STUDY REPORT

Adaptation of the USGBC TSAC Report for Relevance to Australian DWV Pipe

FINAL

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Abstract

This report has been prepared by BRANZ on behalf of PIPA and a consortium of stakeholders to review the US Green Building Council (USGBC) Technical Scientific Advisory Committee (TSAC) report "Assessment of the Technical Basis for a PVC-Related Materials Credit for LEED" to assess and adapt it for relevance to Australian Drain Waste Vent (DWV) pipe.

The report has been peer reviewed by Dr Greg Peters of UNSW and Dr John Schiers of ExcelPlas – reviewers selected and agreed by the consortium members.

The USGBC TSAC report is the most comprehensive assessment of the environmental and health risk implications of using PVC products in construction. The report provides a technical touchstone for industry and environmental groups because it is the first time when both environmental impacts and health risk assessment have been addressed together in a complementary way. Despite reviewing thousands of sources there still remain some significant gaps in coverage of the health risk impacts for PVC products, but even more so for many alternatives.

The PVC industry have faced opposition from environmental groups for many years but claim that their products are no worse for their environmental and health impacts than competing products. This environmental opposition manifests in Australia in a credit within the Green Building Council of Australia's Green Star Rating Systems for minimisation or elimination of PVC, in the Guidelines for the Sydney Olympic Park Authority seeking PVC minimisation and in the NSW Department of Environment and Climate Change registration of PVC as a waste of concern. This report aims to provide evidence to assist all stakeholders to reach rational conclusions based on best available science, by adapting the TSAC report to Australian product, production processes and competing alternatives.

The project has reproduced the TSAC LCA results adapted to Australian product and processes but assessed using the US Environmental Protection Agency's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) impact assessment methodology. Results are compared and contrasted with US results extending the products assessed from PVC, ABS and Cast Iron to also include Copper and HDPE. The results show that against a wide range of environmental impacts, the PVC pipe performs favourably compared to its main competitors, only HDPE pipe having a comparable environmental performance. This performance is demonstrated over production and use phases of the product life cycle.

The project has attempted to reproduce the TSAC Health Risk assessment results, but found that gaps in the available data prevented a complete assessment. Using a strategy of top down adaptation of TSAC results and bottom up estimation of results it has nonetheless been possible to replicate or simulate Australian pipe performance and verify or refute results and conclusions for their relevance to Australian pipe. The health risk assessment demonstrates that particulate emissions from cast iron and copper production dominate the health risks from the pipe alternatives and PVC pipe performance has a lower associated health risk compared to alternatives than that in the US. ABS pipe appears to have a higher associated risk than found in

the TSAC report from production. The assessment has also confirmed that if the frequency of landfill fires is at the high end of the TSAC scenarios, PVC pipe may have a higher end-of-life cancer risk associated with it (but this is still small compared to the particulate emissions risks). Overall, PE pipe has the lowest health risk implications.

A surprise side result form this study was that US dioxin emissions from well managed and controlled incinerated wastes (where the incinerators operate at high temperatures) are probably lower than the dioxin emissions from landfilled waste subject to accidental uncontrolled fires. This means that the dioxin emissions associated with the 100% landfilled wastes in Australia may be higher on average than those where a significant proportion of wastes are incinerated. This is generally counter to the expectations and advocacy of environmental groups.

It is recommended:

- That the PVC pipe industry commit to the recycling of UPVC waste from the waste stream and work with State governments to recover these wastes and mitigate any remaining concerns over UPVC related dioxin or other emissions from landfill fires.
- That this report be presented to NSW DECC with a request to investigate landfill fire frequency and burn mass to confirm and improve these findings and with a commitment in place to recover UPVC waste from the waste stream reconsider PVC as a waste of concern.
- That this report be presented to the Green Building Council of Australia to seek a withdrawal or modification of the PVC minimization credit to permit the use of PVC DWV pipe.
- That this report be presented to the Sydney Olympic park Authority to seek a withdrawal or modification of the PVC minimization requirements in its development guidelines.
- That the pipe industry proceed with a full LCA of their products and establish an ecolabel standard for pipe systems – this report indicates that PVC pipe products are likely to be environmentally preferable.

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1. INTRODUCTION

This report was prepared by BRANZ on behalf of a Consortium facilitated by the NSW Department of the Environment and Climate Change (DECC) comprising the Plastics Industry Pipe Association (PIPA), Vinidex Pty Ltd, Iplex Pty Ltd and the Green Building Council of Australia. The report has been peer reviewed by Dr Greg Peters of UNSW and Dr John Schiers of ExcelPlas – reviewers selected and agreed by the consortium members.

2. BACKGROUND

The PVC industry has been the subject of a concerted campaign of opposition from environmental groups in Australia and internationally for nearly 2 decades. In Australia the campaign was intensified in the preparations for the Sydney "Green" Olympics.

The anti-vinyl campaign was given momentum in US in particular by the popular "Blue Vinyl" documentary style film.

In addition to general concerns about the environmental impacts of PVC, there are particular concerns about human toxic and ecotoxic emissions of:

- Carcinogenic Vinyl Chloride Monomer from PVC resin production
- Carcinogenic and neurotoxic mercury from the manufacture of chlorine
- Androgenic phthalate plasticiser emissions from plasticised PVC
- and above all emission of bio-accumulative dioxins from the burning of PVC at end of life

The Vinyl products industries have always argued that PVC was unfairly singled out for its environmental impacts presenting evidence that its products were in many cases no worse than alternatives and in many cases better when assessed comprehensively using environmental life cycle assessment (LCA). Moreover, they have argued that only environmental health risk analysis can really be used to assess the human health implications of material choices – taking into account emissions, exposures and toxic potency of all of the chemicals released in the vinyl life cycle, but also in the life cycle of common alternatives.

Studies in Europe (EC 2004) and the UK found that when compared to alternatives, PVC products were no better or worse than alternatives in many/most applications using Life Cycle Assessment, but failed to address human toxicity issues with the same degree of rigor. The PVC industry were able to claim that the LCA studies vindicated their position and the environmental groups were able to legitimately criticise the lack of comprehensive assessment of the human toxicity aspects of these studies to provide a definitive answer.

In 2001, the US Green Building Council were developing a version of LEED for the fit-out and refurbishment of commercial buildings. The development committee devised a credit to be awarded for minimising or excluding the use of PVC and this was included in the draft posted for public comment on the USGBC website. This drew immediate and critical response from the Vinyl industry and especially the Vinyl Institute – its Trade Association.

In response to this critical comment, the USGBC withdrew the PVC minimisation credit from the LEED for Commercial Interiors (LEED CI) rating system and established the Technical &

Scientific Advisory Committee (TSAC) to investigate. The TSAC commissioned an expert group to investigate including LCA experts, Toxicology experts and Building material experts.

The charge to the TSAC was ***To review the evidence offered by stakeholders and information from independent sources and to advise the LEED Steering Committee on whether sufficient evidence exists to make a reasoned decision about the inclusion of a credit under LEED related to the use of PVC products in LEED certified buildings, and if not to recommend a defined approach to resolve identified issue.***

The expert group reviewed around 2,600 scientific papers from the literature and from stakeholders. A preliminary draft report was issued in December 2004 identifying gaps in the available data (especially for PVC competing products). The report was finalised in February 2007 with remaining data gaps mainly around end-of-life disposal from back-yard burning and landfill fires.

The USGBC TSAC review is almost certainly the most complete assessment conducted internationally and it confirmed that against a broad range of environmental impacts, PVC DWV pipe was generally preferable to common US alternatives from ABS or Cast Iron. However, when it came to Human Health impacts, ABS was generally better, with Cast Iron generally worst, except for human cancer implications arising from the disposal of pipe in landfill, through incineration or from backyard burning.

In Australia, it was expected that PVC DWV pipe would perform even better compared to ABS and Cast Iron alternatives because of the use of thinner walled pipe, PVC O pipe and foamed core PVC pipe – all of which reduce the quantities of PVC used per unit length of pipe. Also in Australia, PE, copper and fibre cement are more common viable alternatives.

The PVC pipe industry consider that there are three key documents that underpin specifiers' and designers' concerns about the environmental credentials of PVC pipe. These are:

1. Extended Producer Responsibility Priority Statement, Department of Environment and Climate Change (DECC);
2. Green Star Building Rating Tools, Green Building Council of Australia (GBCA);
3. Sydney Olympic Park Design Guidelines, Sydney Olympic Park Authority (SOPA)

These documents encourage avoidance of PVC products in general indicating that PVC is an environmentally unsound building material.

The PVC pipe industries have been working with the Department of Environment and Climate Change in the Sustainability Advantage Programme. Through this programme the DECC are resourcing stakeholder engagement for Vinidex and Iplex with DECC themselves (as stewards of the Extended Producer Responsibility Priority Statement), with GBCA and Sydney Olympic Park Authority.

3. OBJECTIVE

The objective of this report is to adapt the USGBC TSAC PVC pipe findings so that they are relevant to Australian feedstocks, energy sources, production processes and product and compare this to common Australian product alternatives. In doing so, this report should provide the basis for reconsideration of the implications of PVC DWV pipe by the DECC, by the GBCA and by the Sydney Olympic Park Authority.

4. METHODOLOGY

The approach taken was to replicate the goal, scope and LCA methodology used within the US TSAC report as far as possible, but drawing from the Australian dataset provided with the Sima Pro LCA software. Accordingly, this report should be read in conjunction with the original TSAC report (TSAC 2007).

4.1 Functional Unit:

For pipe, the functional unit is defined in the TSAC report as 1 foot of DWV pipe of nominal 3 inch diameter over a 50 year life. The TSAC report compared

PVC
ABS and
Cast iron

In this report, the range of materials was extended to reflect the most common alternatives available in Australia, adding:

PE and
Copper

Fibre cement pipe is also fairly common in Australia and it was intended to also add this. However, it is only available in larger sizes than that used in the TSAC report.

Table 1 - TSAC Data and Metric Conversions

US TSAC Pipe Material Type	Mass per lineal		Pressure rating		Dimensions	
					OD	ID
	lbs / ft	kg/m	psi	kPa	inches	inches
ABS	0.95	1.41				3 nom.
PVC	1.45	2.16	158	1089		3 nom.
CI	5.4	8.04			3.3	2.96
Conversions	0.3048 m/ft 0.4536 kg/lb		6.895 kPa/psi			25.4 mm/inch

Table 2 - Australian Pipe Data and Sources

Pipe Material Type	OD mm	ID mm	density kg/m3	Au kg/m	Sources
ABS	78.9	76.2	1061		http://www.ides.com/generics/PE/PE_typical_properties.htm
Class 12	78.6	74.9	1061	1.9	http://www.deps.com.au/index.php?page=Cascreen_Products
Class 14	71.4	67.5	1061	1.8	http://www.deps.com.au/index.php?page=Cascreen_Products
PVC			1125		http://www.ides.com/generics/PE/PE_typical_properties.htm
Regular				1.6	Vinidex and Iplex
Foamed Core				1.2	Vinidex and Iplex
PVC O				1.7	Vinidex and Iplex
CI	83.8	75.2	7000	7.55	Product catalogue
PE					
Compond 80 av	75.4	64.7	930	1.09	http://www.ides.com/generics/PE/PE_typical_properties.htm
Compound 100 av	75.4	65.8	940	1.00	http://www.ides.com/generics/PE/PE_typical_properties.htm
Copper					
Type A				4.23	AS 1432 Copper Tubes - Pg 24
Type B				3.42	AS 1432 Copper Tubes - Pg 25
Fibre Cement					Not Viable in TSAC dimensions

NB The PVC O pipe is a pressure pipe and of much lower mass per lineal metre than equivalent pressure rated pipes, but of higher mass per lineal metre than the non-pressure equivalents. PVC O pipe is not strictly relevant to the functional unit chosen, but is included for comparative purposes.

4.2 Scope:

The scope of the assessment is cradle to gate for the production of the pipe. End of life impacts are added to the life cycle similarly to US approach, since little data could be found for substantial end-of-use recycling of Australian pipe to justify variation. The mode of disposal was adapted to be 100% landfill since no waste incineration takes place in Australia. Back-yard burning is assumed to not take place in Australia, but is fairly common in rural US.

4.3 Product Alternatives:

The TSAC report studies ABS, PVC and Cast Iron pipe, but this is extended to include Copper and PE pipe in this project. It was intended to also include Fibre Cement pipe, but this is not available in diameters as small as 3 inch nominal. In addition, 3 variants of PVC pipe were included – conventional, foamed core and PVC oriented (PVC O). The wider range of pipe materials reflects the wider range of alternatives commonly used in DWV applications in Australia. All 3 variants of PVC DWV pipe use a smaller mass of PVC per unit length than the US pipe.

4.4 LCA Impact Assessment:

This included LCA impact assessment using the TRACI methodology which is strictly US relevant, but for which there is no Australian equivalent to substitute. For global impact categories the characterisation factors used (to scale impacts for their potency) are likely to be universally applicable, but for more local categories, resource depletion categories or ecological impact categories the results may be only indicative. Since the results are only used comparatively within each category, this is likely to only be a minor problem.

4.5 Health Risk Assessment:

It proved extremely difficult to replicate the TSAC methodology from the sources referenced in the report and many of the sources proved patchy in their coverage of parts of the assessment. To complete an environmental health risk assessment you need:

- Emissions data for each chemical
- Intake Fraction data for each chemical – to determine the dose received as a result of an environmental emission
- Dose/Response data for each chemical – to determine the potency of each chemical for causing mortality or morbidity effects
- Benchmark mortality and morbidity data permitting the calculation of Disability Adjusted Life Years (DALYs) to reconcile mortality and morbidity effects.

Only rarely were the quoted data sources congruent (hopefully for the most significant toxicants) and it is not clear the extent to which the missing emissions would have contributed significantly to the assessment of either the PVC products or alternatives. This is a limitation of the original TSAC work as well as of this replication. In addition, in common with the TSAC report, Human Health Cancer and Human Health Non-Cancer were assessed using different methodologies – it proved impossible to compile the end-of-life data for the non-cancer health impacts.

In order to address this problem, 2 separate approaches were taken to replicating the TSAC report results – Top Down and Bottom up. By combining the two approaches it proved possible to reach reliable conclusions on the validity of the TSAC results for DWV pipe in Australia.

4.5.1 Top Down:

In this approach, the TSAC final results were adapted linearly for variations between US and Australian conditions – e.g. scaled against quantities of material used per foot of pipe between US and Australia, end of life impacts scaled up for the higher proportions of waste going to landfill and the higher dioxin emissions from accidental landfill fires compared to incineration etc. PE pipe and Copper pipe were approximated by assuming similar health impacts per unit mass of pipe to ABS and cast iron respectively. This may seem an invalid assumption except that the dioxin emission estimate for cast iron in the original report is based on the catalysing effect of metals like copper – hence the result predicted for copper may well be more appropriate than the original results for Cast Iron (see TSAC 2007, Section D.2.2). For ABS, the dioxin emission is based on the plastic materials contribution to the total combustible waste, assuming other sources of chlorine are present in the waste - hence it is just as appropriate to assign the same emissions to PE on a proportion of the combustible waste basis.

4.5.2 Bottom Up:

In this approach BRANZ attempted to replicate the TSAC methodology from the available referenced data sources and the Australian emissions profile from the Sima Pro Australian dataset. These data are limited by the gaps in the referenced data sources. Each of the sources quoted data for different lists of chemicals and it was rare for all of the data to come together to generate a final result, requiring compatible data on emissions for each chemical, on Intake Fractions for each chemical, on dose/response data for each chemical and finally benchmarks of mortality. Reassuringly, the results from this analysis fall mid-way between those from the TSAC report showing that the results from this analysis do appear compatible with the original TSAC work – i.e. they are equivalently right or wrong. The TSAC expert group benefitted from a nationally recognised expert toxicologist who has probably ensured that the key toxicants have been accounted for correctly and although BRANZ does not have this level of expertise on toxicity aspects, the results do appear to replicate the TSAC results reliably. It proved impossible to compile the data for non-cancer health risks at the end-of-life.

4.5.3 From TRACI

Finally, the TRACI impact assessment methodology provides direct characterization factors for a range of Health impacts expressed in different units – the Australian Sima Pro data is characterized using these TRACI health classes and the results plotted relative to the maximum in each class. The health categories and units of expression in TRACI are:

Global Warming	HH DALY
HH Cancer Air	(benzene-e / kg)
HH Cancer Water	(benzene-e / kg)
HH Noncancer Air	(toluene-e / kg)
HH Noncancer Water	(toluene-e / kg)
HH Criteria Air	(milli-DALYs / kg)
Smog Air	(g NOx / m / kg)

5. RESULTS

The detailed results are presented in the Appendix and summarized here as a side by side comparison with the original TSAC results and then discussed in context of the text in the TSAC report. Not all of the graphs could be reproduced, but those shown here are sufficient to be able to provide a commentary on the TSAC report results and conclusions. Please note that in the original TSAC work and in this report, the different scenarios described by the assumptions represent extreme highs, extreme lows and an average or mid-point value. These scenarios often result in several orders of magnitude difference in impacts and cannot be construed as ranges (as implied statistically by +- 1 standard deviation of the mean).

5.1 LCA Results

5.1.1 Production Excluding End-Of-Life

TSAC Figure 4-9 shows the LCA results obtained for the US Pipe variants excluding end-of-life. All categories are expressed relative to the largest impact in each category. This shows that Cast Iron has the highest impact across all impact categories. The PVC pipe alternatives are significantly better than cast iron against all categories and better than ABS against some impact categories, but not as good against others. Overall, the ABS pipe is marginally better than the PVC pipe.

The Australian Pipe data shows the LCA results in the same format excluding end-of-life. Once again the Cast Iron pipe has higher impacts against every category, but the copper pipe in many cases has a worse profile again. There are three substantial differences between the TSAC data and the Australian data. Firstly Australian PVC pipe is thinner walled and/or uses foamed core technology, or uses PVC O which is very thin walled for the same function. These pipes therefore use much less PVC per functional unit (foot of pipe). Secondly, Australian cast iron pipe has only about 15-20% recycled content and is principally produced from primary sources using Blast Furnace / Basic Oxygen System processes rather than as assumed in the TSAC report – 100% recycled iron from the Electric Arc Furnace. Primary smelting from ore has a higher impact than secondary smelting. Thirdly, copper is a fairly common alternative in the Australian market and it has generally higher impacts than the equivalent Cast Iron pipe.

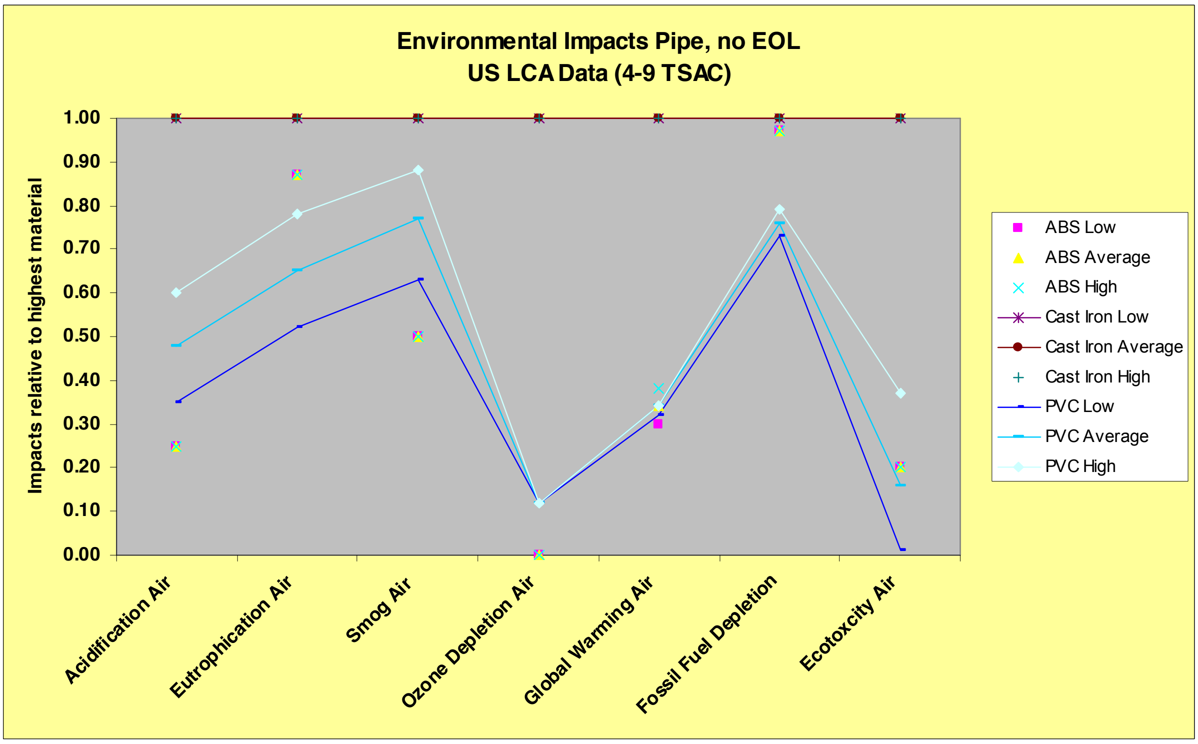
The combination of these two factors gives Australian PVC pipe a substantially better environmental profile for production compared to all alternatives except HDPE which has a comparable performance against many impact categories.

5.1.2 Production Including End-Of-Life

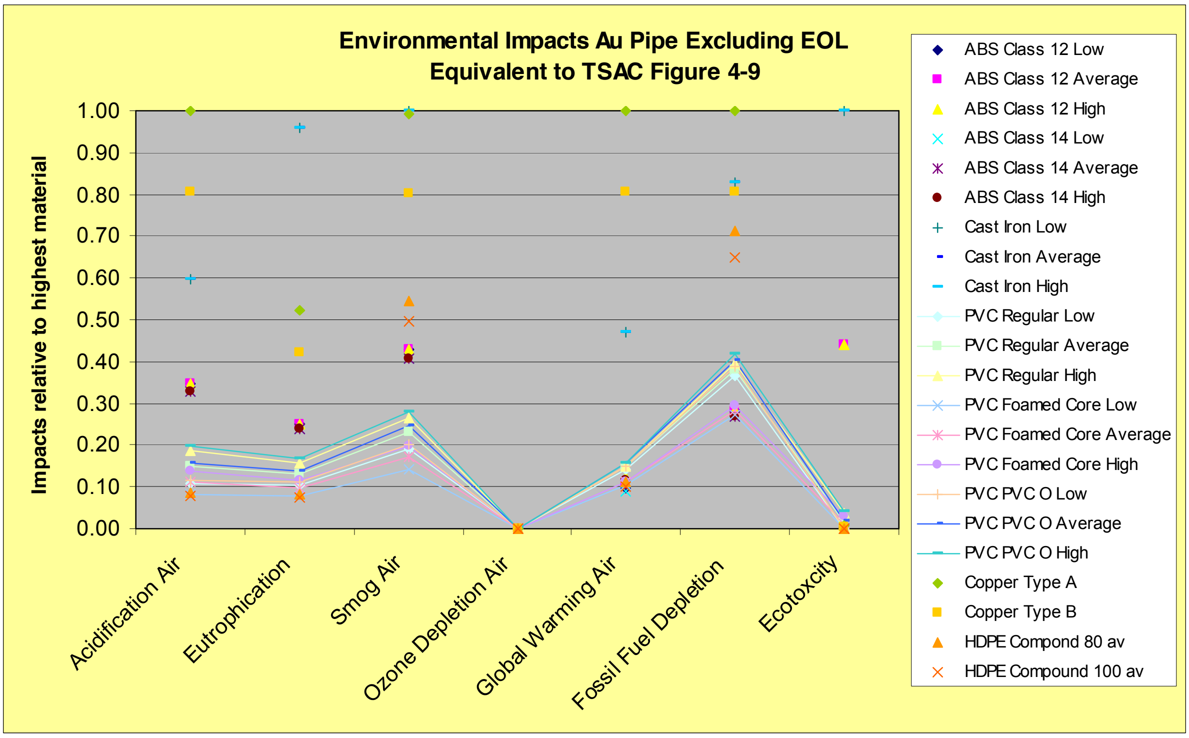
TSAC Figure 4-10 shows the LCA results obtained for the US Pipe variants including end-of-life in the same format as Figure 4-9. This shows that including end-of-life, Cast Iron continues to have the highest impact across all impact categories. The PVC pipe alternatives are still significantly better than cast iron against all categories but the ABS pipe is consistently better than the PVC pipe against most impact categories.

The Australian Pipe data shows the LCA results in the same format including end-of-life. Once again the Copper pipe has the highest impact against most categories but the Australian PVC pipe now shows a substantially better environmental profile for production including end-of life compared to all alternatives except HDPE which again has a comparable performance against many impact categories. Australian ABS pipe is now generally third after PVC and PE for its environmental benefits.

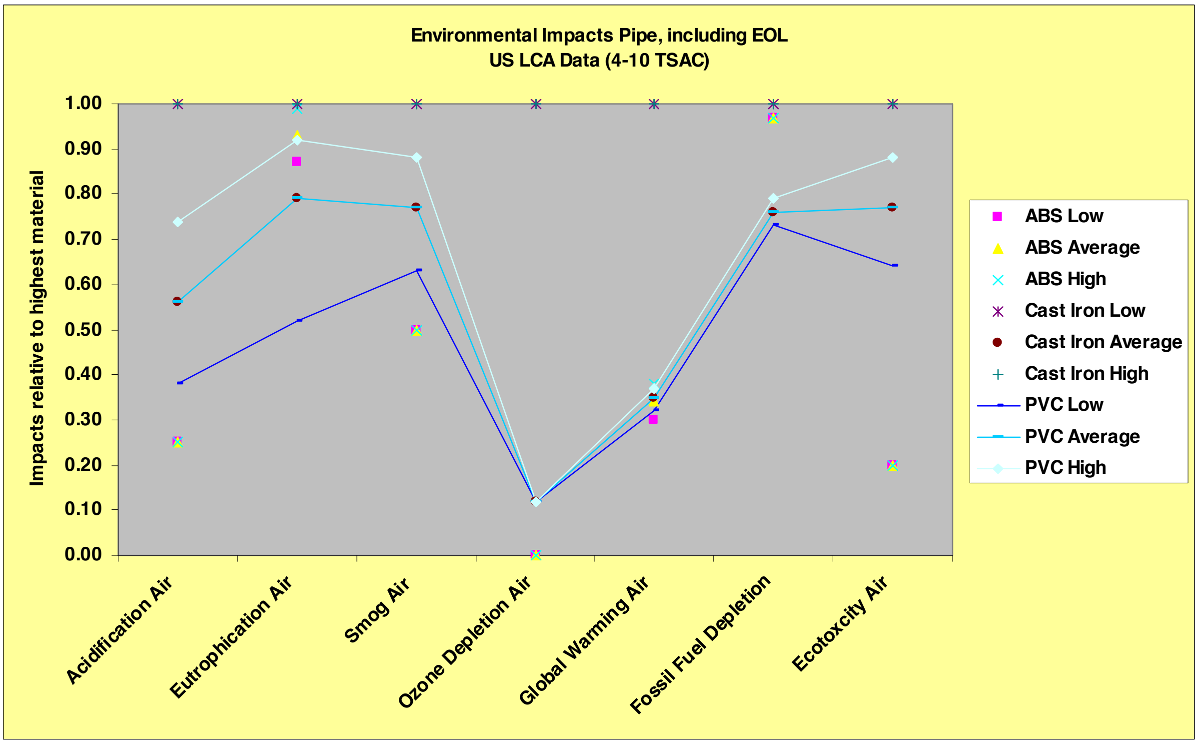
TSAC Report Figure 4-9



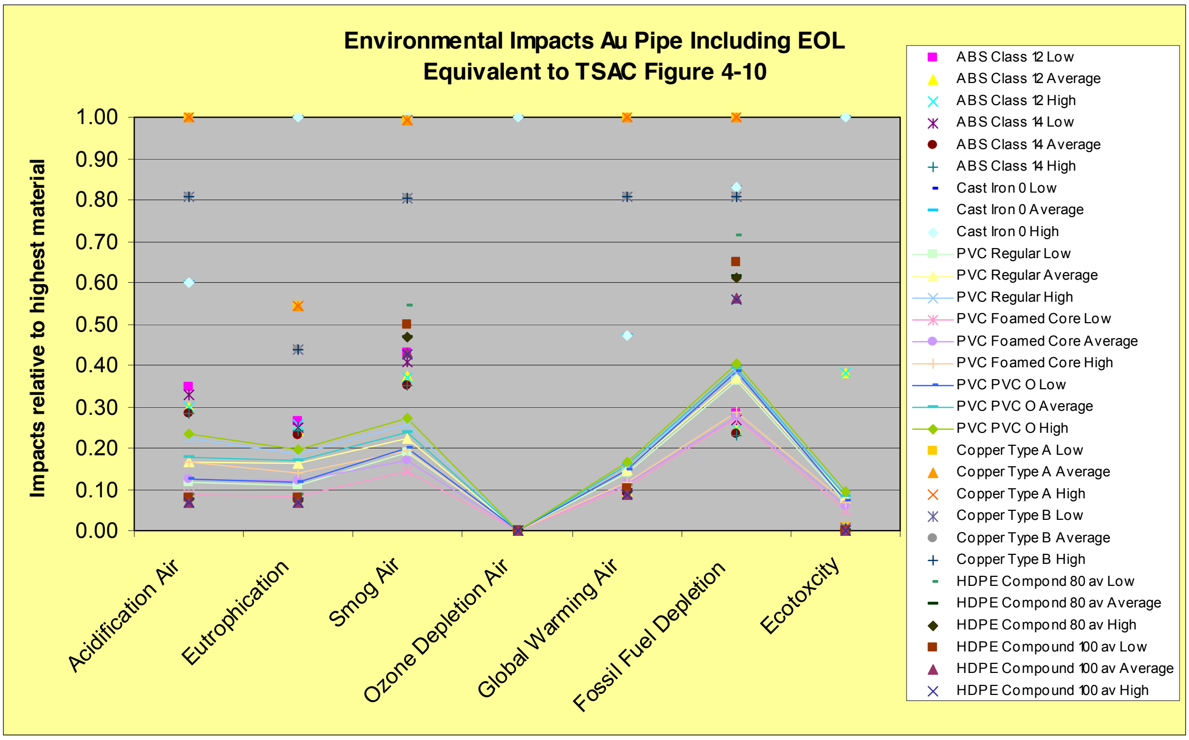
Australian Pipe – Sima Pro Data – TRACI Impact Assessment
Equivalent to TSAC 4-9



TSAC Report Figure 4-10



Australian Pipe – Sima Pro Data – TRACI Impact Assessment
Equivalent to TSAC 4-10



5.2 Human Health Results

Top Down Assessment

Figures 4-11, 4-12 and 4-13 in the TSAC report show the Human Health impacts in aggregate for the different pipe variants. The results are all expressed in micro DALYs and are therefore directly comparable between the categories of:

HH Cancer Stockholm only	Refers to persistent bioaccumulative toxicants listed in the Stockholm convention for Persistent Organic Pollutants
HH Cancer	Refers to all of the human cancer toxicants assessed
HH PM	Refers to human health damage from particulates – including Mortality and morbidity from chronic bronchitis, cardiovascular disease and restricted activity days
HH GW	Refers to human health impacts from global warming
HH Hg High	Refers to human health neurotoxic effects from mercury at a high exposure level
HH Hg Low	Refers to human health neurotoxic effects from low mercury at a low exposure level
Total microDALY	Sums the DALYs from all causes

It should be noted that figure 4-11 uses a logarithmic scale, whereas figures 4-12 and 4-13 use a linear scale. The reason for this is not explained in the TSAC report, but it is reproduced here for comparability.

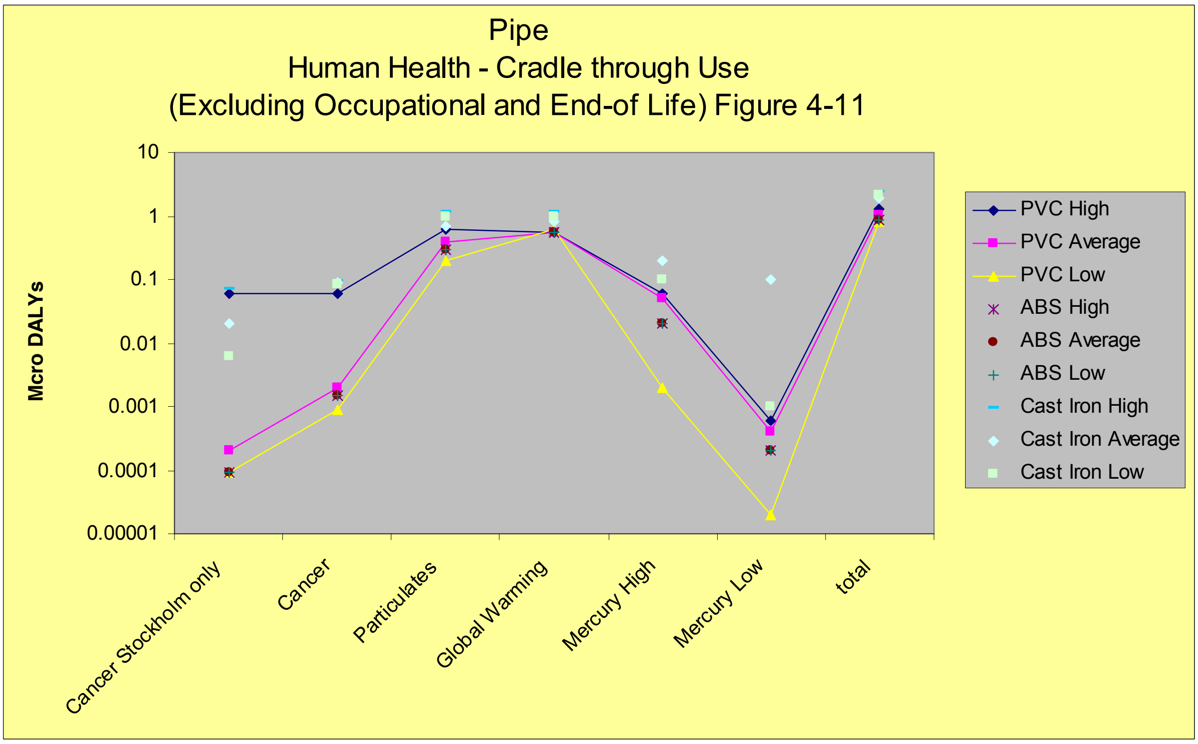
The Equivalent results for Australian pipe are shown below. The Australian pipe results adjust the US results for pipe mass per unit length. The end-of-life results adjust the results also to allow for the lack of waste incineration in Australia. No data could be found to adjust the results for PVC pipe content in waste or landfill fire frequency and burn volume. These data may overestimate the likely emissions and health implications attributable to Australian pipe.

Figure 4-11 shows that cast iron pipe in the US has the highest health impacts against all health risk categories, but for the worst scenario of health risks from PVC pipe similar levels of health risks APPEAR to arise across all of the health impacts. However, the Logarithmic scale accentuates differences in small order risks and diminishes differences in high order risks. Transferring the same data to a linear scale reveals a very different story. This shows that the highest risk health categories by far are those arising from Global Warming and from particulate emissions, and in these two categories PVC pipe performance is amongst the best performer. The logarithmic presentation gives a false impression of the significance of the lower order risks from cancer and mercury.

For Australian pipe, using the top down assessment, the lower mass per unit length of the PVC pipe compared to alternatives even further reduces the impacts of the PVC pipe. It is still accepted that the PVC contribution to cancer from the highest impact assumptions may be comparable to cast iron and copper as the worst cases, but the cancer damage is an order of magnitude smaller that the Global Warming and Particulate damages.

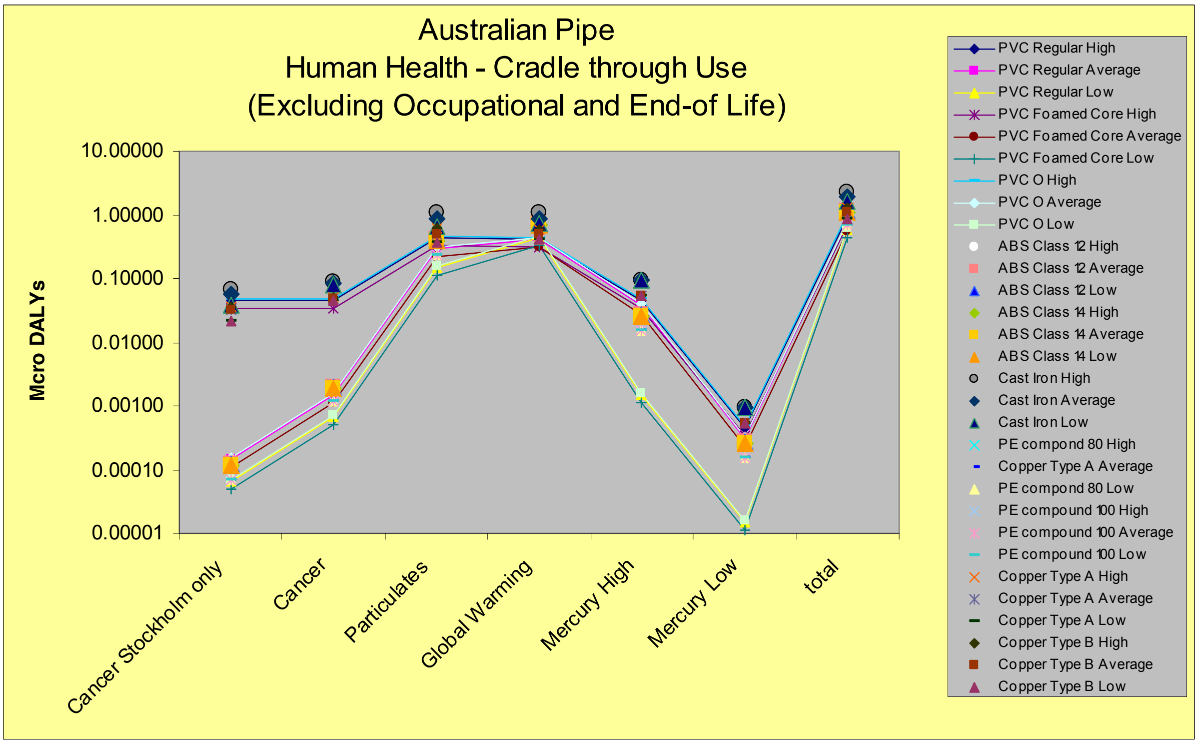
Top down assessment

TSAC Report Figure 4-11 LOGARITHMIC SCALE as reported

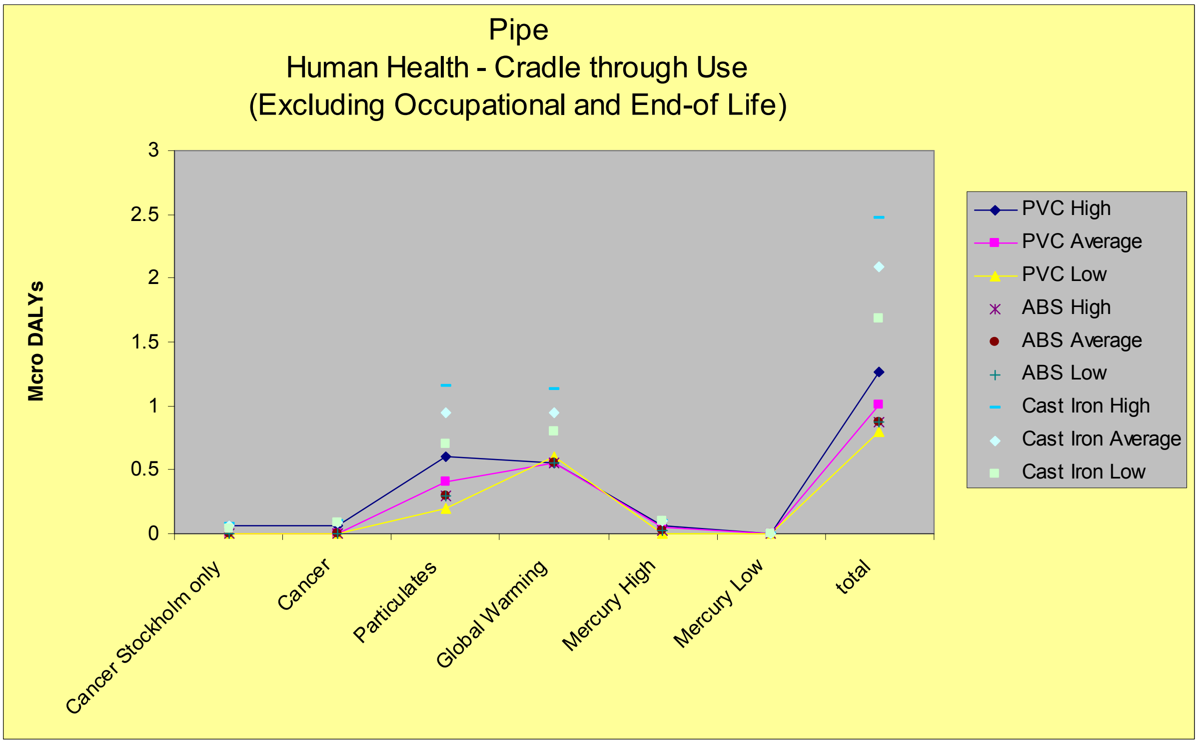


Australian Pipe – Sima Pro Data – TRACI Impact Assessment – LOGARITHMIC SCALE

Equivalent to TSAC 4-11



Top down assessment
TSAC Report Figure 4-11 Transformed to Linear Scale



Australian Pipe – Sima Pro Data – TRACI Impact Assessment – Linear Scale
Equivalent to TSAC 4-11 Transformed to Linear Scale

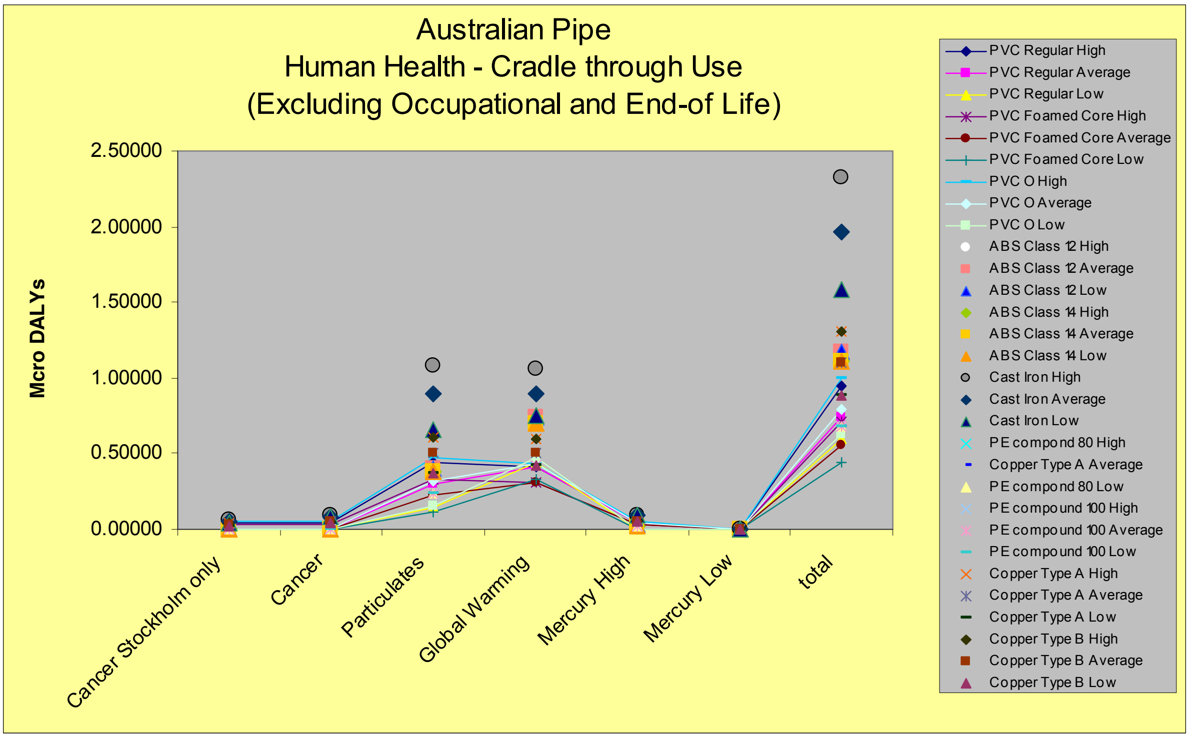


Figure 4-12 from the TSAC report presents the results inclusive of end-of-life considerations which in the US comprise 79.2% of waste going to landfill, 20.6% of waste going to managed waste incineration and 0.2% being disposed of by back-yard burning. The results show that when end-of-life is taken into account, the US PVC pipe may be the largest contributor to Human Cancer health risks compared to ABS and Cast Iron. In the bottom-up assessment below, the low cancer risk for ABS pipe is questioned as a discrepancy – see Bottom-Up Assessment Figures 1 and 2 below.

In Australia, all waste is assumed to go to landfill. The TSAC report describes the method for estimating dioxin from the different disposal routes with Low, Medium and High scenarios of emission with the following results:

Table 3 – Dioxin Emission Scenarios – TSAC Report

Waste Contribution	Landfill Fires			Incinerated Waste			Back Yard Burned		
	Dioxin g TEQ/kg of waste Low	Dioxin g TEQ/kg of waste Med	Dioxin g TEQ/kg of waste High	Dioxin g TEQ/kg of waste Low	Dioxin g TEQ/kg of waste Med	Dioxin g TEQ/kg of waste High	Dioxin g TEQ/kg of waste Low	Dioxin g TEQ/kg of waste Med	Dioxin g TEQ/kg of waste High
ABS	2.0E-11	3.7E-10	2.0E-10	-	2.3E-10	1.2E-10	2.0E-11	3.7E-10	2.0E-10
PE	2.0E-11	3.7E-10	2.0E-10	-	2.3E-10	1.2E-10	2.0E-11	3.7E-10	2.0E-10
PVC	1.2E-07	2.3E-06	1.2E-06	-	2.6E-07	1.5E-07	1.2E-07	2.3E-06	1.2E-06
Cast Iron	4.3E-11	8.1E-10	4.3E-10	-	-	-	4.3E-11	8.1E-10	4.3E-10
Copper	4.3E-11	8.1E-10	4.3E-10	-	-	-	4.3E-11	8.1E-10	4.3E-10
Fiber Cement	2.6E-11	5.0E-10	2.6E-10	-	-	-	2.6E-11	5.0E-10	2.6E-10

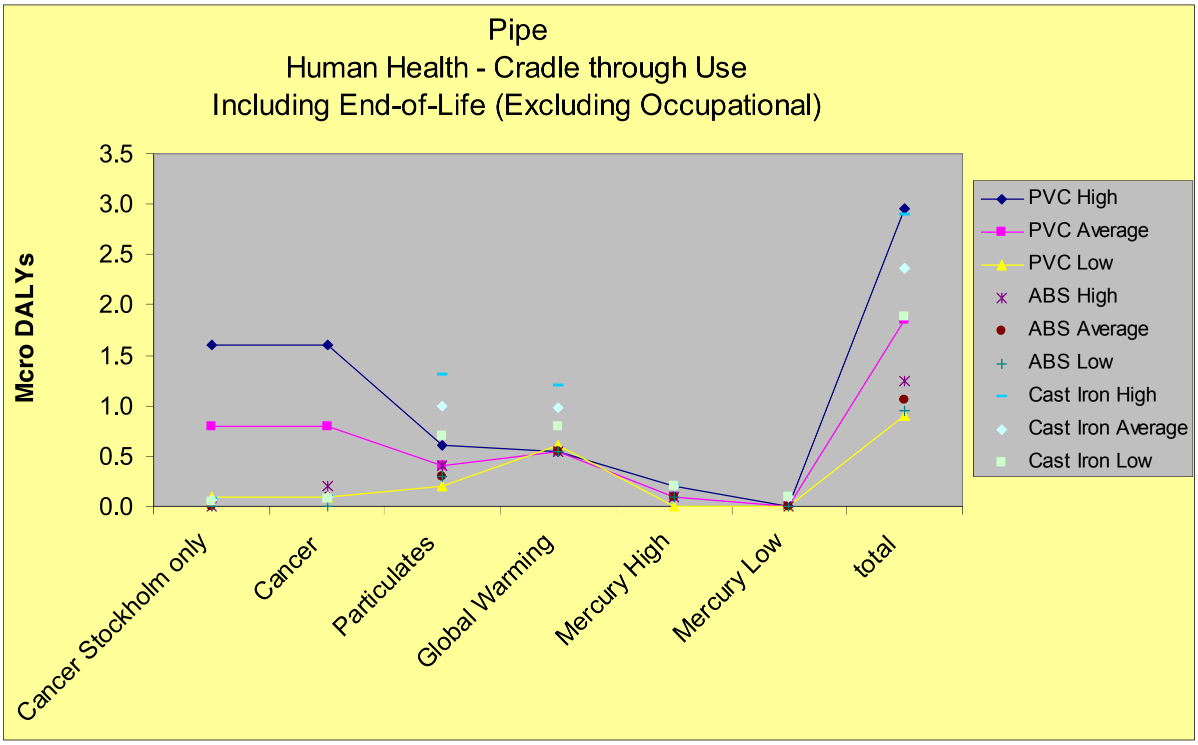
Well managed incinerators operating at high temperatures release low levels of dioxins, whereas uncontrolled accidental landfill fires which may burn at lower temperatures and for long periods under the surface after surface fires are extinguished appear to generate higher emissions per tonne of waste disposed. This means that 100% landfill of waste will release more dioxin than controlled incineration of the same quantity of waste and the dioxin emissions per tonne of waste in Australia are therefore on average higher than in the US. This has been factored into the assessment. (It is ironic that the resistance from environmental groups to controlled incineration may be completely counter-productive to reducing dioxin emissions when these are so often quoted as the reason for avoiding incineration.)

The results presented below for Australian pipe confirm that using the top-down assessment, cancer risk from PVC pipe including end-of-life emissions from landfill fires could indeed be significant and higher than that from other pipes for the medium and high emission scenarios.

It should be emphasised that these results are highly sensitive to assumptions about PVC quantities in the waste stream (i.e recycled rather than landfilled) and to the frequency of landfill fires and burn mass. The TSAC report acknowledges the paucity of data on these key factors. In Australia, there also appears to be conflicting information. An internet search reveals very few reports of major fires – just 2-3 a year across Australia, but small fires may be quite common – several per month in a single landfill district (anecdotal comment from a single NSW landfill manager responsible for several landfill sites when commenting about the training of staff to deal with fires). In the absence of reliable data for Australia, this analysis accepts the same frequency and burn volumes described in the TSAC report.

Top down assessment

TSAC Report Figure 4-12



Australian Pipe – Sima Pro Data – TRACI Impact Assessment
Equivalent to TSAC 4-12

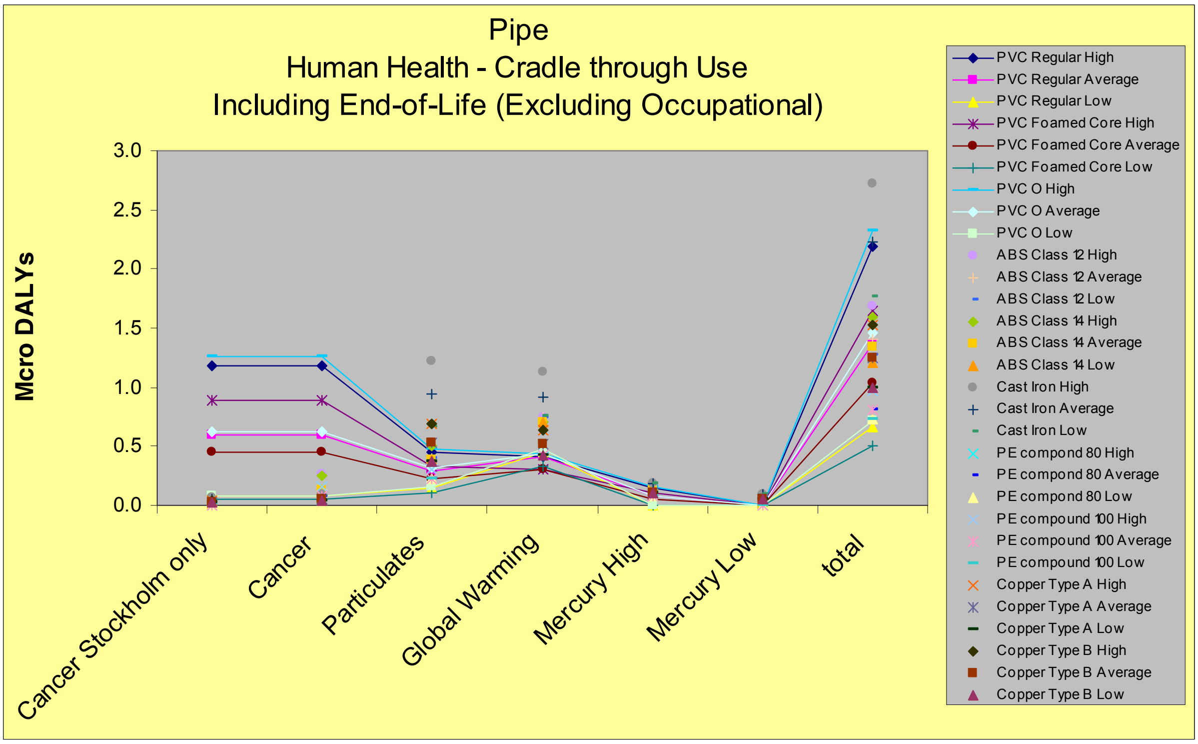
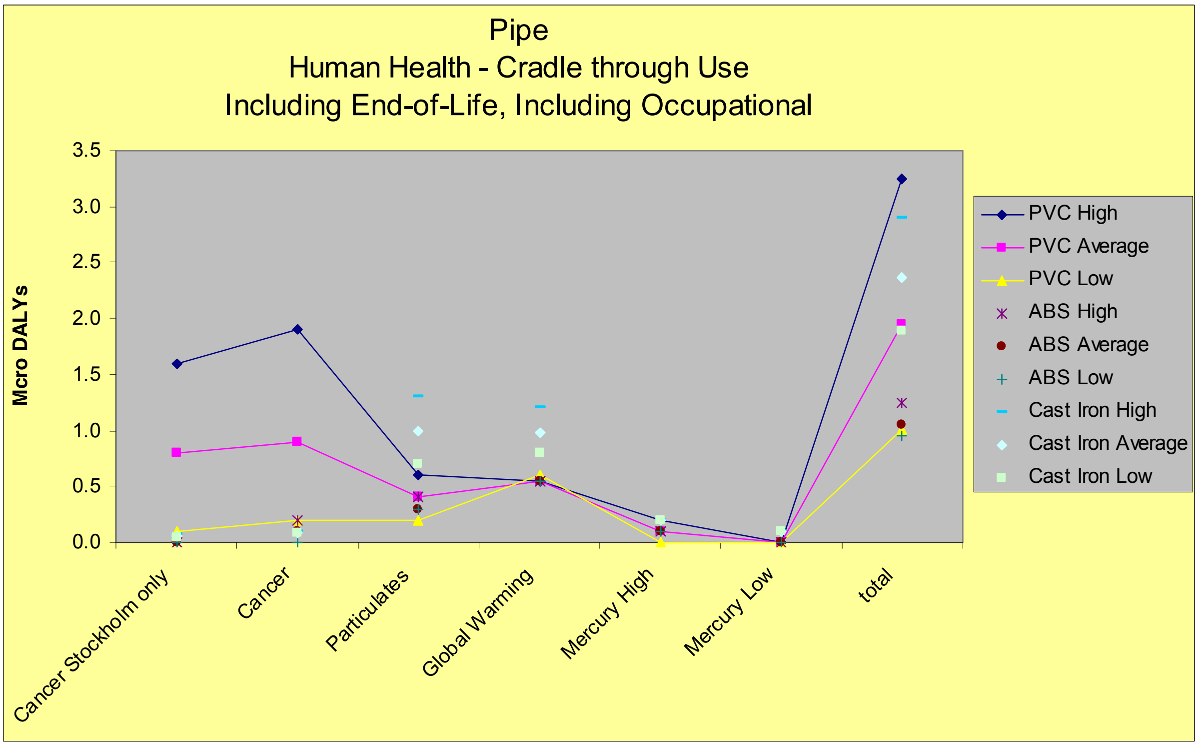


Figure 4-13 extends the analysis to include occupational exposures and health risks. For pipe these are predominantly to the workforce producing the products. Comparing TSAC Figure 4-13 to TSAC Figure 4-12, only the human health cancer figures appear to have varied when occupational exposures are added. The TSAC analysis is clearly focussed on human health cancer. Particulates and mercury have not changed and this is surprising since particulates feature so prominently in the overall production assessment, one might expect the occupational exposures to particulates to be much higher due to longer, closer proximity to the source of the emissions and at higher, less dispersed concentrations, (but for a much smaller workforce than for the general population).

Using the top down approach to assessing these emissions, the Australian pipe results replicate the TSAC US results – the lower mass of PVC per unit length of pipe reduces the impacts, by about 40% overall, but remain higher than the alternatives. These results are somewhat challenged by the findings of the bottom up assessment see Bottom-Up Assessment Figures 1 and 2 below.

Top down assessment

TSAC Report Figure 4-13



Australian Pipe – Sima Pro Data – TRACI Impact Assessment
Equivalent to TSAC 4-13

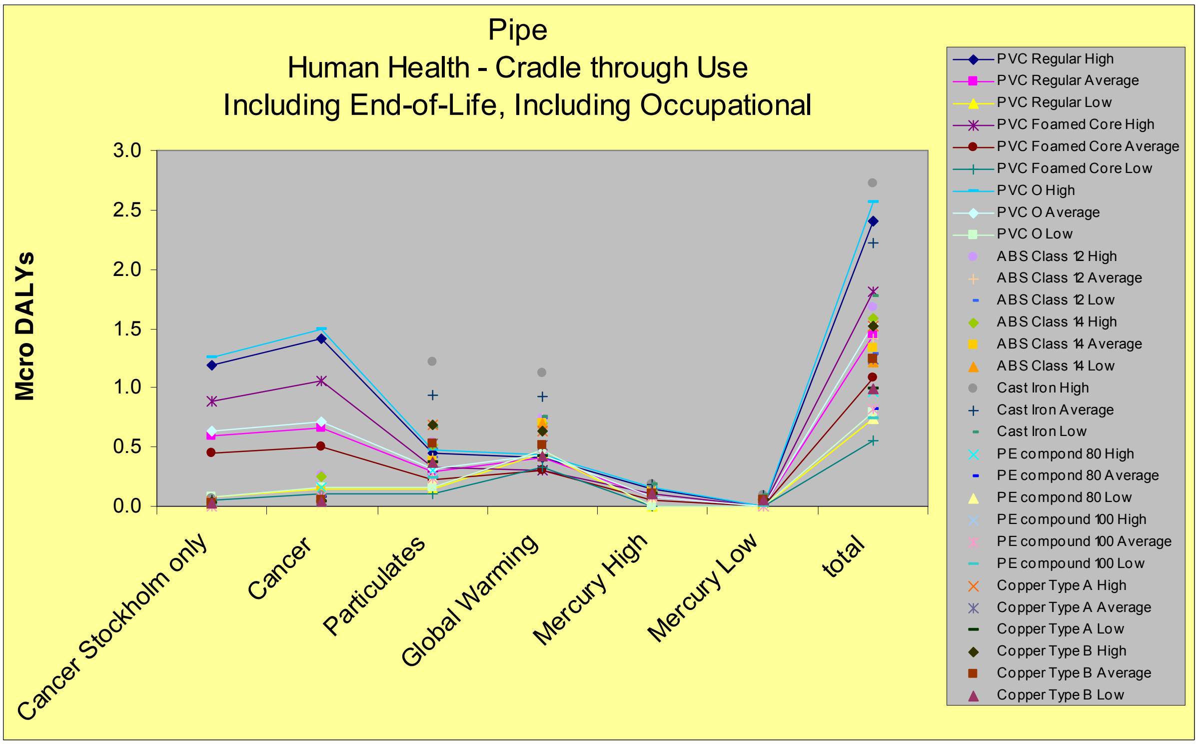
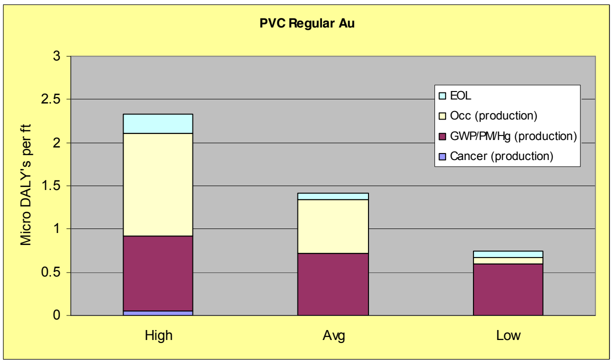
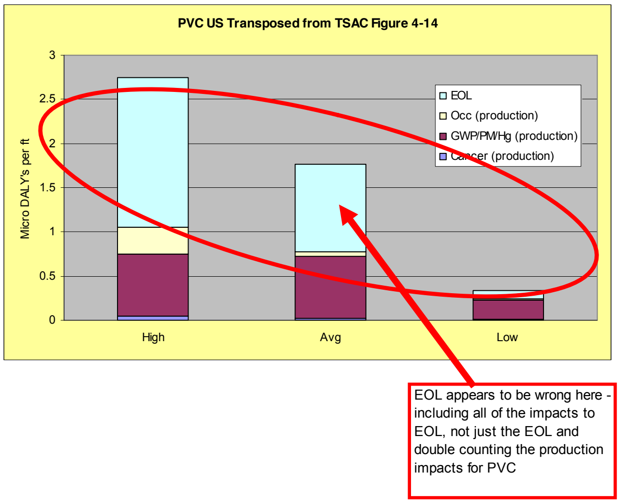


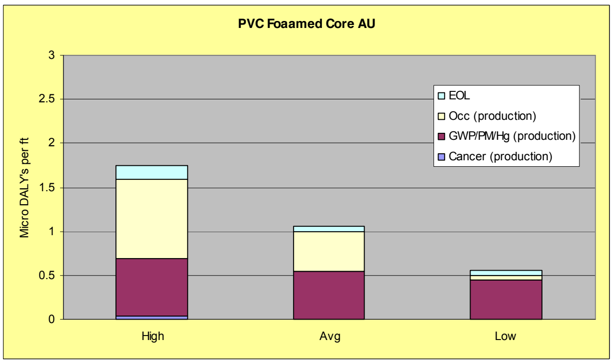
Figure 4-14 compiles the results for all of the pipe variants studied in the TSAC in a 3 dimensional stacked bar graph which BRANZ was unable to replicate graphically. In order to still discuss these results, BRANZ have transposed the data from Figure 14-4 into a series of simpler graphs and presented the Australian pipe data alongside. These are shown below.

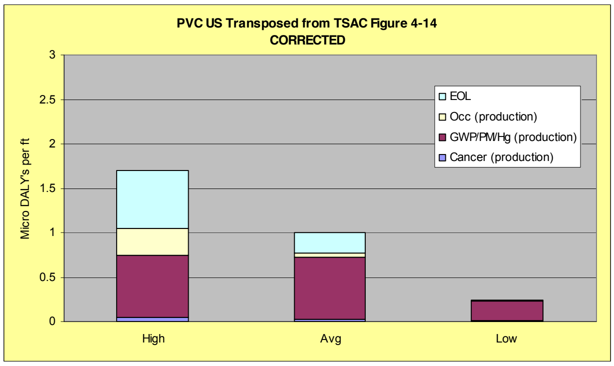
BRANZ were unable to reconcile the end-of-life depiction of the PVC pipe results in Figure 14 with the end-of-life additions moving from Figure 4-11 to Figure 4-12. It appears that the total impact to end-of-life has been allocated to this portion of the stacked bar instead of just the addition from end-of-life – in other words, the production impacts have been counted twice – once in the production impact categories and again summed into the apparent end-of-life bar. This grossly misrepresents the end-of-life impacts for the PVC variants compared to the alternatives. If BRANZ have understood this depiction correctly, they have made best endeavours to correct the graph as shown. This shows PVC pipe in the US to be much more competitive with ABS pipe on human health grounds than implied by Figure 4-14.

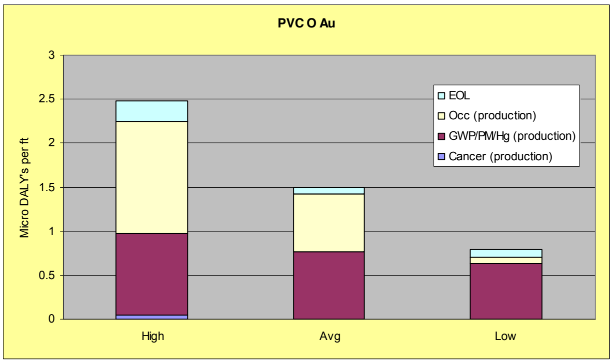
TSAC Report Figure 4-14 PVC Pipe

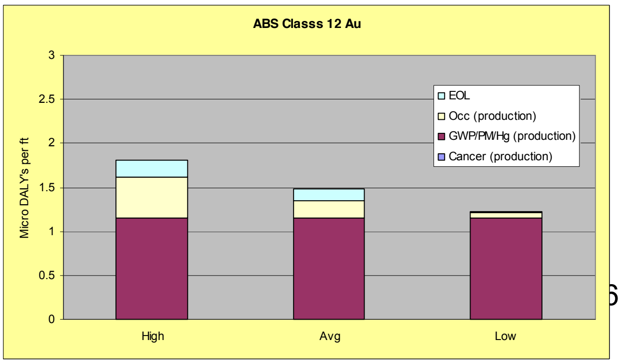












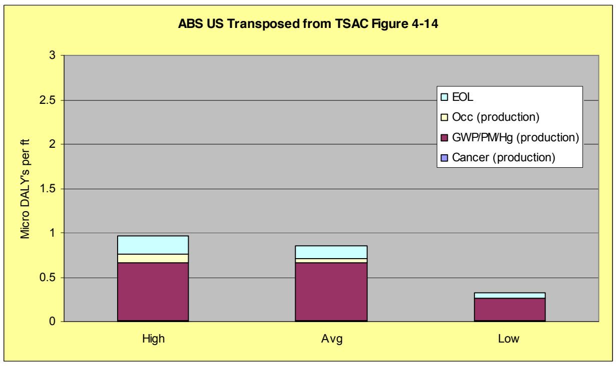
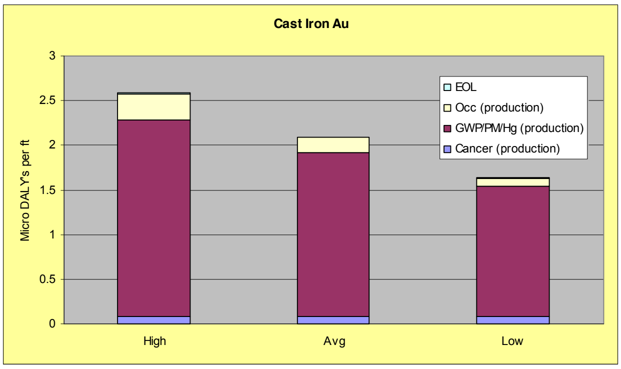
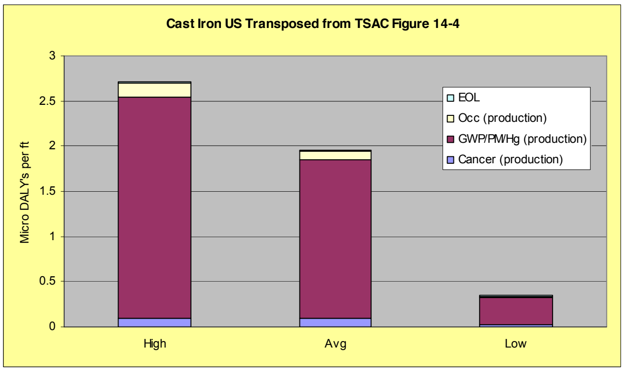
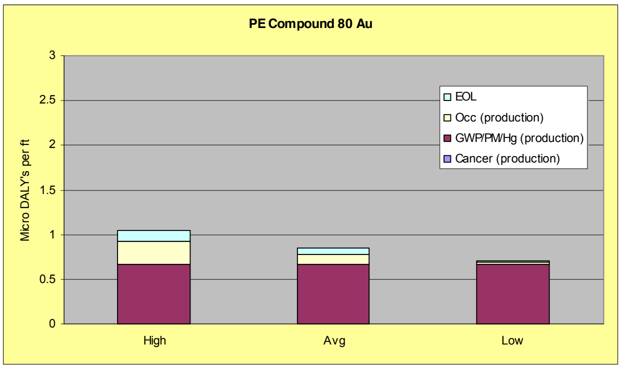
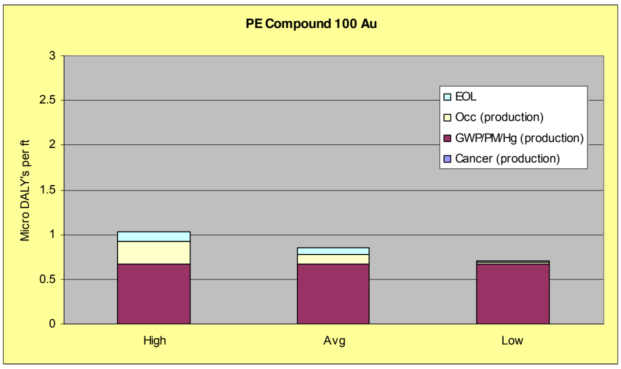


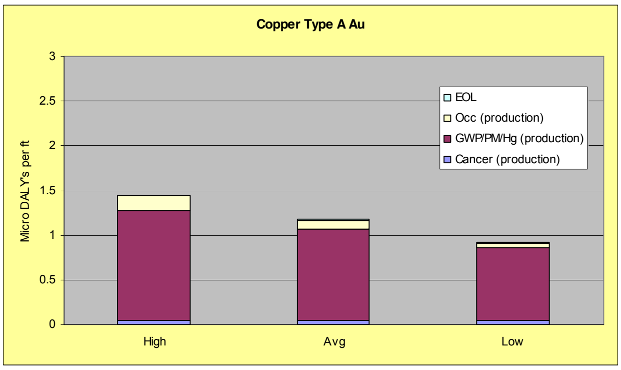
Figure 4-14 continued

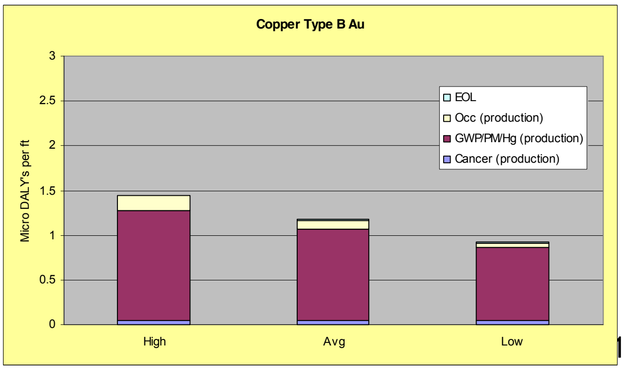












Bottom Up Assessment

Figure 1 below combines all of the health risk assessments that BRANZ were able to complete through to a Disability Adjusted Life Year (DALY) from the available data referenced in the TSAC report combined with the emissions obtained from Sima Pro or added from the TSAC report explicitly. These were cancer and particulates and they are reported together with the equivalent TSAC results mass weighted for the equivalent pipe products. The Australian average results fall within the envelope of the TSAC high and low results for PVC and Cast iron as might be expected.

Bottom Up assessment

Figure 1 - Australian Pipe – Cancer & Particulates – Production – LOGARITHMIC SCALE

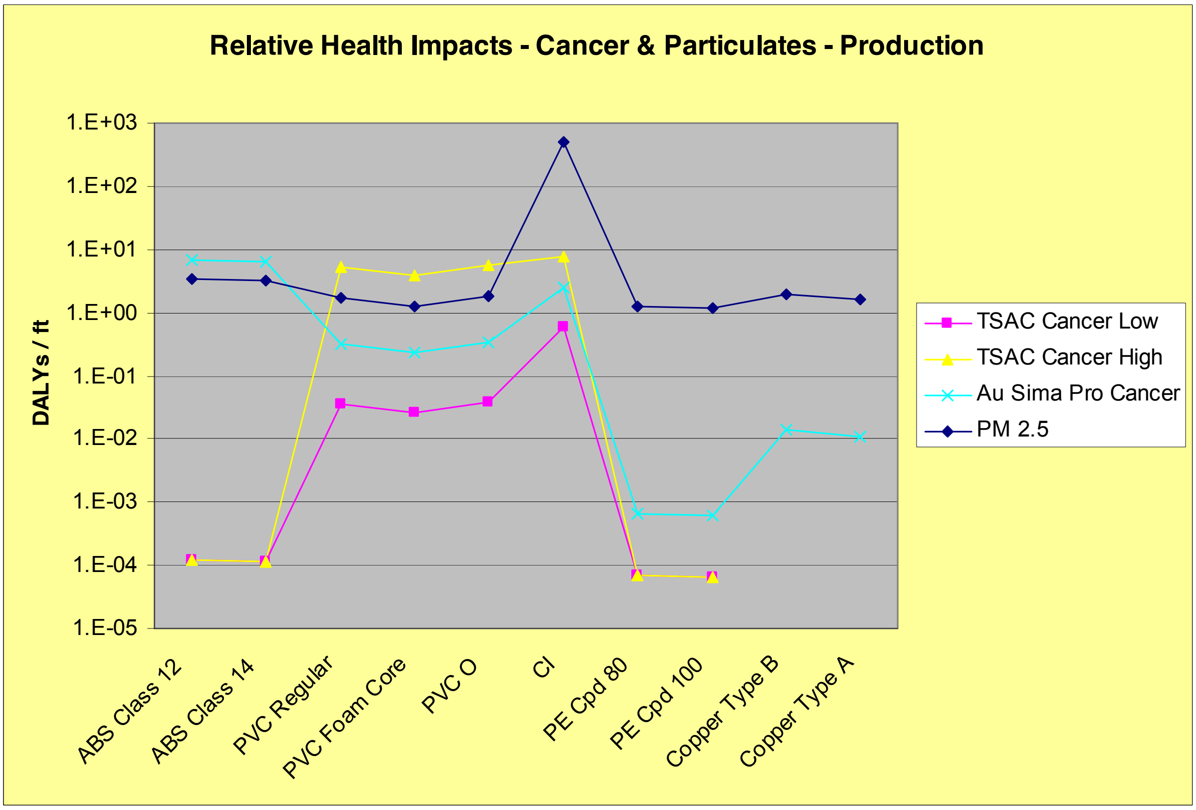


Figure 2 shows a linear plot of the cancer only results illustrating that from Australian production ABS and PE are not immune from cancer impacts and that the ABS results are significantly higher than those for PVC. This is a marked discrepancy from the original TSAC work. This may be due to inclusion of a wider range of toxicants in this work than may have been possible in the original TSAC work. Emissions from Benzo(a)pyrene during production appear to be the largest contributor to these results. BRANZ requested further detail from the USGBC TSAC, but received no reply, so it is not possible to elaborate on this discrepancy.

Figure 2 - Australian Pipe – Cancer Only – Production – LINEAR SCALE

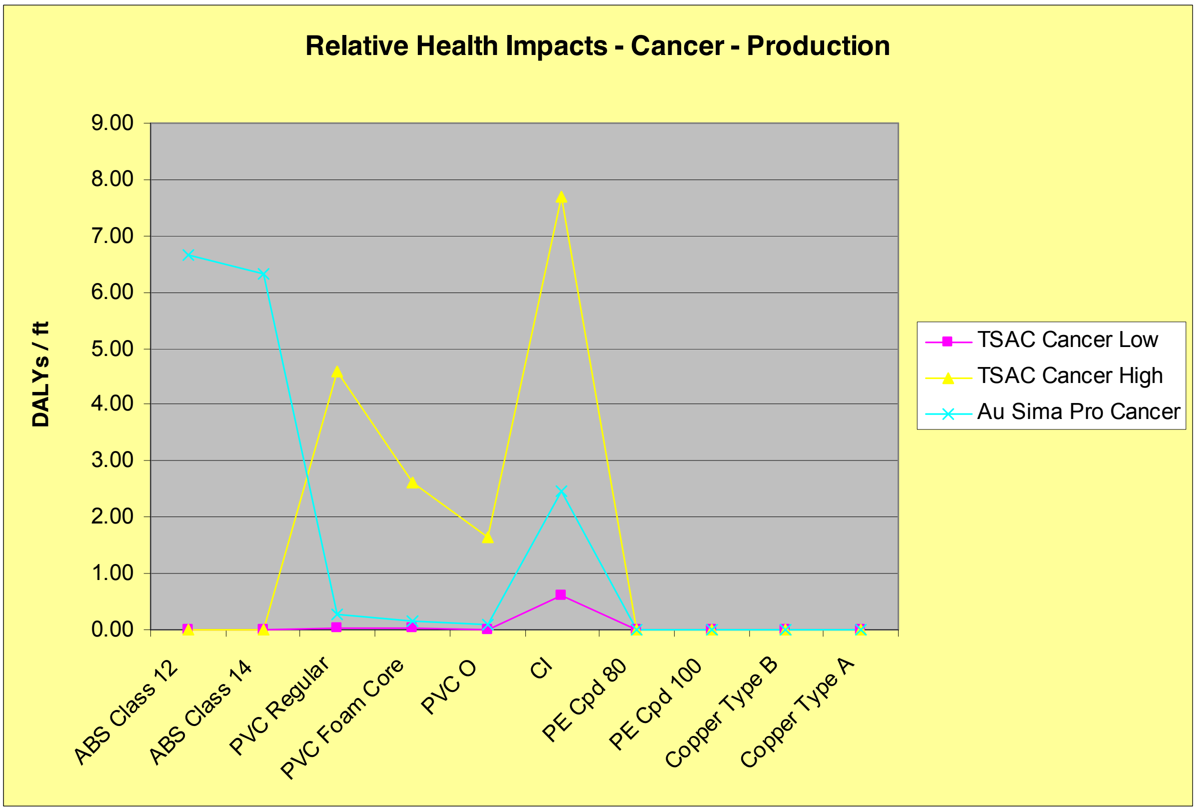
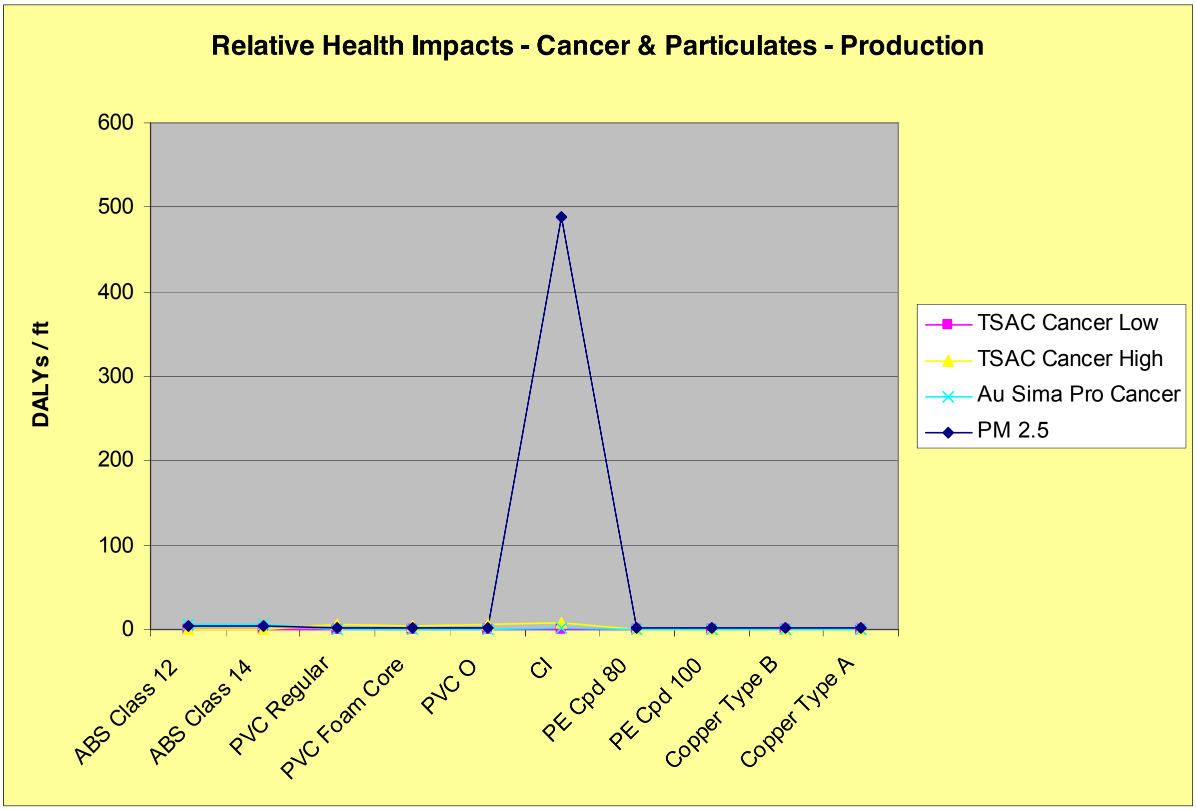


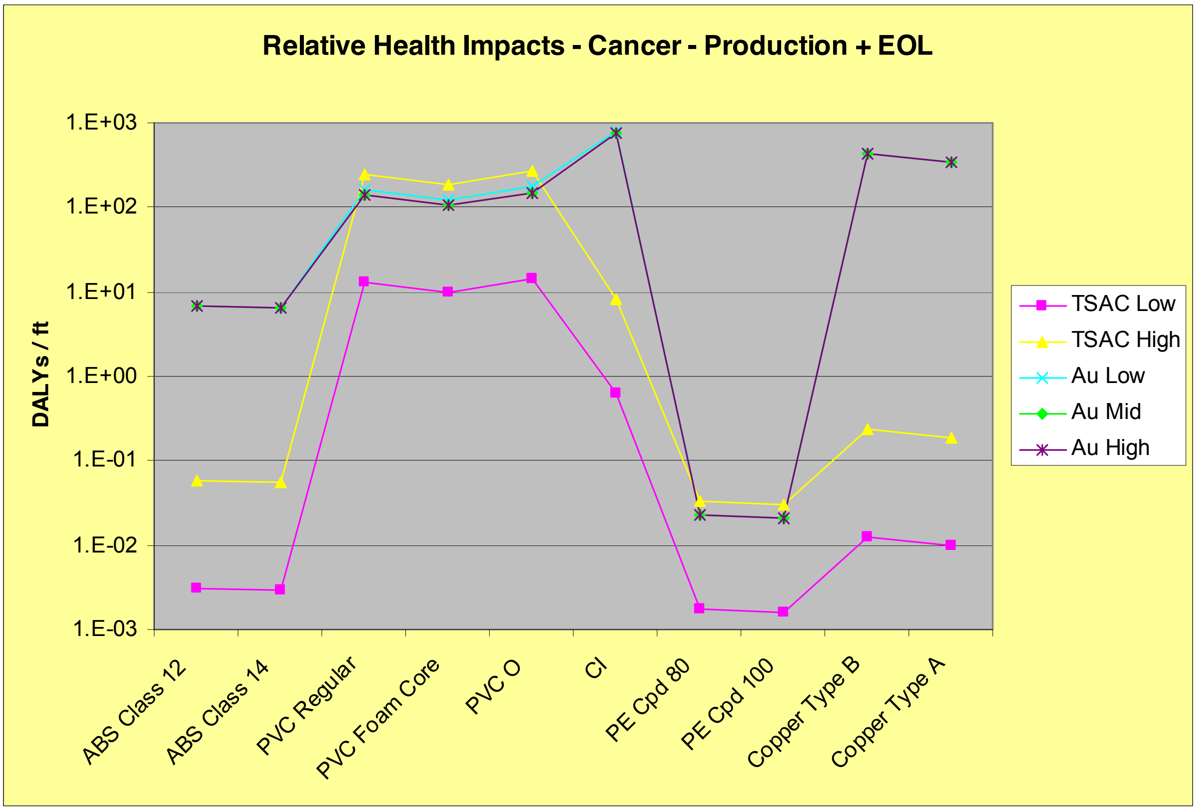
Figure 3 - Australian Pipe – Cancer & Particulates – Production – LINEAR SCALE



Linear plot of the full set of results retaining the particulate figures as in Figure 3, reveals the real scale of the particulate emission health risks from cast iron pipe and the extent to which this dominates the DALY assessment. This confirms a TSAC result from the first draft report, but it is further amplified for Australian pipe because this will predominantly come from primary production – Blastfurnace/Basic Oxygen System rather than the less polluting Electric Arc Furnace for recycled steel (as assumed for US cast iron pipe by TSAC).

Figure 4 below shows the cancer results including end-of-life. They reveal consistent results between this assessment and the TSAC assessment for PVC and PE. The results for ABS and Cast iron are significantly higher for the AU emissions than for the US emissions due to the different production results rather than due to the end-of-life addition.

Figure 4 - Australian Pipe – Cancer – Production plus End-Of-Life – LOGARITHMIC SCALE



The largest change in results for end-of-life comes for the PVC products and for the copper which is assumed to catalyse dioxin formation in fire (similarly to Cast iron). BRANZ are concerned about the linear assumption implicit in the TSAC work for this effect, since catalysis mechanisms may be independent of mass present or depend on surface area affects rather than mass. Accepting this potential limitation, these results confirm TSAC findings that PVC human cancer impacts may increase significantly when end-of life is considered due to dioxin emissions from landfill fires. If the TSAC assumptions for metals are valid, then these produce the largest increase for end-of-life, followed by PVC, followed by ABS, with PE having the smallest end-of-live cancer implications.

The linear scaled version of the graph – figure 5 more appropriately represents the relative significance of the different products for their cancer implications at end-of-life landfill disposal with similar frequencies of burn and similar burn mass and similar waste content assumed to the US.

It did not prove possible to estimate occupational cancer implications using the bottom-up approach. For this approach there must be available data for the each chemical emission, an intake fraction for the corresponding chemical emitted and a cancer potency factor for the same chemical and a current benchmark level of mortality and chronic effect from which to derive a DALY value. Every item of data in this chain must be available for the contribution of a chemical emission to the health impact estimate to be included. In the case of occupational cancer implications too few of these data aligned to adequately characterise the health impacts using this approach. Conclusions regarding this aspect can only be drawn from the top down assessment.

Figure 5 - Australian Pipe – Cancer – Production plus End-Of-Life – Linear Scale

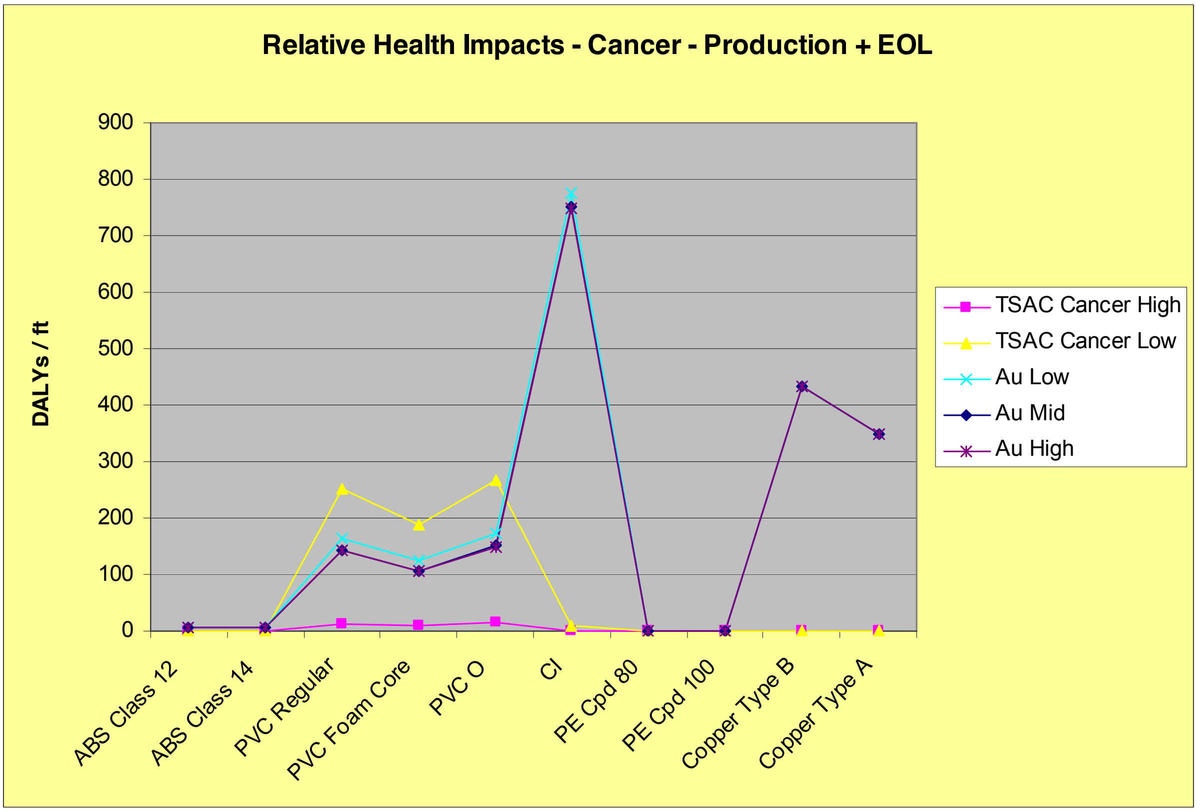


Figure 6 assesses the non-cancer implications of production of the different pipes in Australia. These data use the same approach for determining emissions and population intake fraction, but interpret the data with "Acceptable Daily Intake" (ADI) data from the US Food and Drug Administration. The results are expressed as a Health Index which represents the relative numbers of cases of mortality arising from the different products. According to the TSAC report, any risk smaller than E-06 is considered too small to warrant any action by US EPA.

When considering non-cancer health risks, particulates are the highest risk category, but the risks from these were presented in the DALY format earlier with the cancer results. The next largest non-cancer impacts arise for ABS, then PVC, with Cast Iron, PE and Copper all similar. This is somewhat misleading because the particulate emissions for cast iron and copper were the highest but it did not prove possible to bring all health risk impacts to the single DALY measure.

Only the medium and high scenarios of mercury toxicity exceed the E-6 level for cast iron, all other products having toxicity risks below the action threshold. It is understood by the Australian vinyl industry that virtually all PVC production in Australia uses chlorine from mercury free processes and it is likely that the mercury health risks from Australian pipe are at or below the minimum risk scenario level. University of NSW state that “all VCM used in Australia is imported, the mercury-free statement is a claim about chlorine production by all of the chlorine suppliers of Australia’s overseas VCM suppliers, which is harder to prove than any claim about Australian chlorine production”.

Figure 6 - Australian Pipe – Non-Cancer – Production – LOGARITHMIC SCALE

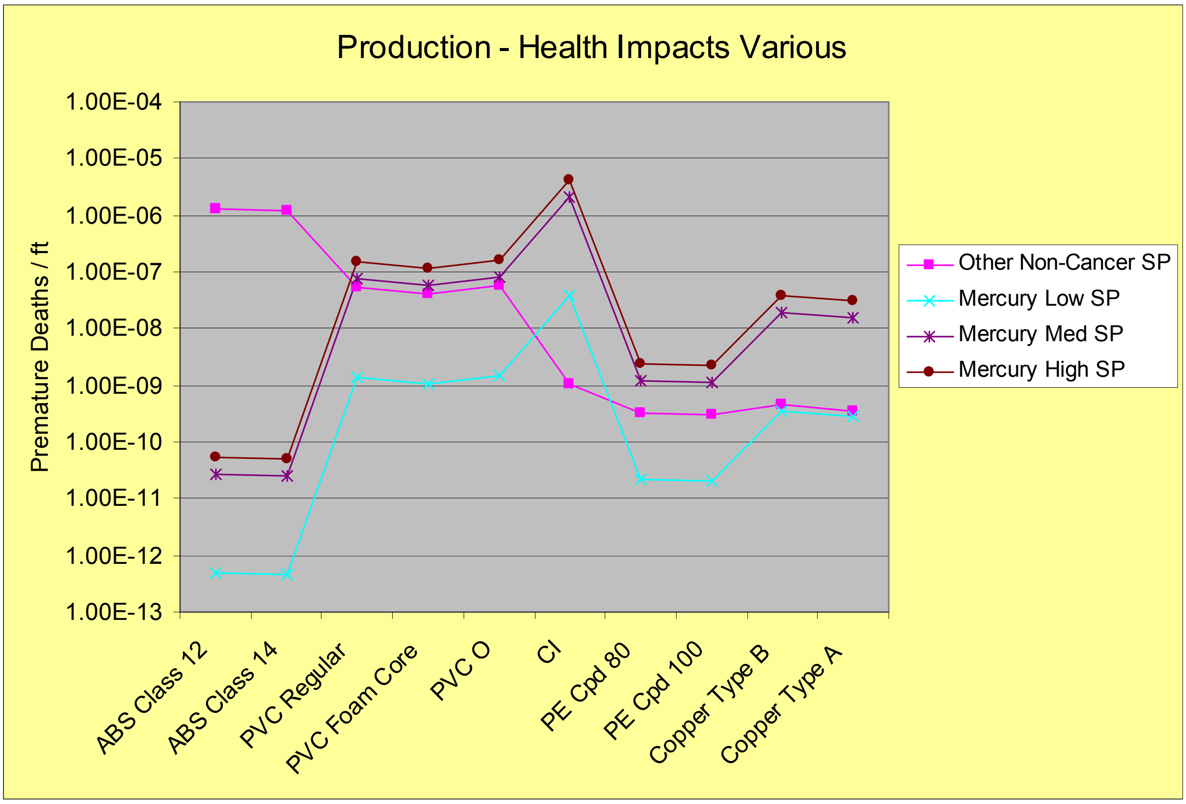
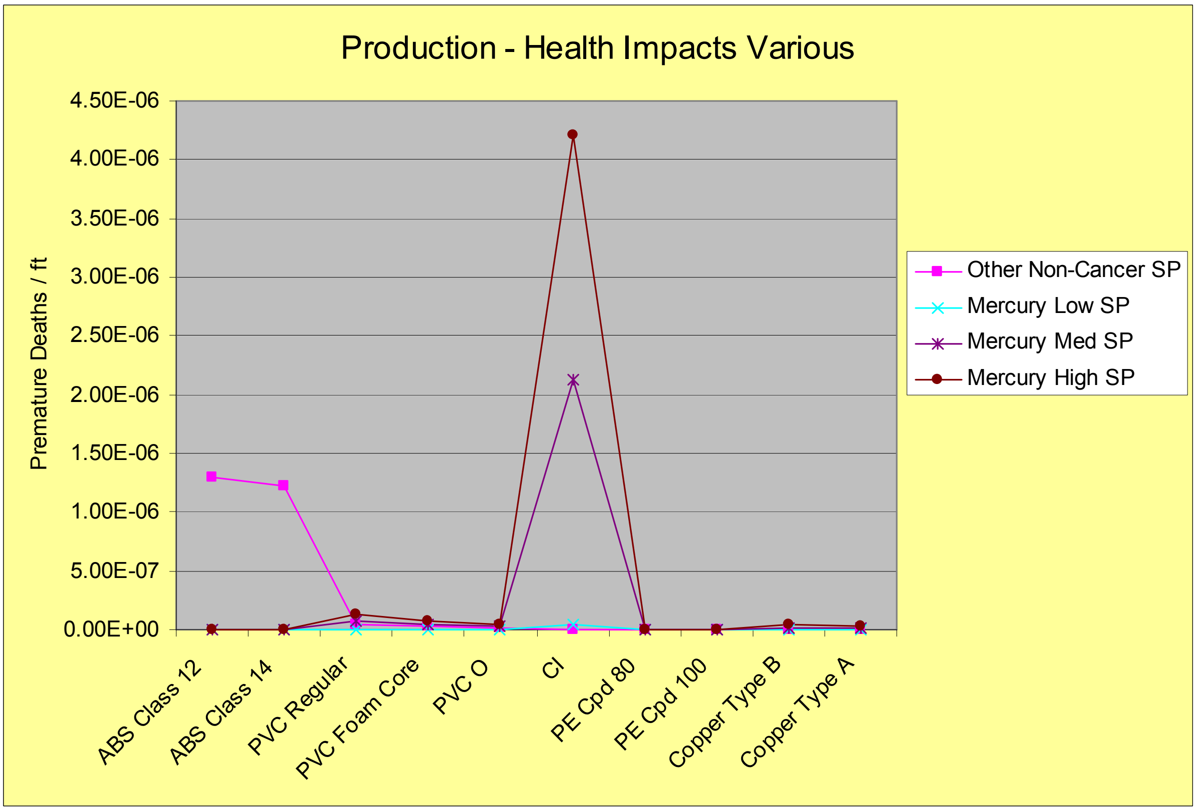


Figure 7 - Australian Pipe – Non-Cancer – Production – Linear Scale

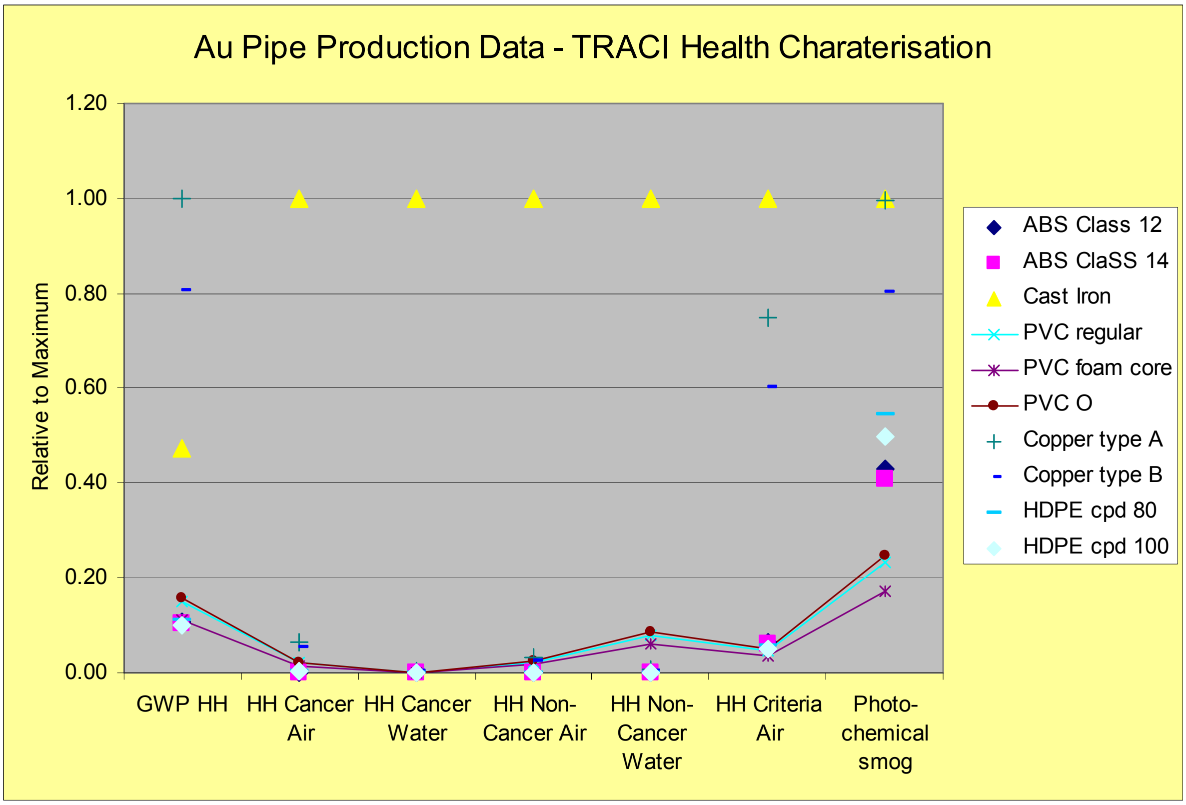


The linear presentation of this data emphasises appropriately the relative risk from Cast Iron pipe and ABS pipe and relative insignificance of the other health risks.

TRACI Health Characterisation

Using the US TRACI method to characterise health risks generates the results shown in Figure 8 for Australian pipe. These results confirm that across a broad range of health impacts, Australian cast iron and copper pipe have the largest health impacts and PVC pipe is amongst the best of the alternatives across all categories.

Figure 8 - TRACI Health Characterisation Auatralian Pipe



6. CONCLUSIONS

The TSAC work appears to have been conducted fairly thoroughly (Over 4,600 medical sources and over 2,000 other sources were assessed from stakeholders and literature internet survey, of which 2057 are included in the study and 2225 actively contribute to the results of the study). However, the detail available in the TSAC report and the quoted references were not always sufficient to fully replicate the TSAC results for Australia. Using the top down and bottom up approaches described, BRANZ have nonetheless been able to characterise the health impacts for Australian DWV pipe similarly to the TSAC work sufficient to verify or modify the conclusions appropriately for Australian DWV Pipe. In addition, some errors have been found in the data and graphs presented in the TSAC report, most particularly the end-of-life results for PVC pipe in Figure 4-14 appear to misrepresent the end-of-life impacts of PVC as far greater than they are.

6.1 TSAC Report Statements

In this assessment, all quotations from the TSAC report are colour coded – a Green highlight signifies a statement that is good for Australian vinyl pipe products, a Red highlight signifies statements that are bad or potentially bad for Australian vinyl pipe products and Yellow highlighted text signifies a qualification or data gap that may be significant, Purple text signifies a qualification that warrants specific attention. This form of presentation enables the positive statements to be seen, but not seen out of context of any qualifications or contradictory statements. Referring to specific statements and conclusions in the TSAC report we can conclude the following:

6.1.1 Key Positive Findings and Issues Identified

Referring to specific statements and conclusions in the TSAC report we can conclude the following:

Executive Summary - Pg 9 line 33-36
"**No single material shows up as the best across all the human health and environmental impact categories, nor the worst**."

Confirmed for Australia, but in the case of DWV pipe, cast iron is consistently worst against most environmental and health impacts and should probably be avoided for this application.

Pg 11 line 8-11
If buyers switched from PVC to aluminium window frames, to aluminium siding, or to cast iron pipe, it could be worse than using PVC." Data on end-of-life emissions are highly uncertain and therefore there is a wide range of exposure possibilities; if end-of-life emissions are close to the upper end of our range, then PVC is among the worst materials studied for health risk, but if end-of-life emissions are close to the lower end of our range of possible values , then PVC is among the mid or better materials studied for health risk in the product categories of window frames, pipe and siding. Policies to prohibit backyard burning and reduce landfill fires would improve the profile of PVC in piping, windows and siding as compared to the other alternatives considered."

Confirmed, except that all waste in Australia is recycled or goes to landfill. This result is particularly sensitive to the frequency and burn mass of landfill fires in Australia and on the proportions of PVC in the waste. The Australian PVC industry should work with State Government to optimise the recycling of PVC from the waste stream so that this valuable resource is not lost to productive use and does not contribute to the burn mass that may release dioxins and other toxicants. Other combustible materials in the waste (ABS and PE pipe) also contribute to the burn mass and release dioxins and other toxicants on combustion and metals in the waste can also contribute by catalysing the production of dioxins. In addition, the public need to be better informed about the emissions from landfill fires and the benefits of incineration with energy cogeneration and useful heat recovery to more productively use wastes and reduce dioxin and other persistent bio-accumulative toxicant emissions.

Pg 11 line 20-23
Environmental Impact The evidence indicates that a credit that rewards avoidance of PVC would steer decision makers toward using materials that are worse on most environmental impacts
Confirmed

6.1.2 Key Findings for Vinyl Pipe

"4.3 Pipe

4.3.1 Summary

Environmental Impacts: Cast iron pipe is generally the worst material relative to environmental impact categories amongst the alternatives studied

Confirmed for Australia

Human Health Impacts: PVC is worst for cancer related impacts amongst the alternatives studied whilst cast iron or PVC is worse for overall health impacts depending on the assumptions when both end-of-life and occupational exposures are included. For the cradle-through-use, cast iron is worst overall among the alternatives studied form a human health point of view."

Refuted for Australia – The bottom-up assessment shows that in Australia, Cast Iron and ABS pipe all have higher cancer related impacts than PVC pipe in production. When end-of life is taken into account, the Cast Iron and Copper remain the worst, but the ABS is better than PVC. Australian PE pipe has the lowest cancer impacts. Although the top down assessment doesn't confirm this, this assessment is limited in the range of factors that it takes into account and provides less relevant evidence for this conclusion. In addition, the TRACI characterisation supports the position that Cast Iron and Copper have higher cancer risks than the PVC pipes, but is less conclusive for ABS.

Pg 49
"The results show that cast iron is consistently the worst material among alternatives studied except for eutrophication, for which ABS is the worst when end-of-life emissions are considered."

Confirmed - Moreover, the thinner walled, foam cored or PVC pipes use substantially less PVC per foot of pipe than the US equivalents, further improving the overall environmental benefits of the Australian PVC pipe.

6.1.2.1 Human Health

Page 53
"*Human Health Impacts – Cradle through Use Plus End-of-Life and Occupational Effects*

Adding the impacts to health from exposures of workers in the production and installation of the products leads to the results shown in figure below. These are the most comprehensive human health results in terms of the scope of the life cycle model. The resulting conclusions are that for overall health impacts, cast iron is worse than PVC for the maximum and average cases. The determination of the worst material among alternatives studied is sensitive to the uncertainties about emission emissions factors in the life cycle and risk modelling of the studied systems. For cancer-related impacts, the maximum and average PVC models are clearly worse than other materials."

Confirmed for Australia that the overall health impacts for cast iron (and copper) pipe are worse than PVC, but in all scenarios for the Australian pipe, not just the maximum and average cases.
Refuted for Australia that the maximum and average PVC models are worse than other materials.

Pg 53

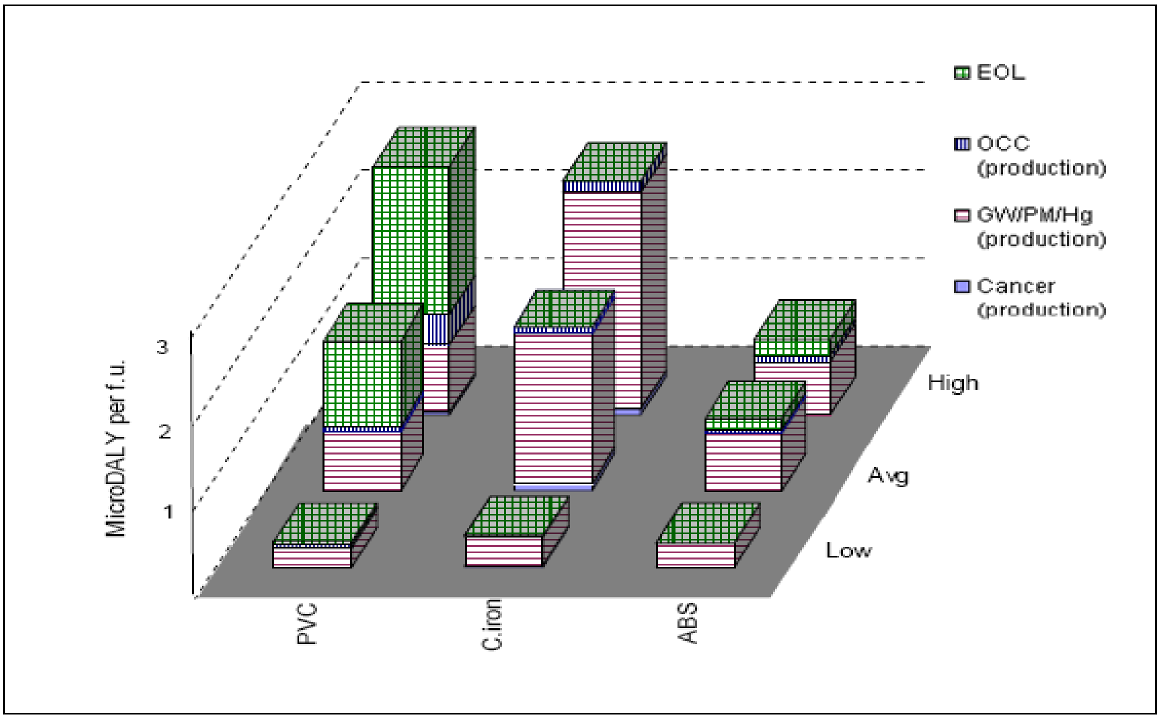


Figure 4-14: High, average and low estimates of human health impacts (microDALY per functional unit) by life cycle stage – Pipe

Refuted for Australia – this graph has inconsistent data with Graphs 4-12 and 4-13 for the end-of-life bars for the PVC pipe – the maximum height of the end-of-life (green and white checked) segment of this bar should be 0.8 DALYs for the High scenario. It seriously over-represents the impacts from end-of-life for PVC pipe.

6.1.3 Data Gaps and Uncertainty

Page 56

Cancer risks for PVC and cast iron pipe generally varied by one order of magnitude between high and low risk estimates. Risks for ABS pipe differed by two orders of magnitude. Risk estimates for both PVC and ABS pipe were driven by the manufacture of the resin. The same assumptions for exposure to thermal degradation products made for vinyl siding were made for PVC pipe. It was assumed that exposure to barium heat stabilizers would occur in the manufacture of PVC pipe; further, exposure to dialkyl tins was assumed, but there are no current dose-response data that could be used to estimate potential health risk from these tin compounds.

There is more certainty in the health risk results for PVC than for ABS

Pg 56

For PVC building materials, we find the manufacture of resin to be overwhelmingly the largest contributor. This is because vinyl chloride monomer (VCM) and ethylene dichloride (EDC), the compound used to make it, are both carcinogens. Further, exposure to both compounds is assumed in the manufacture of PVC resin, even though it is possible any one worker may be exposed to only one compound. While exposure data were available from the Vinyl Institute with regard to VCM, these data were not available for EDC; therefore exposures were assumed limited by the OSHA PEL (permissible exposure limit) for EDC.

The TSAC work assumes “worst case exposure” of workers to VCM and this assumption is replicated for Australian production. In addition, exposure to EDC is assumed at the maximum permissible OSHA limit (because there is no real exposure data).

The estimation of Dioxin emissions is also related to EDC on the basis of 2kg EDC per kg of PVC – which is 25% greater than would be expected from stoichiometry (unless this reaction only achieves 75% yield), so Dioxin emissions may be overestimated by up to 25%.

7. RECOMMENDATIONS

- That the PVC pipe industry commit to the recycling of UPVC waste from the waste stream and work with State governments to recover these wastes and mitigate any remaining concerns over UPVC related dioxin or other emissions from landfill fires.
- That this report be presented to DECC with a request to investigate landfill fire frequency and burn mass to confirm and improve these findings and with a commitment in place to recover UPVC waste from the waste stream reconsider PVC as a waste of concern.
- That this report be presented to the Green Building Council of Australia to seek a withdrawal or modification of the PVC minimization credit to permit the use of PVC DWV pipe.
- That this report be presented to the Sydney Olympic park Authority to seek a withdrawal or modification of the PVC minimization requirements in its development guidelines.
- That the pipe industry proceed with a full LCA of their products and establish an ecolabel standard for pipe systems – this report indicates that PVC pipe products are likely to be environmentally preferable.

8. REFERENCES

A comprehensive bibliography of TSAC sources relevant to PVC, ABS, Cast Iron and supplementary sources for PE, Copper and Fibre Cement has been compiled for this project and is available on request. Key references are listed here:

TSAC 2007, US Green Building Council, Technical Scientific Advisory Committee Task Group Report, Altshuler K, Horst S, Malin N, Norris G, Nishioka Y, USGBC, Washington DC.

TRACI Characterisation Factors – personal communication Jane Bare USEPA.
Bennet DH, Margni MD, McKone TE, Jolliet O (2002) Intake Fraction for multimedia pollutants: a tool for life cycle analysis and comparative risk assessment - Risk Anal 22:905-918

Office of Environmental Health Hazard Assessment**,** 2005, Air Toxics Hot Spots Program, Risk Assessment Guidelines, Part II, Technical Support Document for Describing Available Cancer Potency Factors

CEDI/ADI Table, CFSAN/Office of Food Additive Safety, September 2007, US Food and Drug Administration - **http://www.cfsan.fda.gov/~dms/opa-tedi.html**

EC (2004) Life Cycle Assessment of PVC and of principal competing materials. Final Report. PE Europe GmbH, IKP Universitat Stuttgart, IPU Danmarks Tekniska Hogskolan and Randa Group Spain for European Commission [ec.europa.eu/enterprise/chemicals/sustdev/pvc_en.htm] accessed May 2008

APPENDIX.A LCA DATA

1 LCA Data - TRACI Characterised

2 End of life factor for dioxin emissions to landfill

LCA Data - TRACI Characterised

Sima Pro Au Data				Global Warming Air (CO2-e / kg)	Acidification Air (H+ moles-e / kg)	AcidificationWater (H+ moles-e / kg)	HH Cancer Air (benzene-e / kg)	HH Cancer Water (benzene-e / kg)	HH Noncancer Air (toluene-e / kg)	HH Noncancer Water (toluene-e / kg)	HH Criteria Air (milli-DALYs / kg)	Eutrophication Air (N-e / kg)	Eutrophication Water (N-e / kg)	Ozone Depletion Air (CFC-11-e / kg)	Ecotoxcity Air (2,4-D-e / kg)	Ecotoxcity Water (2,4-D-e / kg)	Smog Air (g NOx / kg)	Surplus MJ (MJ / kg)
ABS	1 kg		AU Data	1.35E+00	1.76E+00	0.00E+00	1.00E-04	1.79E-08	1.81E-02	3.99E-06	3.96E-05	7.39E-04	1.03E-04	6.05E-06	4.18E-05	1.53E-06	2.11E-02	1.10E+00
Cast Iron	1 kg		AU Data	1.47E+00	7.65E-01	0.00E+00	2.13E-02	3.32E-03	6.50E+01	1.32E+00	1.52E-04	3.87E-04	4.18E-04	4.61E-13	5.46E-01	1.56E-02	1.23E-02	8.08E-01
PVC	1 kg		AU Data	2.20E+00	8.94E-01	0.00E+00	2.03E-03	1.11E-05	6.97E+00	4.96E-01	3.40E-05	4.68E-04	4.95E-05	8.19E-06	8.44E-02	5.06E-05	1.34E-02	1.74E+00
Copper	1 kg		AU Data	5.58E+00	2.28E+00	0.00E+00	2.48E-03	1.58E-05	3.68E+00	1.45E-02	2.03E-04	7.52E-04	3.14E-05	1.45E-15	9.10E-03	9.35E-05	2.18E-02	1.74E+00
Fibre Cement	1 kg		AU Data	7.62E-01	2.64E-01	0.00E+00	2.10E-04	1.39E-06	3.18E-01	2.39E-02	2.74E-05	1.19E-04	2.06E-05	1.04E-16	1.03E-03	3.15E-05	3.94E-03	3.47E-01
HDPE	1 kg		AU Data	2.39E+00	7.69E-01	0.00E+00	5.36E-04	5.79E-06	7.57E-01	3.65E-03	5.85E-05	4.73E-04	2.73E-06	2.87E-16	2.19E-03	2.27E-04	4.62E-02	4.78E+00
TSAC	**US Mass**	**US Life**	**Over**	**50**	**Years**													
ABS	1.41 kg	50 Yrs	AU Data	1.91E+00	2.49E+00	0.00E+00	1.42E-04	2.53E-08	2.56E-02	5.63E-06	5.60E-05	1.05E-03	1.46E-04	8.55E-06	5.90E-05	2.17E-06	2.98E-02	1.56E+00
Cast Iron	5.4 kg	50 Yrs	AU Data	7.96E+00	4.13E+00	0.00E+00	1.15E-01	1.79E-02	3.51E+02	7.15E+00	8.23E-04	2.09E-03	2.26E-03	2.49E-12	2.95E+00	8.42E-02	6.65E-02	4.36E+00
PVC	1.45 kg	50 Yrs	AU Data	3.18E+00	1.30E+00	0.00E+00	2.94E-03	1.61E-05	1.01E+01	7.19E-01	4.93E-05	6.79E-04	7.17E-05	1.19E-05	1.22E-01	7.33E-05	1.95E-02	2.52E+00

TSAC Production	**Au Quantities**			Global Warming Air (CO2-e / kg)	Acidification Air (H+ moles-e / kg)	AcidificationWater (H+ moles-e / kg)	HH Cancer Air (benzene-e / kg)	HH Cancer Water (benzene-e / kg)	HH Noncancer Air (toluene-e / kg)	HH Noncancer Water (toluene-e / kg)	HH Criteria Air (milli-DALYs / kg)	Eutrophication Air (N-e / kg)	Eutrophication Water (N-e / kg)	Ozone Depletion Air (CFC-11-e / kg)	Ecotoxcity Air (2,4-D-e / kg)	Ecotoxcity Water (2,4-D-e / kg)	Smog Air (g NOx / m / kg)	Surplus MJ (MJ / m / kg)
ABS		**Au Life**	**Over**	**50**	**Years**													
Class 12	1.9 kg	50 Yrs	AU Data	2.57E+00	3.35E+00	0.00E+00	1.91E-04	3.40E-08	3.44E-02	7.57E-06	7.52E-05	1.40E-03	1.96E-04	1.15E-05	7.93E-05	2.91E-06	4.00E-02	2.09E+00
Class 14	1.8 kg	50 Yrs	AU Data	2.43E+00	3.17E+00	0.00E+00	1.80E-04	3.22E-08	3.26E-02	7.17E-06	7.12E-05	1.33E-03	1.86E-04	1.09E-05	7.52E-05	2.76E-06	3.79E-02	1.98E+00
Cast Iron	7.55 kg	50 Yrs	AU Data	1.11E+01	5.78E+00	0.00E+00	1.60E-01	2.51E-02	4.91E+02	9.99E+00	1.15E-03	2.92E-03	3.16E-03	3.48E-12	4.12E+00	1.18E-01	9.29E-02	6.10E+00
PVC																		
Regular	1.6 kg	50 Yrs	AU Data	3.51E+00	1.43E+00	0.00E+00	3.25E-03	1.78E-05	1.12E+01	7.93E-01	5.44E-05	7.50E-04	7.91E-05	1.31E-05	1.35E-01	8.09E-05	2.15E-02	2.78E+00
Foamed Core	1.2 kg	50 Yrs	AU Data	2.63E+00	1.07E+00	0.00E+00	2.43E-03	1.33E-05	8.37E+00	5.95E-01	4.08E-05	5.62E-04	5.94E-05	9.83E-06	1.01E-01	6.07E-05	1.61E-02	2.09E+00
PVC O	1.7 kg	50 Yrs	AU Data	3.73E+00	1.52E+00	0.00E+00	3.45E-03	1.89E-05	1.19E+01	8.43E-01	5.79E-05	7.96E-04	8.41E-05	1.39E-05	1.44E-01	8.60E-05	2.28E-02	2.96E+00
Copper																		
Type A	4.23 kg	50 Yrs	AU Data	2.36E+01	9.66E+00	0.00E+00	1.05E-02	6.70E-05	1.56E+01	6.15E-02	8.60E-04	3.18E-03	1.33E-04	6.16E-15	3.85E-02	3.96E-04	9.24E-02	7.35E+00
Type B	3.42 kg	50 Yrs	AU Data	1.91E+01	7.79E+00	0.00E+00	8.46E-03	5.40E-05	1.26E+01	4.96E-02	6.94E-04	2.57E-03	1.07E-04	4.97E-15	3.11E-02	3.19E-04	7.46E-02	5.93E+00
Fibre Cement	N/A kg	50 Yrs	AU Data	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HDPE																		
Compond 80 av	1.09 kg	50 Yrs	AU Data	2.62E+00	8.41E-01	0.00E+00	5.87E-04	6.34E-06	8.28E-01	4.00E-03	6.40E-05	5.17E-04	2.98E-06	3.14E-16	2.40E-03	2.49E-04	5.05E-02	5.23E+00
Compound 100 av	1.00 kg	50 Yrs	AU Data	2.39E+00	7.69E-01	0.00E+00	5.36E-04	5.79E-06	7.57E-01	3.65E-03	5.85E-05	4.73E-04	2.73E-06	2.87E-16	2.19E-03	2.27E-04	4.62E-02	4.78E+00
Maximum				2.36E+01	9.66E+00	0.00E+00	1.60E-01	2.51E-02	4.91E+02	9.99E+00	1.15E-03	3.18E-03	3.16E-03	1.39E-05	4.12E+00	1.18E-01	9.29E-02	7.35E+00

End of life factor for dioxin emissions to landfill

AU	32.4 M t/yr	32.4 M t/yr	landfill	42%	constr & dem	% Wt dwv in C&D					
US	230 M t/yr	131 M t/yr	landfill			23.37 M t/yr	Plastics	1.39 M t/yr of PVC		0%	recovered

US	Waste Arising	Waste Arising Mt	Waste Arising %	Waste to Landfill	Waste Incinerated	Waste back-yard burned	Landfill Fires Dioxin g TEQ/kg of waste Low	Landfill Fires Dioxin g TEQ/kg of waste Med	Landfill Fires Dioxin g TEQ/kg of waste High	Incinerated Waste Dioxin g TEQ/kg of waste Low	Incinerated Waste Dioxin g TEQ/kg of waste Med	Incinerated Waste Dioxin g TEQ/kg of waste High	Back Yard Burned Dioxin g TEQ/kg of waste Low	Back Yard Burned Dioxin g TEQ/kg of waste Med	Back Yard Burned Dioxin g TEQ/kg of waste High	Weighted Average Dioxin g TEQ/kg of waste Low	Weighted Average Dioxin g TEQ/kg of waste Med	Weighted Average Dioxin g TEQ/kg of waste High
M t/yr	230			182.16	47.38	0.46												
%				79.20%	20.60%	0.20%												
ABS		21.98					2.00E-11	3.74E-10	1.97E-10	0.00E+00	2.28E-10	1.24E-10	2.00E-11	3.74E-10	1.97E-10	1.59E-11	3.44E-10	1.82E-10
PE							2.00E-11	3.74E-10	1.97E-10	0.00E+00	2.28E-10	1.24E-10	2.00E-11	3.74E-10	1.97E-10	1.59E-11	3.44E-10	1.82E-10
PVC		1.39					1.21E-07	2.26E-06	1.19E-06	0.00E+00	2.58E-07	1.53E-07	1.21E-07	2.26E-06	1.19E-06	9.61E-08	1.85E-06	9.76E-07
Cast Iron							4.31E-11	8.07E-10	4.25E-10	0.00E+00	0.00E+00	0.00E+00	4.31E-11	8.07E-10	4.25E-10	3.42E-11	6.41E-10	3.37E-10
Copper							4.31E-11	8.07E-10	4.25E-10	0.00E+00	0.00E+00	0.00E+00	4.31E-11	8.07E-10	4.25E-10	3.42E-11	6.41E-10	3.37E-10
Fiber Cement							2.60E-11	5.00E-10	2.63E-10	0.00E+00	0.00E+00	0.00E+00	2.60E-11	5.00E-10	2.63E-10	2.06E-11	3.97E-10	2.09E-10

AU	Waste Arising	Waste Arising Mt	Waste Arising %	Waste to Landfill	Waste Incinerated	Waste back-yard burned	Landfill Fires Dioxin g TEQ/kg of waste Low	Landfill Fires Dioxin g TEQ/kg of waste Med	Landfill Fires Dioxin g TEQ/kg of waste High	Incinerated Waste Dioxin g TEQ/kg of waste Low	Incinerated Waste Dioxin g TEQ/kg of waste Med	Incinerated Waste Dioxin g TEQ/kg of waste High	Back Yard Burned Dioxin g TEQ/kg of waste Low	Back Yard Burned Dioxin g TEQ/kg of waste Med	Back Yard Burned Dioxin g TEQ/kg of waste High	Weighted Average Dioxin g TEQ/kg of waste Low	Weighted Average Dioxin g TEQ/kg of waste Med	Weighted Average Dioxin g TEQ/kg of waste High	Factor Au/US Low	Factor Au/US Med	Factor Au/US High
M t/yr	32.4			32.4	0	0															
%				100.00%	0.00%	0.00%															
ABS		3.096313					2.00E-11	3.74E-10	1.97E-10	0.00E+00	2.28E-10	1.24E-10	2.00E-11	3.74E-10	1.97E-10	2.00E-11	3.74E-10	1.97E-10	1.26	1.09	1.08
PE							2.00E-11	3.74E-10	1.97E-10	0.00E+00	2.28E-10	1.24E-10	2.00E-11	3.74E-10	1.97E-10	2.00E-11	3.74E-10	1.97E-10	1.26	1.09	1.08
PVC		0.195809					1.21E-07	2.26E-06	1.19E-06	0.00E+00	2.58E-07	1.53E-07	1.21E-07	2.26E-06	1.19E-06	1.21E-07	2.26E-06	1.19E-06	1.26	1.22	1.22
Cast Iron							4.31E-11	8.07E-10	4.25E-10	0.00E+00	0.00E+00	0.00E+00	4.31E-11	8.07E-10	4.25E-10	4.31E-11	8.07E-10	4.25E-10	1.26	1.26	1.26
Copper							4.31E-11	8.07E-10	4.25E-10	0.00E+00	0.00E+00	0.00E+00	4.31E-11	8.07E-10	4.25E-10	4.31E-11	8.07E-10	4.25E-10	1.26	1.26	1.26
Fiber Cement							2.60E-11	5.00E-10	2.63E-10	0.00E+00	0.00E+00	0.00E+00	2.60E-11	5.00E-10	2.63E-10	2.60E-11	5.00E-10	2.63E-10	1.26	1.26	1.26

APPENDIX.B HEALTH RISK ASSESSMENT

Sima Pro Au TRACI Human Health Characterised

Top Down Assessment

Bottom Up Assessment

Sima Pro Au TRACI Human Health Characterised
Top Down Assessment

Hazard Index Totals for Australian Product			Cancer Stockholm Only	Cancer	Particulates	Global Warming	Mercury High	Mercury Low	total
Cradle through use excluding Occupational and EOL									
PVC Regular		1.60 kg/m							
PVC Regular	High		0.04449	0.04449	0.44489	0.40782	0.04449	0.00044	0.94213
PVC Regular	Average		0.000148	0.001483	0.296593	0.407816	0.037074	0.000297	0.743263
PVC Regular	Low		0.000067	0.000667	0.148297	0.444890	0.001483	0.000015	0.595352
PVC Foamed Core		1.20 kg/m							
PVC Foamed Core	High		0.033367	0.033367	0.333668	0.305862	0.033367	0.000334	0.706597
PVC Foamed Core	Average		0.000111	0.001112	0.222445	0.305862	0.027806	0.000222	0.557447
PVC Foamed Core	Low		0.000050	0.000501	0.111223	0.333668	0.001112	0.000011	0.446514
PVC O		1.70 kg/m							
PVC O	High		0.047270	0.047270	0.472696	0.433304	0.047270	0.000473	1.001012
PVC O	Average		0.000158	0.001576	0.315131	0.433304	0.039391	0.000315	0.789717
PVC O	Low		0.000071	0.000709	0.157565	0.472696	0.001576	0.000016	0.632562
ABS Class 12		1.90 kg/m							
ABS Class 12	High		0.000121	0.002016	0.403182	0.739166	0.026879	0.000269	1.171512
ABS Class 12	Average		0.000121	0.002016	0.403182	0.739166	0.026879	0.000269	1.171512
ABS Class 12	Low		0.000121	0.002016	0.403182	0.739166	0.026879	0.000269	1.171512
ABS Class 14		1.80 kg/m							
ABS Class 14	High		0.000115	0.001910	0.381962	0.700263	0.025464	0.000255	1.109853
ABS Class 14	Average		0.000115	0.001910	0.381962	0.700263	0.025464	0.000255	1.109853
ABS Class 14	Low		0.000115	0.001910	0.381962	0.700263	0.025464	0.000255	1.109853
Cast Iron		7.55 kg/m							
Cast Iron	High		0.065760	0.089246	1.080344	1.061556	0.093943	0.000939	2.326029
Cast Iron	Average		0.056366	0.084549	0.892458	0.892458	0.093943	0.000939	1.964348
Cast Iron	Low		0.037577	0.079852	0.657601	0.751544	0.093943	0.000939	1.583879
PE compond 80		1.09 kg/m							
PE compond 80	High		0.000070	0.001161	0.232184	0.425670	0.015479	0.000155	0.674649
PE compond 80	Average		0.000070	0.001161	0.232184	0.425670	0.015479	0.000155	0.674649
PE compond 80	Low		0.000070	0.001161	0.232184	0.425670	0.015479	0.000155	0.674649
PE compound 100		1.00 kg/m							
PE compound 100	High		0.000070	0.001161	0.232184	0.425670	0.015479	0.000155	0.674649
PE compound 100	Average		0.000070	0.001161	0.232184	0.425670	0.015479	0.000155	0.674649
PE compound 100	Low		0.000070	0.001161	0.232184	0.425670	0.015479	0.000155	0.674649
Copper Type A		4.23 kg/m							
Copper Type A	High		0.036861	0.050025	0.605571	0.595039	0.052658	0.000527	1.303821
Copper Type A	Average		0.031595	0.047393	0.500254	0.500254	0.052658	0.000527	1.101086
Copper Type A	Low		0.021063	0.044760	0.368608	0.421267	0.052658	0.000527	0.887820
Copper Type B		3.42 kg/m							
Copper Type B	High		0.036861	0.050025	0.605571	0.595039	0.052658	0.000527	1.303821
Copper Type B	Average		0.031595	0.047393	0.500254	0.500254	0.052658	0.000527	1.101086
Copper Type B	Low		0.021063	0.044760	0.368608	0.421267	0.052658	0.000527	0.887820
Fibre Cement		N/A kg/m							
Fibre Cement	High		-	-	-	-	-	-	-
Fibre Cement	Average		-	-	-	-	-	-	-
Fibre Cement	Low		-	-	-	-	-	-	-

Top Down Assessment

Hazard Index Totals for Australian Product		Cancer Stockholm Only	Cancer	Particulates	Global Warming	Mercury High	Mercury Low	total
Cradle through use plue EOL excluding Occupational								
PVC Regular	1.60 kg/m							
PVC Regular	High	1.186374	1.186374	0.444890	0.407816	0.148297	0.000445	2.187822
PVC Regular	Average	0.593187	0.593187	0.296593	0.407816	0.074148	0.000297	1.372041
PVC Regular	Low	0.074148	0.074148	0.148297	0.444890	0.001483	0.000015	0.668833
PVC Foamed Core	1.20 kg/m							
PVC Foamed Core	High	0.889780	0.889780	0.333668	0.305862	0.111223	0.000334	1.640866
PVC Foamed Core	Average	0.444890	0.444890	0.222445	0.305862	0.055611	0.000222	1.029031
PVC Foamed Core	Low	0.055611	0.055611	0.111223	0.333668	0.001112	0.000011	0.501625
PVC O	1.70 kg/m							
PVC O	High	1.260522	1.260522	0.472696	0.433304	0.157565	0.000473	2.324560
PVC O	Average	0.630261	0.630261	0.315131	0.433304	0.078783	0.000315	1.457794
PVC O	Low	0.078783	0.078783	0.157565	0.472696	0.001576	0.000016	0.710635
ABS Class 12	1.90 kg/m							
ABS Class 12	High	0.000121	0.268788	0.537576	0.739166	0.134394	0.000269	1.680193
ABS Class 12	Average	0.000121	0.134394	0.403182	0.739166	0.134394	0.000269	1.411405
ABS Class 12	Low	0.000121	0.002016	0.403182	0.739166	0.134394	0.000269	1.279027
ABS Class 14	1.80 kg/m							
ABS Class 14	High	0.000115	0.254641	0.509282	0.700263	0.127321	0.000255	1.591761
ABS Class 14	Average	0.000115	0.127321	0.381962	0.700263	0.127321	0.000255	1.337120
ABS Class 14	Low	0.000115	0.001910	0.381962	0.700263	0.127321	0.000255	1.211710
Cast Iron	7.55 kg/m							
Cast Iron	High	0.065760	0.089246	1.221259	1.127316	0.187886	0.093943	2.719650
Cast Iron	Average	0.056366	0.084549	0.939430	0.920641	0.187886	0.093943	2.226449
Cast Iron	Low	0.037577	0.079852	0.657601	0.751544	0.187886	0.093943	1.770826
PE compond 80	1.09 kg/m							
PE compond 80	High	0.000070	0.154789	0.309578	0.425670	0.077395	0.000155	0.967587
PE compond 80	Average	0.000070	0.077395	0.232184	0.425670	0.077395	0.000155	0.812798
PE compond 80	Low	0.000070	0.001161	0.232184	0.425670	0.077395	0.000155	0.736564
PE compound 100	1.00 kg/m							
PE compound 100	High	0.000070	0.154789	0.309578	0.425670	0.077395	0.000155	0.967587
PE compound 100	Average	0.000070	0.077395	0.232184	0.425670	0.077395	0.000155	0.812798
PE compound 100	Low	0.000070	0.001161	0.232184	0.425670	0.077395	0.000155	0.736564
Copper Type A	4.23 kg/m							
Copper Type A	High	0.036861	0.050025	0.684559	0.631900	0.105317	0.052658	1.524459
Copper Type A	Average	0.031595	0.047393	0.526584	0.516052	0.105317	0.052658	1.248003
Copper Type A	Low	0.021063	0.044760	0.368608	0.421267	0.105317	0.052658	0.992610
Copper Type B	3.42 kg/m							
Copper Type B	High	0.036861	0.050025	0.684559	0.631900	0.105317	0.052658	1.524459
Copper Type B	Average	0.031595	0.047393	0.526584	0.516052	0.105317	0.052658	1.248003
Copper Type B	Low	0.021063	0.044760	0.368608	0.421267	0.105317	0.052658	0.992610
Fibre Cement	N/A kg/m							
Fibre Cement	High	-	-	-	-	-	-	-
Fibre Cement	Average	-	-	-	-	-	-	-
Fibre Cement	Low	-	-	-	-	-	-	-

Top Down Assessment

Hazard Index Totals for Australian Product			Cancer Stockholm Only	Cancer	Particulates	Global Warming	Mercury High	Mercury Low	total
Cradle through use plus EOL plus Occupational									
PVC Regular		1.60 kg/m							
PVC Regular	High		1.186374	1.408819	0.444890	0.407816	0.148297	0.000445	2.410267
PVC Regular	Average		0.593187	0.667335	0.296593	0.407816	0.074148	0.000297	1.446190
PVC Regular	Low		0.074148	0.148297	0.148297	0.444890	0.001483	0.000015	0.742981
PVC Foamed Core		1.20 kg/m							
PVC Foamed Core	High		0.889780	1.056614	0.333668	0.305862	0.111223	0.000334	1.807700
PVC Foamed Core	Average		0.444890	0.500501	0.222445	0.305862	0.055611	0.000222	1.084642
PVC Foamed Core	Low		0.055611	0.111223	0.111223	0.333668	0.001112	0.000011	0.557236
PVC O		1.70 kg/m							
PVC O	High		1.260522	1.496870	0.472696	0.433304	0.157565	0.000473	2.560908
PVC O	Average		0.630261	0.709044	0.315131	0.433304	0.078783	0.000315	1.536576
PVC O	Low		0.078783	0.157565	0.157565	0.472696	0.001576	0.000016	0.789418
ABS Class 12		1.90 kg/m							
ABS Class 12	High		0.000121	0.268788	0.537576	0.739166	0.134394	0.000269	1.680193
ABS Class 12	Average		0.000121	0.134394	0.403182	0.739166	0.134394	0.000269	1.411405
ABS Class 12	Low		0.000121	0.002016	0.403182	0.739166	0.134394	0.000269	1.279027
ABS Class 14		1.80 kg/m							
ABS Class 14	High		0.000115	0.254641	0.509282	0.700263	0.127321	0.000255	1.591761
ABS Class 14	Average		0.000115	0.127321	0.381962	0.700263	0.127321	0.000255	1.337120
ABS Class 14	Low		0.000115	0.001910	0.381962	0.700263	0.127321	0.000255	1.211710
Cast Iron		7.55 kg/m							
Cast Iron	High		0.065760	0.089246	1.221259	1.127316	0.187886	0.093943	2.719650
Cast Iron	Average		0.056366	0.084549	0.939430	0.920641	0.187886	0.093943	2.226449
Cast Iron	Low		0.037577	0.079852	0.657601	0.751544	0.187886	0.093943	1.770826
PE compond 80		1.09 kg/m							
PE compond 80	High		0.000070	0.154789	0.309578	0.425670	0.077395	0.000155	0.967587
PE compond 80	Average		0.000070	0.077395	0.232184	0.425670	0.077395	0.000155	0.812798
PE compond 80	Low		0.000070	0.001161	0.232184	0.425670	0.077395	0.000155	0.736564
PE compound 100		1.00 kg/m							
PE compound 100	High		0.000070	0.154789	0.309578	0.425670	0.077395	0.000155	0.967587
PE compound 100	Average		0.000070	0.077395	0.232184	0.425670	0.077395	0.000155	0.812798
PE compound 100	Low		0.000070	0.001161	0.232184	0.425670	0.077395	0.000155	0.736564
Copper Type A		4.23 kg/m							
Copper Type A	High		0.036861	0.050025	0.684559	0.631900	0.105317	0.052658	1.524459
Copper Type A	Average		0.031595	0.047393	0.526584	0.516052	0.105317	0.052658	1.248003
Copper Type A	Low		0.021063	0.044760	0.368608	0.421267	0.105317	0.052658	0.992610
Copper Type B		3.42 kg/m							
Copper Type B	High		0.036861	0.050025	0.684559	0.631900	0.105317	0.052658	1.524459
Copper Type B	Average		0.031595	0.047393	0.526584	0.516052	0.105317	0.052658	1.248003
Copper Type B	Low		0.021063	0.044760	0.368608	0.421267	0.105317	0.052658	0.992610
Fibre Cement		N/A kg/m							
Fibre Cement	High		-	-	-	-	-	-	-
Fibre Cement	Average		-	-	-	-	-	-	-
Fibre Cement	Low		-	-	-	-	-	-	-

Bottom Up Assessment

		ABS Class 12	ABS Class 14	PVC Regular	PVC Foamed Core	PVC PVC O	CI	PE Cpd 80	PE Cpd 100	Copper Type A	Copper Type B
		DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft
	kg/m	1.9	1.8					1.09	1.00		
Production Phase		DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft
Cancer											
	TSAC Low	1.21E-04	1.15E-04	3.55E-02	2.66E-02	3.77E-02	6.03E-01	6.97E-05	6.37E-05	0.00E+00	0.00E+00
	TSAC High	1.21E-04	1.15E-04	5.25E+00	3.94E+00	5.58E+00	7.68E+00	6.97E-05	6.37E-05	0.00E+00	0.00E+00
	Au Sima Pro	6.66E+00	6.31E+00	3.16E-01	2.37E-01	3.36E-01	2.47E+00	6.65E-04	6.08E-04	1.37E-02	1.11E-02
	Au Sima Pro	6.66E+00	6.31E+00	3.16E-01	2.37E-01	3.36E-01	2.47E+00	6.65E-04	6.08E-04	1.37E-02	1.11E-02
	Au Sima Pro	6.66E+00	6.31E+00	3.16E-01	2.37E-01	3.36E-01	2.47E+00	6.65E-04	6.08E-04	1.37E-02	1.11E-02
Disposal Phase		DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft
Cancer											
	TSAC Low	2.97E-03	2.81E-03	1.32E+01	9.90E+00	1.40E+01	2.22E-02	1.71E-03	1.56E-03	1.24E-02	1.00E-02
	TSAC High	5.73E-02	5.43E-02	2.46E+02	1.85E+02	2.62E+02	4.15E-01	3.30E-02	3.02E-02	2.33E-01	1.88E-01
	Au Low	3.80E-02	3.60E-02	1.64E+02	1.23E+02	1.74E+02	7.72E+02	2.19E-02	2.00E-02	4.33E+02	3.49E+02
	Au Mid	3.28E-02	3.11E-02	1.41E+02	1.06E+02	1.50E+02	7.50E+02	2.19E-02	2.00E-02	4.33E+02	3.49E+02
	Au High	3.26E-02	3.09E-02	1.41E+02	1.05E+02	1.49E+02	7.47E+02	2.19E-02	2.00E-02	4.33E+02	3.49E+02
Production plus EOL											
Cancer											
	TSAC Low	3.09E-03	2.93E-03	1.32E+01	9.92E+00	1.41E+01	6.26E-01	1.78E-03	1.63E-03	1.24E-02	1.00E-02
	TSAC High	5.74E-02	5.44E-02	2.52E+02	1.89E+02	2.67E+02	8.10E+00	3.31E-02	3.02E-02	2.33E-01	1.88E-01
	Au Low	6.70E+00	6.35E+00	1.64E+02	1.23E+02	1.74E+02	7.74E+02	2.25E-02	2.06E-02	4.33E+02	3.49E+02
	Au Mid	6.69E+00	6.34E+00	1.42E+02	1.06E+02	1.50E+02	7.52E+02	2.25E-02	2.06E-02	4.33E+02	3.49E+02
	Au High	6.69E+00	6.34E+00	1.41E+02	1.06E+02	1.50E+02	7.50E+02	2.25E-02	2.06E-02	4.33E+02	3.49E+02
Emission Factors Production Phase		Deaths / ft	Deaths / ft	Deaths / ft	Deaths / ft	Deaths / ft	Deaths / ft	Deaths / ft	Deaths / ft	Deaths / ft	Deaths / ft
Non-Cancer											
	Au Sima Pro High	1.29E-06	1.22E-06	5.43E-08	4.07E-08	5.77E-08	1.02E-09	3.23E-10	2.95E-10	4.42E-10	3.57E-10
Emission Factors Disposal Phase											
Non-Cancer		Could not locate the required data									
Emission Factors Production Phase		DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft	DALYs / ft
PM 2.5	**Au Sima Pro**	3.39E+00	3.21E+00	1.68E+00	1.26E+00	1.78E+00	4.88E+02	1.27E+00	1.16E+00	2.00E+00	1.61E+00
Mercury											
Low	**Au Sima Pro**	4.98E-13	4.71E-13	1.36E-09	1.02E-09	1.45E-09	3.86E-08	2.20E-11	2.01E-11	3.54E-10	2.86E-10
Middle	**Au Sima Pro**	2.74E-11	2.59E-11	7.49E-08	5.62E-08	7.96E-08	2.13E-06	1.21E-09	1.11E-09	1.95E-08	1.57E-08
High	**Au Sima Pro**	5.43E-11	5.14E-11	1.48E-07	1.11E-07	1.58E-07	4.21E-06	2.40E-09	2.19E-09	3.87E-08	3.12E-08