Using WLP in concrete helps to save energy and material by reduction in amount of virgin polymer required for manufacturing PMC. It provides viable means of reducing the carbon footprint of concrete.

Concrete usually uses about 7% and 15% cement by weight which depends on the application and required performance for the concrete. Weighs of one cubic meter (m$^3$) of concrete is approximately 2400 kg. The average cement quantity is around 250 kg/m3. The average CO$_2$ emission of concrete is 100 to 300 kg per m$^3$ (NRMCA, 2012).
• Water Conservation

Using large amounts of fresh water is another issue in concrete industry. The mixing water requirement alone is approximately over 200 million litres per year in Victoria for ready mixed concrete industry and curing concrete. Replacing water with WLP can save thousands of tonnes of water per year.

• Increase Concrete Durability

Increasing concrete durability is a major step toward the sustainable development of concrete (Swamy, 2000). Creating a longer design life for concrete will end up in saving resources and energy and in cutting carbon emission. The key approach to increase concrete durability is reducing the void space in the concrete. This prevents water from accessing corrosive material and resulting in cracking and spalling (Haigh, 2007).

The service life of pavement for instance, is between 15 to 20 years. Current studies suggest that by recycling WLP in rigid pavement concrete, the service life will increase to 30 to 40 years (Quiroz, 2011). Production of concrete can be reduced remarkably as a result of increasing the service life of concrete. This consequently leads into great savings in the amount of resources, energy and water that would otherwise being used for concrete production.

5.4.2 Potential Negative Environmental Impact of WLP in Concrete

Using WLP in concrete can be a great move toward a sustainable future, however there are some concerns regarding the environmental impact of using WLP in cement-based materials including the potential for leaching of the heavy metal ingredients in WLP during the concrete life-cycle.

Recycled materials such as WLP used in applications such as facades, foundations, embankments, road works and etc. are subject to environmental conditions such as rain and consequently their contaminant emissions need to be determined (Disfani et al., 2012). This can be assessed by leaching tests which provide the basis for defining the life cycle of recycled materials within a given time period (Valls and Vasquez, 2002 in Disfani et al., 2012). For each application of recycled material the leachable concentration limits are necessary to limit the potential for leaching of contaminants from waste/recycled material which will remain as a construction material for a long period of time (EPA Victoria, 2009 in Disfani et al., 2012).

WLP may include biocides, heavy metals and solvents such as ethylene glycol and glycol ethers (Nehdi and Arif, 2010). Nehdi and Aref (2010) investigated the impact of using WLP in concrete on its environmental performance. The leachability of WLP concrete was tested under various exposure conditions such as freezing–thawing and wetting–drying cycles in fresh and salt water in the laboratory. Results of this study showed that the heavy metal leachate from 15% and 25% WLP
concrete products were completely within the acceptable range enforced by US EPA hazardous waste regulations (Nehdi and Arif, 2010).

It is recommended that leachability of WLP concrete is tested in Australia to ensure it complies with EPA Victoria regulations.

5.4.3 Summary

Achieving a sustainable approach in construction industry is one of the greatest challenges of 21st century. On the other hand, waste paint can have negative environmental impacts if it disposed illegally. Research studies and limited field trials show that recycling waste paint in construction materials such as concrete helps both managing waste paint and achieving a more sustainable construction industry.

There are a number of Australian legislations and schemes that support take up of waste paint use in construction industry. One of these schemes is the Green Star environmental rating scheme for building which was launched in 2003 and is operated by the Green Building Council of Australia. This scheme supports using recycled materials in building construction.

Table 8 summarises the environmental impacts of replacing WLP in concrete.

<table>
<thead>
<tr>
<th>Environmental Impact</th>
<th>Kg/m³ of concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced polymer consumption</td>
<td>50</td>
</tr>
<tr>
<td>Reduced water consumption</td>
<td>11</td>
</tr>
<tr>
<td>Reduced natural resources consumption</td>
<td>2%</td>
</tr>
<tr>
<td>Increased life and durability</td>
<td>100% (Quiroz, 2011)</td>
</tr>
<tr>
<td>Leachate Potential</td>
<td>Potential negative impact needs to be studied</td>
</tr>
</tbody>
</table>

5.5 Cost Analysis for WLP in Concrete

This section presents a cost analysis for replacement for water in concrete and replacement for polymer in polymer modified concrete (PMC).

5.5.1 Option 1: Replacement for water in concrete

This option involves replacing a percentage of water with Waste Latex Paint (WLP). The cost analysis included the following components: cost of WLP, laboratory testing and raw materials. Assumptions are discussed for each item.
\textbf{Cost of Waste Latex Paint (WLP)}

This cost was calculated as the total costs of the Detox Your Home (DYH) programme. It is assumed to include the total cost to Sustainability Victoria (SV) of administering the programme. The cost data has been obtained from “Detox Your Home – Strategic Review” (Sustainability Victoria, 2011) and has been calculated as a 5-year average, in order to smoothen the price variability over this time period. In order to estimate the costs for 2013, an adjustment was made for inflation using quarterly inflation data (i.e. 2012 – first quarter 2013) obtained from the Reserve Bank of Australia (RBA). SV has estimated the total programme costs per kg increased by 13% over the 5-year period slightly more than the change in CPI, which is consistent with our methodology. The requirement of WLP (in kg) per cubic meter (m$^3$) of concrete is estimated as 21kg/m$^3$ (Rawlinsons Australian Construction Handbook 2013). Therefore, the total cost per kg of WLP for 2013 has been multiplied by 21 in order to reflect the total costs of WLP per m$^3$ of concrete.

The total cost of WLP is estimated to be $81.11 based on the above approach. This would not be incurred by concrete producers, as the DYH program costs are covered by state government (SV).

\textbf{Laboratory testing - Solid Content Test}

This test allows us to determine the water content of WLP and using this information we can calculate the solid content. The process involves oven drying of material at a set temperature for a specified period of time. The solid content is then determined as the difference between the initial mass and the moisture content. The price for the solid content test was obtained from Civil Geotechnical Services price list (2010). This price was adjusted for inflation using the same approach as above.

\textbf{Raw material}

Raw material costs consists of the basic (constant) elements of concrete which includes cement, water, coarse and fine aggregates (Rawlinsons Australian Construction Handbook 2013). The quantity of water which replaces WLP was estimated as $11$kg/m$^3$ (Rawlinsons Australian Construction Handbook 2013). The cost of water was obtained from City West Water (2013) related to the usage prices per day per kilo litre. The cost of water for $11$kg/m$^3$ was deducted from the original concrete costs that consist of the basic elements. This cost was adjusted for inflation using the same methodology as above. Table 9 shows the cost summary for the option of replacing water with WLP in concrete, including laboratory costs for solid/water content of WLP for each cubic meter of concrete.
Table 9 Cost summary for replacement of water in non-structural concrete

<table>
<thead>
<tr>
<th>Elements</th>
<th>Price/Cost ($)</th>
<th>Costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total DYH programme cost /m³</td>
<td>81.11</td>
<td></td>
</tr>
<tr>
<td>Laboratory testing (Unit price)</td>
<td>15.79</td>
<td></td>
</tr>
<tr>
<td>Basic concrete /m³</td>
<td>137.57*</td>
<td></td>
</tr>
<tr>
<td>Cost of water /m³</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Raw materials (basic concrete – cost of water) /m³</td>
<td>135.55</td>
<td></td>
</tr>
<tr>
<td>Total costs of concrete replaced by WLP/m³</td>
<td>234.44</td>
<td></td>
</tr>
<tr>
<td>Total excluding DYH programme costs**</td>
<td>153.33</td>
<td></td>
</tr>
</tbody>
</table>

* This cost of basic concrete does not include the costs of delivery to site, handling, placing, allowance for wastage and loss during handling and placing. As these costs vary according to the purpose for which the concrete is used, they have not been taken into account in this analysis.
** Note: The DYH programme costs will be covered by SV

- **Discussion**

The annual production of concrete in Victoria is estimated to be 5.6 million m³ (CCAA, 2010). This option replaces water in concrete with WLP. The total WLP produced annually is 560 tonnes. This 560 tonnes of WLP will replace 293,333 litres of water and will produce 26,667 m³ of concrete. Given that the annual production of concrete in Victoria is 5.6 million m³, a 0.5% take up by the industry would consume the entire WLP collected annually in Victoria. Option 1 is inclusive of the cost of the DYH programme, the laboratory test, and basic concrete less the cost of water. This is estimated to be $234.44. The total is reduced to $153.33 as SV covers the cost of the DYH programme.

5.5.2 **Option 2 - Replacement for polymer in PMC**

This option involves replacing the polymer content with WLP. The cost analysis included the following components: cost of WLP, laboratory testing and raw materials. Assumptions are discussed for each item.

- **Cost of Waste Latex Paint (WLP)**

This cost was determined using the same methodology as in option 1. The requirement for WLP differs in this option. The quantity of WLP (in kg) per cubic meter (m³) of concrete was estimated as 50kg/m³ (Rawlinsons Australian Construction Handbook 2013). Therefore, the total cost per kg of WLP was multiplied by 50 in order to reflect the total costs of WLP per m³ of concrete.

- **Laboratory testing - Polymer Content Test**

This is a specialised test and as such a test cost of $157.9 for each test has been assumed (after consultation with Swinburne University chemistry laboratory). As the test is more specialised it will
be conducted once for 10 m³ of concrete and consequently the price for each m³ of concrete will be $15.79.

- **Raw materials**

  Raw materials costs consist of the basic (constant) elements of concrete which includes cement, water, coarse and fine aggregates (Rawlinsons Australian Construction Handbook 2013). The polymer (Styrene Butadiene Rubber – SBR) will be replaced by WLP. The cost of polymer was obtained from ICIS, a petrochemical market information provider (2011) and estimated at US$ 4400 per tonne. This cost was converted to AUD at the exchange rate of 0.96US$/A$ dated 22nd May 2013. A per kilogram cost was calculated at 1tonne = 1000kg and this was multiplied by 50kg to estimate the total cost of SBR per m³ of concrete. Both the basic concrete and SBR costs were adjusted for inflation based on the same methodology as above. In addition this option requires the addition of a high range water reducing admixture at a rate of 5 ml/100kg of cement. This translates into 6ml/100kg due to the total cement requirement of a 120kg/m³. The cost of this product was obtained from Sika Australia, a speciality chemical supplier for the building and construction industry. The cost of SIKA-VISCO 10 (a high range water reducing admixture) was estimated to be $6.73 per 20 litres. As this is the current price for the material, no adjustment for inflation was required. The per litre cost was then multiplied by the number of millilitres of admixture to estimate the total cost. Table 10 shows the cost summary for replacement of polymer by WLP in PMC.

| Table 10 Cost summary for replacement of polymer in Polymer Modified Concrete (PMC) |
|----------------------------------|-----------------|-----------------|
| Elements                          | Price/Cost ($)  | Costs ($)       |
| Total DYH programme cost /m³     | 193.11          |                 |
| Laboratory testing (price per m³ of PMC) | 15.79          |                 |
| Polymer – SBR /m³                | 186.82          |                 |
| Basic Concrete                   | 137.57          |                 |
| PMC (Basic concrete + SBR)*      | 324.39          |                 |
| High range water reducing admixture | 0.02           |                 |
| Raw materials (PMC + admixture – SBR) | 137.59          |                 |
| Total costs of PMC replaced by WLP /m³ | 349.49          |                 |
| Total excluding DYH programme costs** | 153.38          |                 |
| Carbon price / m³***             | 0.92            |                 |

* Note: there is no standard price for PMC in the Australian Construction Handbook. Therefore the cost of PMC is estimated to include the cost of basic concrete and SBR.
** Note: The DYH programme costs will be covered by SV
*** Carbon price is taken as $23 per tonne (Australian Government – Clear Energy Future, 2013)
• **Discussion**

The annual production of polymer concrete in Victoria is estimated to be 112,000 m$^3$ (see table 8). This option replaces polymer in concrete with WLP. The total WLP produced annually is 560 tonnes. A 10% take up by the industry would consume the entire 560 tonnes of WLP collected annually in Victoria. In order to replace polymer with WLP the total costs are inclusive of, the cost of PMC concrete, high range water reducing admixture and the laboratory test. The cost of polymer is then deducted and replaced with the cost of WLP in order to arrive at the total cost for option 2, per m$^3$ at $346.49. As SV will cover the cost of the DYH programme, the total is reduced to $153.38. The carbon price is estimated to be $0.92 per m$^3$ based on the cost of $23 per tonne with an estimated usage of polymer for this option at 40kg/m$^3$ of concrete.

### 5.6 Risk Assessment of Using WLP in Concrete

According to AS/NZS 4360:2004 Risk Management Standard and Guidelines, “risk management involves managing to achieve an appropriate balance between realizing opportunities for gains while minimizing losses” which is the most commonly applied approach in Australia.

The main elements of risk management, as outlined in AS/NZS 4360:2004, are:

1. Communicate and consult with internal and external stakeholders
2. Establish the context (internal, external and risk management context)
3. Identify risks (where, when, why and how event could prevent, degrade, delay or enhance the achievement of the objectives.)
4. Analyse risks (identify and evaluate existing controls, determine consequences and likelihood and the level of risk.)
5. Evaluate risks (comparing estimated levels of risk against the pre-established criteria)
6. Treat risks (developing and implementing specific cost-effective strategies and action plans for increasing potential benefits and reducing potential costs.)
7. Monitor and review

Figure 20 illustrates the Risk Management Standard process for identifying, analysing and managing risks (AS/NZS 4360:2004).
According to Australia/New Zealand Risk Management Standard risk assessment is comprised of identifying the risk, analysing and finally evaluating the risks as shown in Figure 20. This section of report will focus on identifying, analysing and evaluating risks associated with reusing WLP in concrete as water and polymer replacement and also as polymer replacement in asphalt sealants.

To evaluate the risk level using the risk management process shown in Figure 20, both the likelihood and consequence of risk needs to be determined and using these two parameters the risk level can be calculated using the terminology shown in Figure 21.

Each of the risks falls into one of the following categories:

- **Workplace health and safety risks**

  Workplace health and safety risks relates to the health or safety of people. Health risks are related to people’s health through chronic exposure leading to illness. Safety risks are those
which have serious consequences, ranging from first aid, lost time injury, to permanent disability or single and multiple fatalities (Department of Resource, Energy and Tourism, 2008).

- **Risks to Natural environment**
  The environmental risk can be the impact of the process of producing concrete and asphalt sealants reusing WLP on the environment or the environment impact of the final product, on the environment such as leachate or negative effect on the air quality.

- **Community health risks**
  This risk involves the potential impacts of operation’s activities (or a product such as concrete) on the health of the local community. As an example; any risk to the community health associated with reduced air quality as a result of using WLP in concrete is included in this category.

- **Business risks**
  Risks such as reputation and financial impact fall into this category.

- **Case specific risks**
  This category contains any risks uniquely related to the product/project. As an example effect of any change in government regulation on water restrictions on the WLP replacement for water in concrete falls in this category.

  Risks associated with using WLP in concrete are listed in Table 11 with likelihood and consequence and risk level for each risk item evaluated and provided. It should be noted that this section only identifies and provides details of risks specifically related to reusing WLP in concrete and does not provide risks generally related to concrete works and production.
<table>
<thead>
<tr>
<th>Category</th>
<th>Risk</th>
<th>Likelihood</th>
<th>Consequence</th>
<th>Risk level</th>
<th>Treatment</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplace health and safety</td>
<td>Workers health due to working with chemicals</td>
<td>Possible</td>
<td>Moderate</td>
<td>High</td>
<td>Safety Date Sheet prepared and monitored regularly</td>
<td>Concrete industry produces a range of products using chemicals and polymers and use of WLP is similar in nature to those practices.</td>
</tr>
<tr>
<td></td>
<td>Fire and explosion due to storage and working with waste paint</td>
<td>Possible</td>
<td>Catastrophic</td>
<td>Extreme</td>
<td>Fire plan and material safety data sheet required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low air quality in work environment</td>
<td>Unlikely</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Air quality monitoring is required</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Groundwater and stormwater contamination due to leachate*</td>
<td>Unlikely</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Research on leachate of contaminant constituents from WLP concrete is required</td>
<td>Australian Standard for Leachate Procedure (ASLP) needs to be followed.</td>
</tr>
<tr>
<td>Business</td>
<td>Negative reputation due to varying quality of final concrete product</td>
<td>Possible</td>
<td>Major</td>
<td>Extreme</td>
<td>Continuous quality control of final product</td>
<td>More research and field trials prior to any large scale application will minimise uncertainties.</td>
</tr>
<tr>
<td>Case specific</td>
<td>Change of government regulation and budget allocation affecting waste paint scheme quantity and cost</td>
<td>Likely</td>
<td>Major</td>
<td>Extreme</td>
<td>Long-term government plan and commitment</td>
<td></td>
</tr>
</tbody>
</table>
6 Asphalt Sealants and Polymer Modified Binders

This section looks into different aspects of the option of using WLP as a replacement for polymer in asphalt sealants and Polymer Modified Binders (PMB).

6.1 Technical Background

Studies have been showing that polymers improve the asphalt performance. Polymer modified binders have been used successfully at locations with high stress, such as intersections of busy streets, airports, vehicle weigh stations, and race tracks (Yildirim, 2007). Pavement with polymer modification show better resistance to rutting and thermal cracking, and decreased fatigue damage, stripping and temperature susceptibility. Polymer modified binders characteristics include greater elastic recovery, a higher softening point, greater viscosity, greater cohesive strength and greater ductility (Yildirim, 2007). This type of asphalt has been used widely around the world. Australian Asphalt Pavement Association (AAPA) introduced guides and specifications regarding polymer modified binders in National Asphalt Specification in 2004.

Polymers that have been used to this product include styrene–butadiene–styrene (SBS), styrene–butadiene rubber (SBR), Elvaloy, rubber, ethylene vinyl acetate (EVA), polyethylene, and others. (Yildirim, 2007). Among them, one of the most effective modifiers for paving asphalt has been SBR (Baochang et al., 2009) usually as a dispersion in water (latex) (Yildirim, 2007). According to Becker et al. (Baochang et al., 2009), SBR polymers increase the ductility of asphalt pavement, which makes flexibility in pavement and prevent crack at low-temperatures.

Several types of asphalt sealants used around the world in a range of applications including:

1- **Crack sealants**: are usually polymer modified bituminous emulsions, and applied by hand along the line of the crack. The result looks like lots of black snakes on the road, which can be seen on council roads (Acrylatex Coatings & Recycling Inc., 2013).

2- **Surface enrichments** (e.g. sealcoat products): This can be used on an aged asphalt pavement or a sprayed seal surfacing that still has high enough surface texture to maintain skid resistance. Often applied as thin a polymer modified emulsion, no aggregate is placed on top as is normally the case. This is applied on low volume roads and airport taxiways.

3- **Strain Alleviating Membranes (SAMs)**: Australian Asphalt and Pavement Association (AAPA) provides specific guidelines about this product (AAPA, 2013). This is where a sprayed seal (also known as a chip seal in NZ & USA and a surface dressing in the UK) is applied over the cracked surface. This involves spraying a polymer modified binder
(PMB) over the pavement, spreading single sized aggregate over it, and pneumatic tyred rolling. The road is then reopened to traffic. The common generic polymer types used for the manufacture of PMBs specified in the Austroads Framework for Polymer Modified Binders and Multigrade Bitumens are Styrene Butadiene Styrene (SBS), Polybutadiene (PBD) and Ethylene Vinyl Acetate (EVA). Polymer concentration in the mixture depends on how bad the cracking of the asphalt cover is (AAPA, 2013). This is often applied on arterial roads and highways, and is by far the major market for synthetic polymers in bitumen. Figure 22 shows the manufacturing process for this product.

![Figure 22 Manufacturing process of polymer modified binder (AAPA, 2013)](image)

4- **Strain alleviating membrane interlayers (SAMIs).** There is also an AAPA specification for this product. This is similar to a SAM, except that the SBS content is much higher, following its placement layers of hot mix asphalt are placed on top. The purpose of a SAMI is twofold. Firstly to prevent any cracking from the base-course reflecting through the new asphalt, and secondly to waterproof the underlying pavement.

### 6.2 Technical Feasibility Study of WLP in Asphalt Sealants and PMB

There are no research studies in Victoria and Australia on this application and as such local tests based on Australian Standards (following AAPA, Austroads and VicRoads guidelines) are required to investigate whether the final product meets road authorities’ specifications. It is recommended that laboratory and pilot-scale investigations be carried out to address technical details of WLP use in asphalt sealants. Proposed program should produce recommendations on optimum mass ratio of WLP to for each application.

Table 12 summarises different technical feasibility aspects of the recommended option of using WLP in asphalt sealants looking at stages shown in Figure 16.
Table 12 Technical feasibility assessment for WLP in asphalt sealants

<table>
<thead>
<tr>
<th>Stage</th>
<th>Assessment</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste Paint Collection</td>
<td>Similar to current conducted by toxfree</td>
<td>NA</td>
</tr>
<tr>
<td>Transport to storage and sorting facility</td>
<td>Similar to current conducted by toxfree</td>
<td>NA</td>
</tr>
<tr>
<td>Sorting Waste Paint</td>
<td>Similar to current conducted by toxfree</td>
<td>NA</td>
</tr>
<tr>
<td>Paint extraction</td>
<td>Similar to current conducted by toxfree</td>
<td>NA</td>
</tr>
<tr>
<td>Technical evaluation tests on waste paint</td>
<td>Water content, polymer content and pigment content</td>
<td>Frequency and number of tests depends on volume, final application and outcomes of initial research work</td>
</tr>
<tr>
<td>Transport and handling</td>
<td>Similar to current procedure from toxfree to geocycle</td>
<td>NA</td>
</tr>
<tr>
<td>WLP Consolidation</td>
<td>Water content needs to be reduced below a certain level determined at the research phase</td>
<td>Technical and financial costs vary with water content orf each WLP patch</td>
</tr>
<tr>
<td>Production line</td>
<td>Similar to adding water and polymer to concrete</td>
<td>An allocated tank (mixer) with capability of weight measurement will be required</td>
</tr>
</tbody>
</table>

6.3 Volume Considerations for WLP in Asphalt Sealants and PMB

The limited data on reusing WLP in asphalt sealants as a replacement for polymer does not provide any details on what percentage of polymer can be replaced with WLP. Research in this application is at its very early stages and as such many assumptions need to be made in volume calculations. The percentage of polymer in asphalt sealants varies from 7 to 20% (King and King 1988). With an assumption that 50% of polymer can be replaced with WLP; the WLP percentage in asphalt sealant will be 3.5% to 10% (average of 7% is used in calculations).

Table 13 shows rough estimations on WLP quantity required to replace 50% of polymer used in asphalt sealants.

Table 13 Volume considerations for WLP in concrete and asphalt sealants

<table>
<thead>
<tr>
<th>Application</th>
<th>Annual production (thousands m$^3$) (Australia)</th>
<th>Replaced polymer (kg/m$^3$)</th>
<th>Required WLP (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Sealants</td>
<td>Up to 50</td>
<td>34</td>
<td>1700</td>
</tr>
</tbody>
</table>
6.4 Environment Impact Assessment of WLP in Concrete

This section provides an overview of the major environmental impacts and considerations associated with recycling WLP in concrete and also asphalt sealants. Understanding the environmental impacts of each option helps in making informed decisions on whether or not to proceed with a project.

6.5 Positive Environmental Impact of Recycling WLP in Asphalt Sealants

Asphalt sealants are one of the major energy consuming materials in road construction and maintenance. Using recycled materials helps to reduce the negative environmental impact of asphalt binders. In the following section the positive impacts of recycling WLP in asphalt binders is discussed.

6.5.1 Reduce Greenhouse Gases and Resource Conservation

Asphalt sealants and polymer modified binders are produced from bitumen, combining agent (added to improve performance and shelf life) and polymers. Replacing the polymer used in asphalt sealants (partially or completely; based on research result and application) will reduce greenhouse gas generation of the final product and also will save resource and energy used in production of the polymer product.

6.6 Potential Negative Environmental Impact of WLP in Asphalt

Similar to the application of WLP in asphalt which was discussed in section 2.2.4, there is a possibility that during production of asphalt sealants using WLP; released vapours adversely affects the air quality. This potential negative impact is heavily reliant on the temperature of mixture in the manufacturing process, supplier, transport, user storage and application. It should be noted that there is a rapid move away from hot mix asphalts and binders toward warm mix asphalt and binders within the asphalt industry which will resolve the issues around the potential negative impact of this option.

AAPA (2013) requires the manufacturer to establish guidelines for the heating and storage of PMBs to avoid fuming or degradation of binders in the manufacturing process, supplier storage, transport, user storage and application. Guidelines should include the range of application temperatures, the maximum holding time at the maximum application temperature, the recommended storage temperature and the maximum time that materials may be held at the recommended storage temperature (AAPA, 2013). A summary of manufacturers’ guidelines for heating and storage is published in AAPA Advisory Note 7 - Guide to the Heating and Storage of Binders for Sprayed Sealing and Hot Mixed Asphalt.
Further research including air quality monitoring is required to investigate the potential negative impact of WLP when it is used as a polymer replacement in asphalt sealants.

6.6.1 Summary

Achieving a sustainable approach in the construction industry is one of the greatest challenges of 21\textsuperscript{th} century. On the other hand, waste paint can have negative environmental impacts if it disposed illegally. Research studies and limited field trials show that recycling waste paint in road work materials such as asphalt sealants and PMB helps both managing waste paint and achieving a more sustainable construction industry. Table 14 summarises the environmental impacts of replacing WLP in asphalt sealants and PMB.

<table>
<thead>
<tr>
<th>Environmental Impact</th>
<th>Kg/m\textsuperscript{3} of asphalt sealants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced polymer consumption</td>
<td>34 (Assumption)</td>
</tr>
<tr>
<td>Increased life and durability</td>
<td>20% (Assumption)</td>
</tr>
<tr>
<td>Impact on air quality</td>
<td>Potential negative impact needs to be studied –</td>
</tr>
<tr>
<td></td>
<td>Less important for warm mix products</td>
</tr>
</tbody>
</table>

6.7 Cost Analysis for WLP in Asphalt Sealants

This option involves replacing the polymer content of asphalt sealants with WLP. The cost analysis included the following components: cost of WLP, laboratory testing and raw materials. Assumptions are discussed for each item.

6.7.1 Cost of Waste Latex Paint (WLP)

This cost was determined using the same methodology as in option 1. The requirement for WLP differs in this option. The quantity of WLP (in kg) per cubic meter (m\textsuperscript{3}) of asphalt sealants was estimated to be 63kg/m\textsuperscript{3}. Based on the assumption (refer section 6.2) that 50% of polymer can be replaced with WLP, the total quantity of WLP that replaces polymer in asphalt sealant is estimated to be 31.5kg/m\textsuperscript{3}. Therefore the total cost per kg of WLP was multiplied by 31.5kg in order to reflect the total costs of WLP per m\textsuperscript{3} of asphalt sealant.

6.7.2 Laboratory testing

This is a specialised test and as such a test cost of $157.9 for each test has been assumed (after consultation with Swinburne University chemistry laboratory). As the test is more specialised it will be conducted once for 10 m\textsuperscript{3} of asphalt sealants and consequently the price for each m\textsuperscript{3} of concrete will be $15.79.
6.7.3 Raw materials

Raw materials costs consist of the basic (constant) elements of asphalt sealants which include bitumen, combining agent and polymer. The polymer (Styrene Butadiene Rubber – SBR) will be replaced by WLP. The cost of polymer was obtained from ICIS, a petrochemical market information provider (2011) and estimated at US$ 4400 per tonne. This cost was converted to AUD at the exchange rate of 0.96US$/A$ (dated 22nd May 2013). A per kilogram cost of SBR was calculated at 1tonne = 1000kg and this was multiplied by 63kg to estimate the total cost of SBR per m³ of asphalt sealants. The cost of asphalt sealant is based on the retail price of asphalt crack filler of $15 per litre (Bunnings, 2013).

Both the asphalt sealant and SBR costs were adjusted for inflation based on the same methodology as above. Table 15 summarises the cost calculation for this option.

<table>
<thead>
<tr>
<th>Elements*</th>
<th>Price/Cost ($)</th>
<th>Costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total DYH programme cost /m³</td>
<td>121.66</td>
<td></td>
</tr>
<tr>
<td>Laboratory testing (price per m³)</td>
<td>15.79</td>
<td></td>
</tr>
<tr>
<td>Cost of asphalt sealant /m³</td>
<td>15,000</td>
<td></td>
</tr>
<tr>
<td>Polymer – SBR /m³</td>
<td>294.24</td>
<td></td>
</tr>
<tr>
<td>Raw materials (asphalt sealant - SBR)</td>
<td>14,705.76</td>
<td></td>
</tr>
<tr>
<td>Total costs of asphalt sealant replaced by WLP/m³</td>
<td>14,843.21</td>
<td></td>
</tr>
<tr>
<td>Total excluding DYH programme replaced by WLP/m³</td>
<td>14,721.55</td>
<td></td>
</tr>
<tr>
<td>Carbon price /m³***</td>
<td>$ 1.45</td>
<td></td>
</tr>
</tbody>
</table>

* See appendix for details
** Note: The DYH programme costs will be covered by SV
*** Carbon price is taken as $23 per tonne (Australian Government – Clear Energy Future, 2013)

6.7.4 Discussion

This option involves replacing the polymer content in asphalt sealant with WLP. This includes the costs of the DYH programme, the laboratory test and the asphalt sealant less the cost of polymer, which is estimated to be $14,843.21. As SV will cover the cost of the DYH programme the overall cost is reduced to $14,721.55. The carbon price is estimated to be $1.45 per m³ based on the cost of $23 per tonne with an estimated usage of polymer for this option at 63kg/m³ of asphalt sealant.

As with all research, there are a few limitations. This cost analysis was limited to the data available at the time of preparing this report and was constrained by the components considered in these options. Further, no capital outlay has been included in the analysis. No potential revenue stream has been included and should be considered in order to determine the commercial viability
of these options. In addition, technical trials to determine the structural integrity of the modified concrete options should be conducted to ascertain the suitability prior to commercial production.

6.8 Risk Assessment of Using WLP in Asphalt Sealants and PMB

Risks associated with using WLP in asphalt sealants and polymer modified binders are listed in Table 16 with likelihood and consequence and risk level for each risk item evaluated and provided. It should be noted that this section only identifies and provides details of risks specifically related to reusing WLP in asphalt sealants and PMB does not provide risks generally related to production, handling, storage and constructing and maintenance of pavements using asphalt sealants.
<table>
<thead>
<tr>
<th>Category</th>
<th>Risk</th>
<th>Likelihood</th>
<th>Consequence</th>
<th>Risk level</th>
<th>Treatment</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplace health and safety</td>
<td>Workers health due to working with chemicals</td>
<td>Unlikely</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Safety Data Sheet prepared and monitored regularly</td>
<td>Asphalt sealant industry works regularly with chemicals as part of daily operation and this lowers the risk likelihood due to trained and experienced workers.</td>
</tr>
<tr>
<td></td>
<td>Fire and explosion due to storage and working with waste paint</td>
<td>Unlikely</td>
<td>Catastrophic</td>
<td>Extreme</td>
<td>Fire plan and material safety data sheet required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low air quality in work environment</td>
<td>Likely</td>
<td>Moderate</td>
<td>High</td>
<td>WLP and mixture temperature and air quality monitoring is required</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Negative impact on air quality during production and placement</td>
<td>Possible</td>
<td>Moderate</td>
<td>High</td>
<td>Research on effect of WLP in air quality during production is essential.</td>
<td>The production temperature plays an important role.</td>
</tr>
<tr>
<td>Business</td>
<td>Negative reputation due to varying quality of final product</td>
<td>Possible</td>
<td>Major</td>
<td>Extreme</td>
<td>Continuous quality control of final product</td>
<td>More research and field trials prior to any large scale application will minimise uncertainties.</td>
</tr>
<tr>
<td>Case specific</td>
<td>Change of government regulation and budget allocation affecting waste paint scheme quantity and cost</td>
<td>Likely</td>
<td>Major</td>
<td>Extreme</td>
<td>Long-term government plan and commitment</td>
<td></td>
</tr>
</tbody>
</table>
7 Recommendations

Results of technical feasibility, volume considerations, environmental impact assessments, cost analysis and risk assessments of using WLP in concrete (as water and polymer replacement) and as a polymer replacement in asphalt sealants suggest that there is a knowledge gap between the current practice in Australia for reusing WLP. This requires further research and pilot studies as the first step toward finding a sustainable solution for WLP management in Victoria.

The following recommendations are made following the research carried out globally and analysis carried out in this report:

1. Further research on both using WLP as a polymer and water replacement in Polymer Modified Concrete (PMC) and also as polymer replacement is Asphalt Sealants and Polymer Modified Binders (PMB) is recommended. Local research following local standards and then comparing results with local authorities’ specifications on these products is the very first step toward finding sustainable solutions for WLP in Victoria.

2. Due to the fact that research on reusing WLP in asphalt sealants is at its very early stages, risks associated with uncertainties in final product quality and performance, are higher. There is also the possibility of a negative impact on air quality. As such it is recommended to first start with use of WLP as a water and polymer replacement in PMC and in the next stage move toward the other option.

3. Using WLP in Polymer Modified Concrete (PMC) and also Asphalt sealants and Polymer Modified Binders (PMB) are the commercially viable options if technical requirements are met. This is due to high price of Polymer in final cost of these products.

4. Working with local government authorities (councils and end-users such as VicRoads) to trial these products is highly recommended. Trials with lower performance requirements are recommended first. For concrete this can be curb side concrete, pedestrian walks and bike trails. For Asphalt sealants low volume traffic roads and pedestrian walks are recommended.

5. State and Local government (Sustainability Victoria and Municipal association of Victoria), along with industry representatives (APMF) and research institutions need to work on developing a framework for introducing new incentives for industries reusing WLP in construction activities (PMC and PMB industries). This is essential to help the program in taking its first steps in Victoria.
6. Raising consumer awareness is vital in reaching a sustainable solution for waste paint in Victoria. Consumer awareness can potentially improve consumers’ participation in collection programs and it can furthermore, create an increased market for recycled products such as concrete produced with WLP to be used in masonry blockfill.
8 Acknowledgment

The Authors would like to acknowledge Australian Paint Manufacturing Federation (APMF) and Dulux Australia for the valuable information, resources and comments provided throughout the project. Information and insight provided by toxfree helped in finalising the report and is appreciated.
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### Appendix A

**Option 1 – Quantity of components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Control</th>
<th>WLP 15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Kg/m³</td>
<td>Constant</td>
<td>280 280</td>
</tr>
<tr>
<td>Water Kg/m³</td>
<td>Difference = 11</td>
<td>140 129</td>
</tr>
<tr>
<td>WLP Kg/m³</td>
<td>Difference = 21</td>
<td>- 21</td>
</tr>
<tr>
<td>Course aggregate Kg/m³</td>
<td>Constant</td>
<td>1050 1050</td>
</tr>
<tr>
<td>Fine aggregate Kg/m³</td>
<td>Constant</td>
<td>750 750</td>
</tr>
</tbody>
</table>

**Option 2 – Quantity of components**

<table>
<thead>
<tr>
<th>Component</th>
<th>SBR</th>
<th>WLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Kg/m³</td>
<td>Constant</td>
<td>120 120</td>
</tr>
<tr>
<td>Water Kg/m³</td>
<td>Constant</td>
<td>40 40</td>
</tr>
<tr>
<td>SBR Kg/m³</td>
<td>Difference = 40</td>
<td>40 -</td>
</tr>
<tr>
<td>WLP Kg/m³</td>
<td>Difference = 50</td>
<td>- 50</td>
</tr>
<tr>
<td>Course aggregate Kg/m³</td>
<td>Constant</td>
<td>110 110</td>
</tr>
<tr>
<td>Fine aggregate Kg/m³</td>
<td>Constant</td>
<td>100 100</td>
</tr>
<tr>
<td>High range water reducing admixture mL/100kg</td>
<td>0.5 5</td>
<td></td>
</tr>
</tbody>
</table>

**Option 3 – Quantity of components**

<table>
<thead>
<tr>
<th>Component</th>
<th>SBR</th>
<th>WLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBR Kg/m³</td>
<td>63</td>
<td>-</td>
</tr>
<tr>
<td>WLP Kg/m³</td>
<td>-</td>
<td>31.5</td>
</tr>
</tbody>
</table>