green building council australia

Literature Review and Best Practice Guidelines for the Life Cycle of PVC Building Products

15.01.10

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1.0 Foreword

The GBCA has undertaken a review of historical and current criticisms of the Polyvinyl Chloride (PVC) industry. These criticisms have been raised in the public domain by stakeholders, including Environmental Non-Government Organisations (ENGOs), who are concerned about the potential risks and impacts associated with the PVC life cycle. A review of independent scientific literature was simultaneously conducted to improve the GBCA's understanding of the science behind the environmental impacts, human health risks and current practices associated with the life cycle of PVC.

The findings of these two reviews are presented in this report. Each concern is outlined, the information from the scientific literature which relates to this concern is summarised, and then conclusions on how the concern might be addressed are provided.

Further information relevant to this work is given in the following format:

- General overview of PVC production;
- Uses of PVC in the built environment;
- Review of Life Cycle Assessments (LCAs) related to PVC and common functional use alternatives in building applications;
- PVC industry actions related to concerns over PVC and its environmental or health impacts.

2.0 Production and Use of PVC – An Overview

PVC is a synthetic solid resin material (a plastic) also commonly referred to as 'vinyl'. PVC is formed from vinyl chloride monomer (VCM) (in pressurised liquid form) in a manufacturing process that polymerises VCM into solid powder or granule (CA EPA, 2006).

The first stage in the production of PVC is to make ethylene dichloride (EDC). Chlorine is extracted via electrolysis from brine (usually from sea water). Ethylene is derived from hydrocarbon raw materials. Chlorine and ethylene are reacted in the presence of oxygen to form EDC.

The EDC is then decomposed through a thermal 'cracking' process resulting in VCM and hydrogen chloride (HCl). The HCl is further reacted with ethylene and oxygen to produce more EDC and water (AV, 2009).

The next step in making PVC involves batch reactor processes where VCM is polymerised with itself or copolymerised with varying amounts of vinyl acetate, ethylene, propylene, vinylidene chloride, or acrylates. The polymerisation process can be undertaken in a number of ways (e.g. suspension, emulsion, bulk, and solution). The result of the polymerisation process is PVC resin.

As with most plastics products, PVC products contain additives. Lubricants and stabilisers are the two most common types of additives in PVC. Lubricants aid in the processing of PVC. Stabilisers prolong the life of PVC products by reducing the degrading effects of heat and ultraviolet (UV) light which would otherwise cause chlorine to be lost from the PVC in the form of HCl gas. The presence of these additives (mixed in varying amounts) results in a wide range of products (CA EPA, 2006).

Plasticisers are another type of common additive which give increased flexibility. The single largest group of plasticisers used in manufacturing PVC products is a class of compounds called phthalates (EC 2000).

PVC products which have plasticisers incorporated are characterised as flexible PVC, whilst those with no plasticisers are called rigid PVC. Flexible PVC is mainly used in cables, flooring, coated fabrics and car parts. The main applications of rigid PVC include pipes, profiles, sheets and bottles (Scheirs, 2003).

3.0 Uses of PVC in the Built Environment

In Australia, over 75% of all PVC products are used in the built environment, primarily in base building applications (Scheirs, 2003). Image 1 below provides an illustration of the major uses of PVC in the Australian built environment. It confirms conduit, pipes and fittings as the dominant use of PVC in building product applications. Flooring is the second major use of PVC in building/fitout products. Cable and wire insulation are shown as the third most common use of PVC, followed by PVC windows and doors (which are classified under the heading rigid profiles) as a small percentage.

Image 1 also summarises data on the production sources of the approximate 238,569 tonnes of PVC produced per year in Australia, for the listed product applications. The majority of the PVC used in each of these product applications is produced domestically with the exceptions of flooring, windows and doors which are the primary applications containing imported PVC.

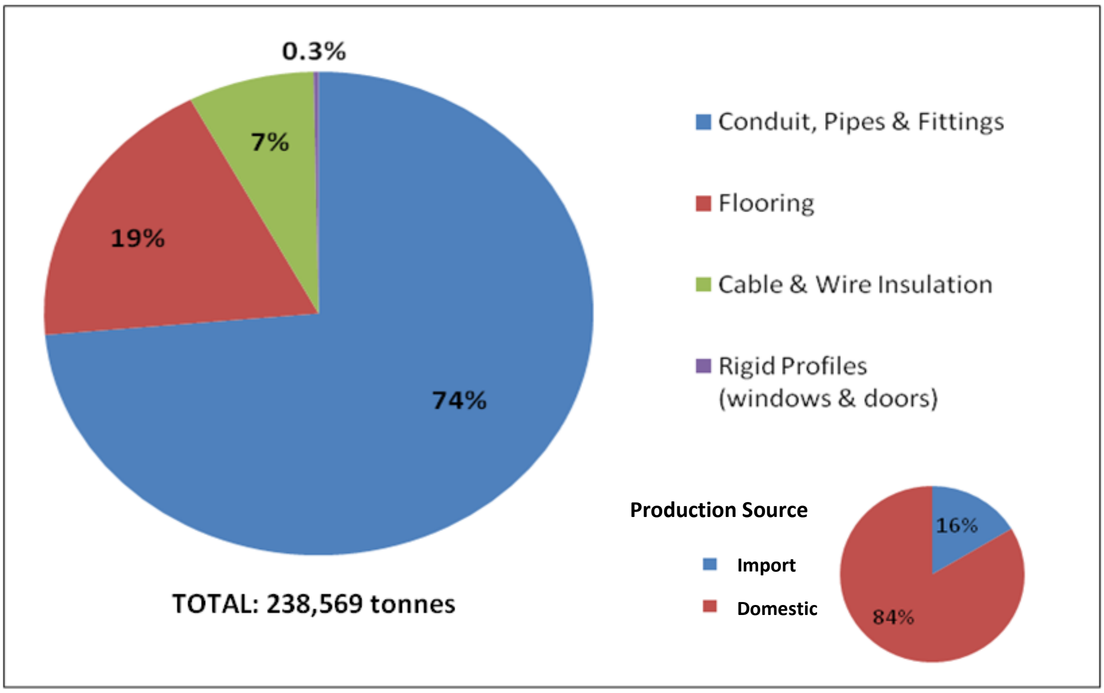

Image 1 – Major PVC Product Applications and Production Sources for the Australian Built Environment
(extracted from market data provided by Vinyl Council of Australia 2009)

4.0 PVC Production and End of Life Management – Literature Review

This section provides an overview of health and environmental concerns that have been voiced by stakeholders (both to the GBCA and in general public discussion) relating to PVC production and end of life product management. These concerns relate to the following stages of the PVC life cycle:

- Chlorine Manufacture
- Vinyl Chloride Monomer and Ethylene Dichloride
- Dioxin Emissions during PVC Production
- Additives Health Concerns – Lead, Cadmium, Tin and Phthalates
- Gases Created in an Accidental Building Fire
- End of Life Product Recycling
- Leaching of Additives in Landfill
- Emissions from Waste Fires

Each of these aspects is addressed in three parts:

- Concern – Describes the life cycle health and/or environmental impact of concern as voiced by stakeholders.
- Literature Review – Provides a summary of literature reviewed as part of the PVC credit review process, as related to each concern.
- Conclusions – Draws conclusions and/or recommendations (where recommendations are warranted) on whether the concern needs to be addressed in Green Star.

4.1 CHLORINE MANUFACTURE

Concern

Mercury emissions arising from chlorine production are a source of global mercury pollution. Mercury is implicated in many health concerns.

Literature review:

- The PVC production process is the world's largest single user of chlorine, consuming approximately 35% of chlorine produced worldwide (IARC, 2008, WCC, 2006). Average PVC resin consists of 57% chlorine (Scheirs, 2003).
- Chlorine is produced through electrolysis of saturated brine (salt water). There are three basic processes for the electrolytic production of chlorine. These are the diaphragm cell process (developed in 1885), the mercury cell process (developed in 1892), and the membrane cell process (developed in 1970) (EU, 2001).
- The pollution output related to the chlorine manufacturing process that is of most concern is mercury pollution to air, soil and water (EU, 2001).
- Mercury pollution is implicated in many health hazards. Inorganic mercury can be metabolised by anaerobic bacteria to form highly toxic methyl mercury, which is an organic form of mercury that bioaccumulates in the food chain (EU, 2001).
- World chlorine production is predominantly being converted to the use of the membrane cell process. According to the European Commission (EC, 2001) the best available technology for the manufacture of chlorine is membrane cell and non-asbestos diaphragm technology. The membrane cell process has inherent advantages over both older processes, as it does not use mercury or asbestos, and it is the most energy efficient (EC, 2001).
- The World Chlorine Council (WCC), representing chloro-alkali manufacturers and related industries in 27 countries, has committed to the application of best available technologies in the industry in order to minimise mercury emissions from this source. Members of WCC have also committed to the safe disposal of mercury from decommissioned plants and have imposed a ban on sale or transfer of mercury cells to a third party for re-use. Existing mercury cell chloro-alkali manufacturing plants will be progressively decommissioned and measures to reduce emissions from those still operating have been implemented (WCC, 2006).

- In 2006 mercury emissions from chlorine manufacture accounted for less than 1% of total global emissions of mercury(natural and human induced emissions combined) (WCC, 2006). More significant sources of mercury emissions are volcano eruptions, coal fired power stations and crematoria.
- The UN Environment Programme's (UNEP) Governing Council meeting in Nairobi in February 2009 agreed to a global treaty to tackle mercury emissions. This treaty will be enforced by 2013 (UNEP, 2009).

Conclusions

- While PVC manufacture is a major global user of chlorine, the contribution to global mercury emissions from chlorine manufacturing plants is small.
- Mercury emissions from this source are set to be further reduced due to the global process of decommissioning of existing mercury cell production plants. Mercury emissions are therefore mostly a historical concern attributed to PVC.
- Sourcing chlorine from membrane cell plants represents best available practice as this eliminates potential mercury emissions in the life cycle of PVC products. Non asbestos diaphragm cell production is also preferable to mercury based production processes.
- The membrane cell process is the least energy intensive of the three chloro-alkali processes.

4.2 VINYL CHLORIDE MONOMER AND ETHYLENE DICHLORIDE

Concern

The toxicity of the main constituents of PVC, as well as the resulting industrial waste, represents a human health risk.
The acetylene-based VCM manufacture process is a source of global mercury pollution.

Literature review

Vinyl Chloride Monomer (VCM)

- VCM is commonly produced by the thermal cracking of ethylene dichloride. An alternative method of VCM manufacture is the acetylene-based process, where acetylene is reacted with hydrogen chloride over a mercury-based catalyst. Most acetylene-based plants have been decommissioned; however, some still remain active in China (IARC, 2008).
- VCM is not manufactured in Australia but is imported for local PVC resin production. (DEWHA, 2009).
- VCM is a known human carcinogen and a known human mutagen (IARC, 2008).
- In the 1970s a rare form of cancer was discovered in PVC workers. This cancer, angiosarcoma of the liver, is caused by exposure to VCM, and over 200 deaths have been recorded in former PVC workers. Since the 1970s the industry has implemented

major changes (primarily a 'closed lid' production process), and since changes were implemented no PVC worker has developed the disease (ECVM, 2009).

- In relation to occupational exposure to VCM the European Union (EU) sets an occupational exposure limit of 3ppm for 8 hours weighted average. Several EU Member States and companies set lower maximum levels, typically 1ppm. A 1ppm limit is also set for VCM emissions from final products (ECVM, 2009).
- The Australian National Pollution Inventory has established an 8 hour occupational exposure limit to VCM of 5ppm (in air) (NPI, 2000).
- The following conversion factors apply:
    - 1ppm = 2.589 mg/m^3
    - 1 mg/m^3 = 0.386ppm (Adapted from WHO, 2000).
- The main sources of VCM emissions are industries that manufacture or use it (e.g. the chemicals and plastics industries). These emissions are primarily to the air, with a small percentage to water. Diffused sources of VCM emissions include treated wastewater that has been contaminated with vinyl chloride or chlorinated hydrocarbons and emissions from landfill. VCM is predominantly used in the manufacture of PVC (NPI, 2007).
- Routes of human exposure to VCM arising from PVC manufacture are (based on potential to cause harm):
    - Air contamination from VCM and PVC production plants. For example, general environmental levels of VCM from all sources in Europe are likely to lead to average exposures of 2-10 μg/day. (WHO, 2000).
    - Contaminated foods and liquids from PVC packaging. This was identified in the 1970s however has decreased substantially with the implementation of more stringent manufacturing specifications for PVC. It is estimated that the maximum intake per person in foods and liquids would now be less than 0.1 μg/day (WHO, 2000).
- Provided that state-of-the-art production technologies and management systems are employed, the environmental and health risks from the production and use of VCM are low (EC, 2004).
- Based on VCM emission data from European PVC manufacturing plants, the top 25% of plants emit 18g of VCM per one tonne of PVC produced, the median emission rate in the example of European PVC production plants is 43g/tonne. (EC, 2006)
- The Australian PVC industry Product Stewardship Program set a 50g/tonne VCM emission benchmark for local PVC manufacturing in 2006. This limit has been consistently met by the Australian PVC resin producer. In 2009 this benchmark was reduced to 30g/tonne. (VCA, 2009)
- In EDC, VCM and PVC manufacturing facilities the greatest occupational risk is the releases of toxic gases, particularly when overheating situations occur (e.g. chlorine, ethylene, ethylene dichloride, hydrogen chloride, vinyl chloride monomer and chlorinated by-products including dioxins). During VCM feed stock production, factories operating in compliance with strict air quality management requirements can address

the occupational risk involved. Accidental releases of these gases from such facilities do nevertheless occur, and may impact soil, water and air (CA EPA, 2006).

Mercury

- Mercury pollution is a global health concern (UNEP, 2008).
- The mercury catalyst VCM manufacturing process is a major global user of mercury (UNEP, 2008).
- An estimated 600-800 tonnes of mercury was consumed by the VCM manufacturing sector in 2005, out of a total of 3,000-3,9000 tonnes of mercury used globally each year. China is the location of the majority of this process capacity (62 facilities in 2008). Russia also has a few plants using this process. It is believed that some facilities in other parts of the world also use the mercury process (UNEP, 2008).
- China's VCM production will continue to expand and the mercury catalyst process will be used to meet much of this demand. It is estimated that mercury demand for this sector in China may be 1,000 metric tonnes per year by 2010 (UNEP, 2008).
- The quality of the mercury-produced VCM may limit its market range. As such, there may be economic incentives for switching to a non-mercury process (UNEP, 2008).

Ethylene Dichloride (EDC)

- EDC has been reported in animal experiments to be carcinogenic by ingestion, resulting in liver and kidney damage (WHO, 2008).
- EDC is classed as a possible carcinogen by the US EPA (US EPA, 2000), however this is not supported outside of the USA. EDC is not classed as a carcinogen by the WHO (WHO, 2008) or the International Agency for Research on Cancer (IARC, 2009).
- EDC vapour can induce effects on the human nervous system, liver, and kidneys, as well as respiratory distress, cardiac arrhythmia, nausea, and vomiting. Long-term (chronic) inhalation exposure has been found to affect the liver and kidneys of animals. Decreased fertility and increased embryo mortality have been observed in inhalation studies of rats. Epidemiological studies are not conclusive regarding the carcinogenic effects of EDC (US EPA, 2000).
- The predominant use of EDC is in the manufacture of Vinyl Chloride for the PVC industry as well as other plastics (US EPA, 2000).
- In EDC, VCM and PVC manufacturing facilities the greatest occupational risk is the release of toxic gases, particularly when overheating situations occur (e.g. chlorine, ethylene, ethylene dichloride, hydrogen chloride, vinyl chloride monomer and chlorinated by-products including dioxins). During VCM feed stock production, factories operating in compliance with strict air quality management requirements can address the occupational risk involved. Accidental releases of these gases from such facilities do nevertheless occur, and may impact soil, water and air (CA EPA, 2006)

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- PVC solid waste sludge can contain organohalogens, including dioxins (EC, 2004). Dioxins are a group of persistent organic pollutants (POPs). POPs are organic compounds of natural or anthropogenic origin that resist photolytic, chemical, and biological degradation. Dioxins can cause severe health effects at very low exposure (EA, 2002).
- In Victoria (the location of Australia's only PVC production plant) this industrial waste is classed under the Environmental Protection (Industrial Waste Resources) Regulations 2009, as class A; 'not permitted in landfill'. Before this regulation came into place this waste was treated as hazardous waste in prescribed landfill under the Environment Protection (Prescribed Waste) Regulations 1998, and the Industrial Waste Management Policy (Prescribed Industrial Waste) (VIC EPA, 2009).
- High temperature emission-controlled incineration is an acceptable method of treatment for PVC sludge waste (EC, 2004). In Australia diversion of sludge waste to other beneficial uses is preferred by the Environmental Protection (Industrial Waste Resources) Regulations 2009 (VIC EPA, 2009). An example of one such use is as a supplement fuel in cement kilns.
- Waste water from PVC manufacturing plant should be treated to eliminate toxins (EC, 2006).
- The European Commission considers that where state-of-the-art production technologies and management are employed, the environmental risks from production of EDC, VCM and PVC are low. However, several non state-of-the-art facilities do exist (e.g. Eastern Europe) (EC, 2004). State-of-the-art technology for VCM/ EDC/PVC in the European context include:
    - Waste: Solid waste and sludge can contain organohalogens, including dioxins. Incineration is therefore preferable to land filling.
    - Water: Advanced wastewater treatment should prevent emissions of halogenated hydrocarbons like EDC and dioxins in treated effluents. Residues from those treatments may undergo further treatment to destroy possible captured contaminants.
    - Air: Proper emission reduction measures are necessary to ensure that VCM and EDC emissions and other contaminants will be close to, or below, the negligible risk level.
    - Products: Efficient stripping must ensure minimal VCM residue exists in the final polymer.

(Adapted from EC, 2004)

Conclusions

VCM:

- The health risks of VCM are significant and well documented.
- The VCM manufacturing industry has adopted closed lid processes and highly monitored manufacturing practices which have significantly reduced the amount of VCM released.
- VCM produced from non-mercury and non-acetylene processes are preferred sources.
- Best practice occupational exposure to VCM should not exceed 1ppm (8h TWA).
- Concentration of VCM in PVC resin should not exceed 1ppm.
- No safe exposure level of VCM has been conclusively derived. Occupational exposure levels set by governments in Europe and Australia are the best indicator of safe practice. Safe practice for air and water emissions of VCM is less than 43g/tonne of PVC produced. Levels of 18 g/tonne are achievable in some production facilities in Europe.

EDC

- The health risks of EDC are significant and well documented.

VCM, EDC and PVC

- PVC sludge from VCM, EDC and PVC manufacturing facilities should be treated by high temperature emission-controlled incineration or, where unavailable, another government-approved hazardous waste treatment.
- Water effluent from VCM, EDC and PVC manufacturing plants should be treated to eliminate toxins.
- At VCM, EDC and PVC manufacturing facilities, modern plants employing best practice technologies (e.g. closed lid formulations as detailed by EC, 2004 in the European context) are the preferred source of material for best practice PVC product.

4.3 DIOXIN EMISSIONS AND PVC PRODUCTION

Concern

The manufacture of PVC is a source of dioxin emissions. Dioxin emissions are a major health concern.

Literature Review:

- Dioxins are a group of persistent organic pollutants (POPs). POPs are organic compounds of natural or anthropogenic origin that resist photolytic, chemical, and biological degradation. Dioxins bio-accumulate in animals fatty tissue. Dioxins can also travel long distances in the atmosphere and can reach remote areas well away from the emission source. Dioxins can cause severe health effects at very low exposure (EA, 2002).
- The Stockholm Convention focuses on eliminating or reducing the releases of 12 POPs, the so called "Dirty Dozen"; amongst these 12 are dioxins (UNIDO, 2009).
- Significant dioxin formation can occur in the chlorine production process if graphite anodes are used (UNEP, 2003). Many industrialised countries replaced the graphite anodes in the 1970s (UNEP, 2003).
- The most significant source of dioxin emission is uncontrolled combustion (i.e. biomass burning, waste burning and accidental fires). Uncontrolled combustion (e.g. bushfires) is estimated to contribute to nearly 70% of total emissions to air and over 80% of total emissions to land in Australia. Waste disposal and land filling is estimated to be the largest source of dioxin emissions to water, contributing over 75% of total emissions in Australia (DEH, 2004).
- The proportion of dioxin emissions from all chemical processing industries in Australia is below 1% (this includes PVC). This figure does not include the embodied dioxin emissions associated with PVC produced in Australia, as VCM (and its precursor EDC) are imported (DEH, 2004).
- In the UK, where EDC, VCM, and PVC are all domestically manufactured, emissions for all halogenated chemical manufacturing total 0.02g TEq (Toxic Equivalent) annually. In comparison, emissions from crematoria in the UK total 1g TEq annually. Whilst not all dioxin types are equally toxic. The TEq unit of measurement takes this into account to present an overall toxicity measure (CSIRO, 2001).

Conclusions

- The level of dioxins emitted due to best practice production of PVC and its constituents is much less than that from other sources. Therefore, there is insufficient rationale for discrimination against PVC building products on the basis of dioxin emissions.
- The use of best available technologies for EDC, VCM and PVC manufacturing described in section 4.2 ensures minimal risks.
- The use of non-graphite anodes in chlorine production represents best practice in relation to minimising dioxin emission in the PVC lifecycle.

4.4 Additives – Lead Cadmium Tin and Phthalates

Background

Additives to PVC predominantly consist of stabilisers and plasticisers. Table 2 presents PVC products of relevance to the credit review, and the current most common additives in these products in Australia.

PVC Product	Stabilisers		Plasticisers	
	Historic	Current	Historic	Current
Flooring	lead, calcium zinc	calcium zinc, butyltin, epoxidised soy bean oil	diethylhexyl phthalate (DEHP), benzyl butyl phthalate (BBP)	diisodecyl phthalate (DIDP), diisononyl phthalate (DINP)
Cable	lead	calcium zinc	DEHP, DIDP, chlorinated paraffin	DIDP,DINP,Trioctyl Trimellitate (TOTM)
Pipe/Conduit	lead, salts of fatty acids, calcium zinc	calcium zinc, organic stabilisers, organotin	N/A	N/A
Rigid Profile	lead, salts of barium and cadmium,	calcium zinc, organic-based stabilisers	N/A	N/A

Table 2 – Current and historic Stabilisers and Plasticisers in PVC products of interest in Australia, (data provided by the Australian Vinyl Corporation)

Concern

Some stabilisers used in PVC products are considered toxic and represent a health risk.

Literature review (Stabilisers)

Lead

- Organic lead compounds are readily assimilated by living organisms and are many times more toxic than inorganic lead salts. Stabilisers such as lead stearates are classified as inorganic lead compounds. (Scheirs, 2003).
- The percentage of lead in lead-stabilised PVC products is typically about 0.1-1.8 wt%.(Scheirs, 2003).

- Lead stabiliser replacement has gradually taken place in the PVC industry. Calcium/Zinc (Ca/Zn) stabilisers and organic-based stabilisers which do not contain lead are the preferred alternatives. Australian pipe manufacturers phased out lead in PVC potable water pressure pipe applications as early as 1988 (Scheirs, 2003).
- Lead stabilisers are not of concern in the manufacture and in-use stage of PVC product life cycles, but are only a concern for some end of life aspects such as waste incineration. (EU, 2004). Building and demolition waste is not incinerated in Australia so this concern is not relevant to the Australian context of this review.
- Numerous studies have confirmed that lead stabilisers are locked into the polymer matrix so that the lead does not migrate from the plastic. While leaching is still possible under specific conditions, the ability of lead to leach is extremely low (Scheirs, 2003).

Cadmium Stabilisers

- Most cadmium compounds are harmful and dangerous to the environment. Some are classified as known human carcinogens. (Scheirs, 2003).
- The EU issued a directive in 1988 which imposed a ban on the use of cadmium in most PVC products in Europe (Scheirs, 2003).
- Australian manufactured PVC products do not use cadmium stabilisers however imported products may do so (Scheirs, 2003).

Organotin Stabilisers

- All tin stabilisers are classified as toxic and a few are also classified as toxic for reproduction (EC, 2009).
- Organotin stabilisers, specifically octyl and methyl tin products, have extensive national approvals for food contact applications (Scheirs, 2003).
- Organotin stabilizers are not persistent in the environment due to microbial activity. All organotin stabilizers degrade into inorganic tin (Scheirs, 2003).
- Organotin stabilisers are used in PVC pipe in Australia. In Europe they are used in flooring products. The most common uses of organotin stabilisers worldwide including Australia are in pipe, rigid profile, rigid sheet and bottles (Scheirs, 2003).The risk associated with the use of organotin stabilisers in PVC has been concluded to carry minimal risk due to a number of factors, particularly low toxicity resulting from minimal exposure, limited leaching from the finished PVC products and very low ecotoxicity due to rapid degradation (CSIRO 2001).
- Following a risk assessment, risk reduction measures are currently under discussion at EU level. These measures may include a prohibition of butyl tin stabilisers in 2010 (excluding a few applications). Use of octyl tin may be limited in a few applications where the products are in contact with the skin (EC, 2009).

Calcium Zinc Stabilisers (Ca/Zn) and Organic Stabilisers

Calcium zinc stabilisers and organic stabilisers are the main alternatives to heavy metal based stabilisers. No health or environmental concerns have been identified for these stabilisers as part of this review.

Stabilisers General

The main concern is that stabilisers, and their breakdown products (as well as pure PVC solids), could be released in solid (particulate), liquid, or gaseous form during the production of PVC products. Workers could be exposed under these conditions. However, closed lid production limits this. Exposure is limited to times when chemicals are being added to the closed mixers (CA EPA, 2006).

Conclusions (Stabilisers)

- The PVC industry has recognised concerns relating to cadmium and lead stabilisers and has largely phased these out, or is in the process of doing so. Such stabilisers are no longer being used in the majority of products relevant to this review.
- Avoiding the use of these stabilisers, particularly cadmium, represents best practice.
- Alternative stabilisers include calcium zinc stabilisers, organic and organotin stabilisers. These are acceptable from a health and environmental point of view when used in PVC products relevant to this review.
- Manufacturing facilities operating closed lid formulations (as previously described in section 4.2) represent best practice with regards to minimising occupational exposure to stabilisers, or release of stabilisers into the environment.

Plasticisers

Concern

Some plasticisers used in PVC products are considered toxic and represent a health risk.

Literature review (Plasticisers)

- Plasticisers are used to make PVC soft and flexible. Plasticisers are only used in plasticised (flexible) PVC and not in rigid, un-plasticised PVC (uPVC) Common plasticisers are phthalates (or phthalate esters) (AV, 2009).
- There are 24 different phthalates plasticisers used in Australia (NICNAS, 2008). Only a few of these are relevant to PVC products in the built environment.
- Table 2 lists the most common phthalates used as plasticisers in PVC building products.
- The 24 phthalates studied by NICNAS display different toxicity levels and risks. Acute toxicity, skin and eye irritation and sensitisation potential are low for all phthalates (NICNAS, 2008).

- The widely held view of potential reproductive and developmental toxicity associated with certain phthalates is confirmed in rodent studies, especially those with straight chain carbon backbones of C4-C6. In particular this relates to diethylhexyl phthalate (DEHP), benzyl butyl phthalate (BBP) diethyl butyl phthalate (DBP) which are relevant to PVC products in the built environment. The use of other phthalates according to NICNAS does not pose a significant health risk (NICNAS, 2008).
- DEHP can migrate from plastics. It has been detected in water, soil and food and is considered a widespread environmental contaminant. DEHP can enter the environment via a number of different routes, one of which is leaching from PVC products during use (Scheirs, 2003).
- Other phthalates have also been detected in a range of environmental water samples including drinking water. Advances in detection methods have decreased the detection threshold of phthalates in water (Scheirs, 2003)
- The main alternative substances used for phthalate replacement are adipates, citrates, cyclohexyl and di-isononyl cyclohexane. These are now mainly used in plastic toy products and therefore not relevant to this review. Adipates are not used in building products due to their inferior performance (Scheirs, 2003).
- Plasticisers, and their breakdown products, might be released in solid (particulate), liquid, or gaseous form during the manufacture of PVC products. Exposure of workers could occur under these conditions, however, closed lid formulation practices typically limits exposure to times when chemicals are being added to the closed mixers (CA EPA, 2006).
- Phthalates can enter the environment during plasticiser production, distribution and in the process of incorporation into PVC resin (Scheirs, 2003).
- Large releases of additive chemicals to the general environment are rare. Under a catastrophic scenario (e.g. spill or fire and/or poor manufacturing management conditions) large spills are possible (CA EPA, 2006).
- DEHP is no longer used in the vinyl flooring manufactured in Australia, nor is it used in most PVC cable and wire insulation manufactured in Australia. It is however still used overseas and will therefore be present in most imported cable and wire products and to a lesser degree in some imported flooring products.

Conclusions (Plasticisers)

- The concerns related to the toxicity of some phthalates used in PVC building products have been confirmed. These concerns primarily relate to the short-chained phthalates DEHP, BBP and DBP.
- Avoiding or substituting these phthalates represents best practice for plasticised PVC building and fit out products.
- Manufacturing facilities operating closed lid formulations represent best practice with regards to minimising occupational exposure to plasticisers and minimising release of plasticisers to the environment.

4.5 ACCIDENTAL BUILDING FIRES

Concern

PVC emits toxic gases when burned. This is a health concern for building occupants and fire fighters during a building fire.

Literature Review

- Rigid PVC is very difficult to ignite compared with other plastics; this is due to the chlorine content which acts as a fire suppressant. Rigid PVC will only ignite if a sustained heat source is present. Flexible PVC is easier to ignite due to the high flammability of plasticisers. This sometimes requires flame retardants to be incorporated depending on product requirements and plasticiser loading. PVC may actually play a beneficial role in suppressing building fires due to its high ignition temperature (CSIRO, 2001).
- When burned PVC can impact the health of fire fighters and individuals in the vicinity of the site; however this is true of many other materials. The major gases produced in the burning of PVC resin include carbon monoxide, carbon dioxide, hydrogen chloride, water and trace amounts of other products of incomplete combustion, including dioxins (CSIRO, 2001, CA EPA, 2006, USGBC, 2007). Fire-fighters not using a breathing apparatus when fighting a fire are taking an unnecessary risk, regardless of the presence of PVC (USGBC, 2007).
- PVC's impact when burned is no different in comparison with many other materials (e.g. other plastics), the exception being hydrogen chloride which is an irritant and highly corrosive (CSIRO, 2001).
- Carbon monoxide is the most significant health risk in building fires. However, PVC does not stand out in this respect given that many other materials are far more significant sources of carbon monoxide as a result of fire (CSIRO, 2001).
- Overall there is insufficient data to warrant a discrimination of PVC products in the built environment based on the impact of toxic gases created during a building fire (USGBC, 2007).

Conclusions

- There is insufficient rationale for discrimination against PVC products in the built environment on the basis of the impact of toxic gases created in an accidental building fire.

4.6 END OF LIFE PRODUCT RECYCLING

Concern

Low recycling levels of post-consumer PVC waste represents a weakness in the PVC life cycle when compared with current end of life recycling rates of other plastics.

Literature Review

- PVC products are fully recyclable as a thermoplastic resin and can effectively be recycled if efficiently collected and sorted from the waste stream. Recycled feed stock can be readily used again in newly manufactured products (CA EPA, 2006).
- Post-industrial PVC is routinely and easily recycled (i.e. manufacturing residues and scrap) in many applications (CA EPA, 2006). In Australia the main streams of post-consumer PVC waste are containers and cable insulation. Approximately 1500-2000 tonnes of post-consumer PVC cable insulation are recycled in Australia each year (Scheirs, 2003).
- In 2007, a total of 11,623 tonnes of PVC was recycled (PACIA Annual Recycling Survey, 2008) of which nearly 3,000 tonnes was packaging and more than 8,600 tonnes was durables including building products. PVC waste is estimated to constitute less than 1% of all waste landfilled each year in Australia (Hyder, 2005).
- Available literature refers to the following limiting factors in the recycling of PVC:
  - Contamination commonly occurs between combinations of rigid and flexible PVC, metals and other plastics (e.g. copper residue in cable insulation) (Scheirs, 2003). Additives, which are used in a large variety of products and in various combinations, are also a major source of PVC recyclate contamination.
  - Many PVC products are durable rigid long-life items especially when used in the built environment context (e.g. piping). The long life of these products has traditionally limited the amount of post-consumer material available for recycling into new products (Scheirs, 2003, Hyder, 2008, CA EPA, 2006).
  - The recycling of some products may serve to spread toxic additives into new products. Although many new PVC products are heavy metal free, PVC recyclate may contains some heavy metal content and will continue to do so for many years (Scheirs, 2003). Encapsulating such recyclate within new products can address this by eliminating contact between the user and heavy metals.
  - PVC materials in composite products are often not salvaged. When PVC composite materials are salvaged they are often down-cycled due to the difficulty associated with separating the products into uncontaminated single stream components (CA EPA, 2006). Some programs for recovery of PVC from composite products do exist (e.g. recovery of carpet backing).
  - Note: many of these constraints are not unique to PVC but are common in one way or another to many other materials.

- Most pipe products (of various materials) are not recovered from the ground after use and the bulk is left in situ. PVC pipe that is recovered is largely land filled in Australia (Scheirs, 2003, PACIA, 2008). Above ground pipe can be more easily recovered and recycled.

- In Europe less PVC is land filled in comparison with Australia (Scheirs, 2003). This is due to a successful waste sorting system (CA, ERP, 2006) and the widespread use of emission-controlled PVC incineration for energy recovery (e.g. Germany) (Scheirs, 2003). The incineration of PVC waste is also common in the USA (USGBC 2007) however is not practiced in Australia apart from medical waste. PVC in medical waste is not relevant to this review.
- The building construction and demolition (BC&D) sector contribution to post-consumer recycled PVC material represents a minor percentage of the PVC that is recycled in Australia. The main barriers to recycling PVC in this sector include:
    - lack of awareness by some companies about the ability to recycle PVC from BC&D sources;
    - perception that PVC recyclate has a low value, particularly when compared with reprocessing costs;
    - perceived difficulty in handling material, particularly compaction issues;
    - relatively low volume of material when compared with other materials, and a perception that recycling BC&D sourced PVC is not worthwhile.

    (Adapted from Hyder, 2008)
- Most PVC recyclate available in Australia is then used in the following products: industrial and domestic flexible hose; general pipe; household pipe and fittings; industrial pipe; flooring (Hyder, 2008).
- PVC recycling can be most easily carried out through simple mechanical melting and re-moulding of similar materials. It can also be recycled through more complex heat-driven or solvent chemical recycling. This involves degrading mixed PVC wastes into their chemical components and using them again as raw materials in the production of virgin PVC. These processes are not cost effective at present (CA EPA, 2006).
- The advantages of increasing PVC recyclate into virgin PVC processes include reducing worker exposure to toxic substances during virgin feedstock production since recycling does not involve Chlorine, EDC, and VCM production. Also increased recycling will reduce the risks associated with PVC in landfill fires and illegal or waste burning (CA EPA, 2006).
- PVC manufacturers should support a voluntary collection of waste PVC construction products as a means of avoiding waste-related concerns (Scheirs, 2003).

Conclusions

- PVC can be recycled and PVC products are being recycled in Australia.
- Levels of PVC recycling are not limited by the material itself but by industry practices. Recommendations to overcome these are given below.
- PVC product manufacturers should provide the market with extended supplier

responsibility (take-back agreements) for their products. This commitment will facilitate increased recycling and create awareness of recycling opportunities.

- Design for dematerialisation and recycling of post-industrial PVC waste are also useful measures for reducing the overall impact of products.
- The building construction and demolition sector should be fully informed about the advantages and ease of PVC recycling.

4.7 Additives in Landfill

Concern

PVC additives leach from landfills contaminating water and soil and therefore represent a health risk when landfill is used to dispose of PVC.

Literature review

- In landfill, plasticisers can leach into the environment from PVC products after disposal. This has now been widely reported in a number of published studies. The overall conclusion however is that PVC is stable in landfill and does not contribute significantly to landfill leachate and gas emissions (Scheirs, 2003).
- An EU study undertaken in 2000 found that the PVC polymer is resistant and stable under soil-buried and landfill conditions. In addition, because stabilisers are encapsulated in the PVC matrix, the migration rate is expected to be extremely low and would only affect the surface of the PVC rather than the bulk of the material. Losses of additives at a low range have been detected. Heavy metals placed in an acidic medium, resulted in elevated concentrations in the leachates. Therefore a problem is created in the early stage of a landfill site where acidogenic conditions are common. However, the conclusions of this study indicate that the contribution PVC to the total load of lead and zinc in typical landfill leachate is negligible (EU, 2000).
- Despite the above mentioned points on resistance and stability of the PVC polymer, emissions of phthalates to landfill leachates and into the aquatic environment cannot be excluded. This is particularly true in the case of DEHP and DIDP in old and new PVC flooring which demonstrates no decrease in release after treatment under aerobic conditions. Considerable amounts of plasticisers and stabilisers are released in leachate in landfills more than 20 years old. A release of phthalates under such conditions is reported in the literature in a range of 4% to 40 % (EU, 2000).
- Technical barriers (i.e. physical barriers) associated with landfill liners and pipes for leachate flow and collection are restricted by an estimated lifetime of up to 80 years. However there are no reliable estimates of how long PVC will continue to leach. Emissions of additives derived from the presence of PVC in landfills are therefore likely to last longer than technical barriers, thus a problem may arise in the future where landfill liners are breached and leachate enters ground water (EU, 2000).
- Conclusions regarding the release of other additives (e.g. cadmium and lead) were not

well established by the EU study. Although both were found in leachate, they may arise from a variety of sources including PVC (EU, 2000).

- While PVC materials are likely to contribute to gas emissions from landfills, VCM found in landfill is emitted through several processes in which PVC products are probably not a significant player. PVC does not de-polymerise to VCM and/ or other degradation products unless placed under extreme thermal, chemical or photolytic conditions. PVC sludge waste from manufacturing facilities may however be a significant source; chlorinated solvents and VCM aerosol propellants are other sources of VCM emissions from landfill (VCM is no longer used as a aerosol) (EC, 2000, CA EPA, 2006).
- PVC manufacturers should support a voluntary collection of waste PVC construction products as means of avoiding waste-related concerns (Scheirs, 2003).

Conclusions

- It is possible for PVC additives to leach from landfills
- Studies on the amount of leachate differ in their results.
- There is a clear rationale for reducing the amount of PVC going to landfill.
- The avoidance of lead and cadmium stabilisers and certain phthalates in PVC products manufactured according to best practice will eliminate the potential risks of these additives contaminating the environment as a result of landfill disposal.

4.8 Waste Fires

Concern

Toxic gases are emitted when PVC waste or waste containing PVC is burned. This represents a health risk.

Literature review

- The presence of chlorine is a major contributor to the formation of dioxins and furans during the combustion of waste. The amount of dioxins greatly depends on the fire conditions (i.e. oxygen availability and temperature), the type of catalyst available (e.g. copper), and the presence of chlorinated material (EC, 2000, Scheirs, 2003).
- Inorganic chlorine will always be present in landfill from non-PVC sources. Even if no PVC was present, the potential for dioxin release as a result of landfill fire exists (CSIRO, 2001).
- Studies in the area of uncontrolled burning have found that when the PVC level in the waste is increased from 0 to 1%, the total dioxin emissions increase seven-fold (Scheirs, 2003).
- The mutagenicity of particulates from combustion of PVC is higher than those produced

from the combustion of other commodity plastics such as PS, PET, and PE (Scheirs, 2003).

- In Australia, backyard burning is uncommon (Scheirs, 2003). Under the Australian Protection of the Environment (Control of Burning) Regulation 2001, backyard burning is illegal and the lighting of fires in landfill is also illegal (DECC, 2008). Data related to the occurrence of accidental landfill fires in Australia is limited. Waste incineration (controlled or uncontrolled) is not practiced in Australia, with the exception of medical waste (which is not relevant to this review).
- No data on the occurrence, severity and frequency of landfill fires in licensed and unlicensed landfills in Australia is publicly available. Licensed landfills are those accepting greater than 5,000 tonnes per annum (which includes the major city landfills and most likely the resting place for most building construction and demolition waste). Unlicensed landfills are those typically run by regional councils, taking less than 5,000 tonnes per annum. Therefore, it cannot be conclusively derived whether landfill fires are a major source of dioxin emissions in Australia.
- PVC manufacturers should support a voluntary collection of waste PVC construction products as a means of avoiding waste-related concerns (Scheirs, 2003).

Conclusions

- The presence of chlorinated products in waste results in increased dioxin emissions in the event of burning in landfill areas as well as in non-high temperature and non-emission controlled waste incineration (e.g. backyard burning).
- Landfill fires are illegal in Australia and no data is available on accidental landfill fires. Waste incineration is also illegal in Australia and is not commonly conducted in backyards (as it is in the US). It is difficult to determine to what extent landfill fires contribute to poor end of life management outcomes for PVC, due to the lack of publicly available data on this topic in Australia. However, there is no clear rationale for discrimination of PVC building products based on this concern.
- Risks from landfill fires do contribute to the rationale for the diversion of PVC waste from landfill wherever possible. PVC manufacturers should, either independently or through their industry associations, work with local and state governments to facilitate measures that will achieve increases in the collection and recycling of end of life PVC products.
- The GBCA encourages local, state and federal waste management authorities to improve their reporting practices on landfill fires.

5.0 Summaries of PVC Life Cycle Assessments

This section provides summaries of three important PVC life cycle assessments (LCA) released in the past decade. These LCAs provide detailed comparisons between PVC and non-PVC alternatives specifically in relation to building products.

5.1 USGBC TSAC 2007

The United States Green Building Council (USGBC) Technical and Scientific Advisory Committee (TSAC) provides the latest study to inform LCA-based decision making for PVC product categories relevant to this review. In 2001 the USGBC commenced a process aimed at establishing the merit of a credit in the LEED rating tools that encourages the avoidance of PVC in building products. The study concentrated on PVC flooring, Drain Waste Vent (DWV) pipe, siding (cladding) and PVC windows as the four most common PVC uses in the US built environment. The study concluded that the performance of PVC relative to the alternative materials depends on two factors; life cycle scope, and whether the focus is human health or environmental impacts.

Where human health risks are the focus then PVC was reported as consistently the worst among the materials studied, in particular if occupational exposure and end-of-life issues such as backyard burning and landfill fires are included. However, in some cases such as windows and sidings, PVC performs on par and sometimes better than alternatives.

Where environmental concerns are the focus then PVC performs better in most uses studied (with the exception of flooring).

The USGBC summarised the outcomes of the TSAC report as follows:

From an all of life perspective, no single material shows up as the absolute best across all human health and environmental impact categories included in the study, nor does any material consistently presents itself as the worst.

- Cancer - PVC is consistently the worst for each of the four product types studied (windows, siding, pipes and flooring).
- Human Health - PVC consistently comes out either tied for worst or absolute worst.
- Environmental ranking - PVC's performance is mixed, still absolute worst in the case of flooring and sheet vinyl - but better than one alternative and roughly equal to the alternatives in the case of siding, DWV pipe and PVC windows. Within the specific environment subcategories performance is scattered with only cork flooring consistently outperforming every other alternative in its category in all environment indicators.

(Adapted form USGBC, 2007)

5.2 TSAC Adaption by BRANZ 2009

In an Australian specific, and Drain Waste Vent (DWV) pipe specific, adaption of the USGBC TSAC report to Australia, BRANZ have concluded that the differences between the situation as described in the US and Australia renders PVC preferable in Australia. This is mainly due to the fact that PVC pipe uses less material in Australia than its US counterpart because Australian multi-layered oriented PVC pipe (PVC-O) is significantly thinner. In addition, landfill fires and waste incineration do not seem to occur in Australia to the same extent as in the US. Two peer reviews of the BRANZ report were carried out by independent LCA practitioners on behalf of the Department of Environment and Climate Change (DECC). In general terms these peer reviews confirm the overall conclusions that, from an environmental impact perspective, PVC pipe performs in a similar way to, or better than, alternative pipe materials.

(Adapted from BRANZ, 2009)

In 2009 peer reviews of this report, commissioned by DECC, were conducted by:

Greg Peters, Centre for Water and Waste Technologies, School of Civil and Environmental Engineering, University of New South Wales (UNSW); and

John Scheirs, ExcelPlas Polymer Technology and Testing.

A life cycle assessment comparing pipe materials conducted in Europe in 1999 (with a similar scope to the BRANZ report) found that comparable conclusions also apply within a European context (CSIRO, 2001).

5.3 European Commission 2004

The European Commission study is a literature review of LCA studies from across Europe. Although the studies concentrated on product use rather than material impact the following generalisations have been made by the study:

- The production process of PVC (particularly the processes from the extraction of crude oil and rock salt up to VCM production) plays a highly significant role in the environmental impacts of the material. The production of stabilisers and plasticisers also play a significant role.
- Mechanical recycling, which loops the material back directly into new life cycles, substitutes the processes of resource extraction and virgin PVC production. A factor to consider is the lack of a strong commodities market for plastics recyclate (in contrast to some metals for example). In addition, products with recycled content may not be accepted by the consumer due to lower optical or aesthetic quality (even if the technical quality, mechanical properties and durability are the same).
- Incineration, in conjunction with municipal waste disposal, is a simple option that allows for the partial recovery of energy and substances, if state-of-the-art technology is applied.
- Depending on the kind of product, the environmental impact during use or at the end of useful life, can be even more important than the environmental impact of material production; the main factors to consider in such evaluation are weight, durability,

maintenance frequency and lower thermal conductivity.

The study draws the following conclusions relevant to the Green Star PVC credit review:

- The overall impacts of PVC products appear to depend not only on the production of PVC but also on the application characteristics (e.g. type of compound, use phase impact, product durability, recyclability). For instance, the overall environmental impacts may only become apparent when the use phase is considered.
- Flooring application – Linoleum has environmental impacts comparable to, or slightly fewer than, PVC flooring of equivalent quality in the production phase.
- Pipes – Some studies see clear advantages for concrete and fibre cement pipes, some report clear advantages for polymer pipes such as PVC and Polyethylene (PE), whereas others conclude that the material plays no role as long as cast iron is not chosen.
- Cable Insulation – PVC cable insulation does not seem to have significant competitors in most cable applications. This has resulted in a general lack in availability of PVC cable LCA studies. Economically feasible options currently exist for the recycling of recovered PVC cable insulation. Such options are made feasible because of the high value of the copper and aluminium metals which are actively recovered from cable and wire waste streams, thereby significantly minimising the overall associated impacts

(Adapted from EC, 2004).

5.4 PVC Life Cycle Assessment Conclusions

A life cycle assessment is a useful tool for comparing the relative merits of products made from different materials. From the studies summarised above, PVC cannot be ruled out as a material for use in the built environment.

6.0 Overview of PVC Industry Action

The PVC industry (domestic and global) has undertaken many changes and commitments aimed at reducing or eliminating the environmental impact and health risks associated with PVC, which came to international attention in the 1970s. This section provides a summary of these actions in Australia and Europe.

Australia

In 2002 the Vinyl Council of Australia (VCA) initiated an industry-wide product stewardship program (PSP) that has developed key action areas in response to human health and environmental impact concerns, as related to PVC production and end of life management.

The outcomes of the PSP, which are relevant to the scope of the PVC credit review, include the following achievements and commitments.

Achievements:

- Established a membership-based, independently audited PSP;
- Replaced Cadmium stabilisers in the product supply chain in 2004;
- Phased out Lead stabilisers for pipe and fittings;
- Reduced VCM emissions in Australian-manufactured PVC resin to less than 50g/tonne of PVC produced;
- Reduced residual VCM emissions in finished resin powder to less than 1ppm; and
- Published independently-audited annual performance reports against the PSP signatories' progress on the commitments required by the program.

Commitments:

- To coordinate and operate the Vinyl-2-Life action plan, which was commenced in 2006 (in collaboration with NSW DECC). This action plan:
  - Promotes the capability for re-processing contaminated waste PVC cable sheathing granulate;
  - Identifies additional sources of waste which can be reprocessed by PVC pipe manufacturers (e.g. sources of rigid UPVC waste).
  - Identifies potential recyclers/ re-processors of vinyl floor coverings both in Australia and overseas.
  - Commits relevant PSP signatories to trial recovery of end-of-life flooring and installation off-cuts when fitting new vinyl floor coverings.
- To replace Lead in all PVC product applications by 2011 (this has already been achieved in PVC pipe);
- To reduce VCM emissions in local production of PVC resin to less than30g/tonne of PVC.
- To require all signatories to reach or exceed the program's minimum acceptable standards in environmental management relating to their respective operations.
- To require open disclosure of general information on additives used in PVC products or components to stakeholders upon request.
- To monitor national and international scientific research and to share pertinent information with signatories and stakeholders.
- To substitute Lead, Cadmium & hexavalent chrome pigments by 2010 where technically feasible and alternatives are available.

At the time of this report, the not-yet-released 2009 updates to the commitment agreements propose:

- To reduce the VCM emissions standard for local production of PVC resin to less than 30g/tonne of PVC.
- To require use of mercury-free processes throughout the supply chain in relation to both mercury cell chlorine and mercury process VCM production.

Europe

The European Council of Vinyl Manufacturers (ECVM) introduced measures to eliminate additives of concern and improve end of life recycling of PVC products. The EU Vinyl 2010 Commitment includes:

- Compliance with ECVM Charters on PVC production standards.
- A plan for full replacement of lead stabilisers by 2015 (in addition to the replacement of cadmium stabilisers which was achieved in March 2001).
- The recycling of an additional 200,000 tonnes/year of post-consumer PVC waste above that already recycled by the end of 2010.
- The recycling of 50% of the collectable available PVC waste for window profiles, pipes, fittings and roofing membranes in 2005, and flooring in 2008.
- A research and development programme on new recycling and recovery technologies, including feedstock recycling and solvent-based technology.
- A social charter signed with the European Mine, Chemical and Energy Worker's Federation (EMCEF) to develop social dialogue, training, health, safety and environmental standards, including transfer to EU accession countries.

(Adapted from Vinyl 2010, 2009)

Conclusions

The outcomes of the GBCA’s review of PVC industry actions in Australia and in Europe are aligned with the findings and some of the conclusions presented in the literature review sections of this report (4.1 to 4.8). Australian and European PVC manufacturers appear to be successfully addressing the minimisation of health risks associated with PVC building materials through a combination of their current practices, commitments to improving practices, and their recent achievements pertaining to PVC production and end of life PVC product management.

7.0 Best Practice Guidelines for PVC in the Built Environment

The Best Practice Guidelines for PVC in the Built Environment (Guidelines) represent the most significant outcome of the credit review. The Guidelines address opportunities for the minimisation of environmental and health risk impacts of the PVC life cycle. They also recognise some of the recent achievements and commitments of leaders in the PVC industry, as well as those that are in the process of implementing certain best practice outcomes across the industry. The Guidelines include strict minimum compliance requirements for PVC supply chain constituents, PVC resin production, PVC product manufacture and end of life management.

The Guidelines are presented in two parts.

1) Manufacture of PVC Resin; and
2) Manufacture and End of Life Management of PVC Products.

These guidelines are intended to be used by manufacturers of PVC resin, PVC conduit, pipes and fittings, cable and wire insulation and flooring that wish to substantially minimise the health risks and environmental impacts arising from the life cycles of their products.

7.1 MANUFACTURE OF PVC RESIN

The following Guidelines represent best practice in risk avoidance and management in the manufacturing of Chlorine, EDC, VCM and PVC resin. They are based on the conclusions identified in sections 4.1 to 4.3 of this document.

- Chlorine shall be sourced from membrane cell or asbestos-free diaphragm cell chlorine production processes. Chlorine should be sourced from production plants using non-graphite anodes. Chlorine produced by mercury cell processes shall not be sourced.
- VCM shall be sourced from non-mercury production processes.
- EDC and VCM, as well as PVC resin, shall be sourced from closed lid production manufacturing plants and processes that implement the following strategies:
  - Waste: Hazardous solid waste and sludge, which can contain organohalogens including dioxins, shall be disposed of via government-approved high temperature emission-controlled incineration. Where incineration is not available or is illegal then diversion to other beneficial uses followed by disposal to hazardous waste landfill is acceptable, provided that these processes are government-approved.
  - Water: Effluents shall be treated using advanced wastewater treatment processes to prevent emissions of halogenated hydrocarbons, such as EDC and dioxins, from being released in treated effluents. Residues from those treatments shall undergo further treatment to destroy possible captured contaminants.
  - Air: Effective emission reduction measures shall be used to ensure that VCM and/ or EDC emissions and possibly other contaminants, are close to, or below, negligible risk levels. In the case of VCM and PVC manufacturing plants the occupational

exposure limit of VCM shall not exceed 1ppm (for 8 hours weighted average in 95% of cases).

- PVC Resin shall be sourced from manufacturing plants and processes that practice the following emissions-related indicators:
    - Air and Water: VCM emissions from PVC manufacturing (both to air and water) shall not exceed 43g/tonne of product produced (measured on an annual basis).
    - Products: VCM emissions from raw PVC resin shall not exceed 1ppm when delivered to the end processor.
- An Environmental Management System (EMS) that encompasses the above Waste, Water, Air and Product-related requirements, as well as continuous improvements in performance targets pertaining to these areas, shall be in place.

7.2 MANUFACTURE AND END OF LIFE MANAGEMENT OF PVC PRODUCTS

The following Guidelines represent best practices in risk avoidance and management in the manufacturing of PVC products. They are based on the conclusions identified in section 4.4 of this document. Post-consumer recycled PVC content that is used in the production of new PVC products is excluded from the following criteria, provided appropriate isolation measures are followed.

- Stabilisers - cadmium and lead stabilisers shall not be used in PVC products.
- Plasticisers - diethylhexyl phthalate (DEHP), benzylbutyl phthalate (BBP), and diethylbutyl phthalate (DBP) shall not be used in PVC products.

The following Guidelines pertain to PVC product end of life management. They are based on the conclusions identified in sections 4.5 to 4.8 of this document.

- Suppliers of PVC pipe and conduit, PVC flooring, and PVC cable insulation, shall commit to offering contractual agreements with their customers for extended supplier responsibility (product stewardship). These extended supplier responsibility contracts shall entail arrangements to take products back at the end of the product's in-use phase for some form of recycling or reuse.
- Manufacturers of domestically-produced PVC products, as well as suppliers of imported PVC products, shall demonstrate that they have established the capacity to deliver the terms of the extended supplier responsibility contract. Independent verification of at least one of the following is required:
    - Suppliers of PVC products have committed to offering contractual agreements with their customers for extended supplier responsibility (product stewardship). These extended supplier responsibility contracts shall entail arrangements to take products back at the end of the product's in-use phase for some form of recycling or reuse. Producers shall demonstrate that they have established the capacity to deliver the terms of the extended supplier responsibility contract.

AND/OR

- o Existing contractual agreements with recycling and waste transport service providers for the collection of end of life product and delivery of that product to a recycling service provider or manufacturer that will reuse or recycle the material. Agreements must service at least two or more Australian capital cities to demonstrate that adequate geographic coverage exists to recover domestically-sold end of life product;

AND/OR

- o Installation of specialist equipment or technologies that enables post-consumer PVC waste to be recycled into new products.

Proposals for other innovative end of life initiatives may be considered on a case-by-case basis. Clear justification, including quantification of the amount of PVC waste that will be diverted from landfill as a result of implementation, must be provided.

Note: Extended Supplier Responsibility is the only recognised performance-based measure that can be applied to products which is expected to result in products being diverted from landfill at end of life. Whilst measures such as inclusion of recycled content, design for disassembly and dematerialisation are all useful initiatives to reduce environmental and health impacts associated with end of life product disposal to landfill, it is difficult to establish performance targets pertaining to these initiatives. Hence the rationale for limiting end of life Guidelines to extended supplier responsibility has been adopted.

8.0 General Recommendations

The GBCA offers the following general recommendations to the Australian PVC industry as well as public and private providers of waste management services. Adoption of these recommendations will improve Australia's capacity to achieve widespread implementation of best practice end of life PVC product management.

- The building construction and demolition sector should be fully informed on the advantages and ease of PVC recycling, and PVC building products industries should play an active role in educating this sector.
- PVC resin and product manufacturers should support a voluntary collection of waste PVC construction products as a means of avoiding waste-related concerns.
- PVC product manufacturers should provide the market with extended supplier responsibility (take-back agreements) for their products. This commitment will facilitate increased recycling and create awareness of recycling opportunities.
- Government departments responsible for overseeing waste management services should improve reporting practices associated with documenting the occurrence, severity and frequency of landfill fires in licensed and unlicensed landfills in Australia, and make this information publicly available.

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