Possible Environmental Impacts of Recycled Glass Used as a Pavement Base Material

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ABSTRACT

In theory, glass diverted or recovered from the MSW stream can be used as feedstock (glass cullet) in the production of new glass containers. However, post-consumer glass typically contains a mixture of clear and coloured material and is often contaminated with other wastes, characteristics that are impediments to the production of new containers. Also, sorting and cleaning of glass diverted from MSW to make it feasible for use in bottle industries are time consuming and costly tasks. There is, however, the potential to use recycled glass as a sub-base material for road pavement construction. Geotechnical investigations to date suggest that use of recycled glass as a roadway sub-base could be cost-effective, and thus preclude the need for expensive sorting. There is, however, the necessity to further investigate the potential short- and long-term toxicity, health hazards, and/or environmental pollution associated with use of mixed glass cullet as an aggregate, considering conditions during stockpiled storage and after placement. This paper presents the results of laboratory tests on recycled glass regarding its
potential to release pollutants to the environment via leaching. Five random samples of crushed glasses were collected from a recycling company in Melbourne, Australia. The parameters tested for each sample are total organic matter, heavy metals, sulphates, chlorides, conductivity, pH and surfactant levels. It is found that in most cases, the contamination levels were within the State of Victoria’s EPA-specified limits for manual handling, thus indicating that recycled glass likely could be safely used in pavement sub-bases.

**Keywords:** Recycled glass, pavement base material, leaching, heavy metals, total organics and surfactant

**INTRODUCTION**

Recycled coloured glass typically is recovered from municipal solid waste at recycling facilities. This material consists of broken glass bottles and other containers of clear and coloured glass which is normally too costly to sort by colour. (Only clear glass cullet can be used to produce new clear glass containers so cullet with a mixture of colours has a relatively low market value. In fact, when market prices fall too low for a prolonged period of time it’s not uncommon for glass that a city has diverted from the waste stream for subsequent recycling is instead sent to a landfill because storage space is limited or costly.) Consequently, alternative uses of post-consumer glass are being sought. In some countries, crushed recycled glass from recycling industries is being used as a substitute for soil and/or an aggregate in the construction industry (Disfani et al., 2012). Typical uses are as a drainage layer and daily cover material in landfills.
(Reindl, 2003; Tsai et al., 2009). However, municipalities and the recycling industries are interested in finding broader, higher quality and more cost effective beneficial uses of mixed cullet. One of the additional potential uses is as construction aggregate (CWC, 1998; Wartman et al., 2004; Tsai et al., 2009). In various construction projects, the use of mixed recycled glass (glass cullet) requires a sufficient volume of cullet to be stored on-site. In many occasions cullet is stockpiled without any cover for from several months to years, which may lead to release of contaminated leachate (Tsai et al., 2009). That is, if incident precipitation and/or uncontrolled stormwater is allowed to percolate into the stockpiled cullet, the resulting leachate could become contaminated with chemicals present on the surface of the glass; unless collected and treated, this leachate has the potential to pollute local ground and surface water.

There have been some studies of the leaching of heavy metals from recycled glass (CWC, 1996 and Wartman et al., 2004). Testing conducted by Clean Washington Center (CWC, 1996) reported a higher level of lead concentration (>5mg/L) in one out of 50 samples when tested per the Toxic Characteristic Leaching Procedure (TCLP). Wartman et al. (2004) investigated leaching of heavy metals from recycled glass under landfill and soil conditions. They reported trace amounts of lead, chromium, barium and mercury under landfill conditions in very few samples. Although the exact source of these heavy metals was unknown, it was surmised that colouring ingredients in some commercial glassware, thermometer glass materials, printing pigments in labels, and bottle capping material were likely sources. Disfani et al. (2011b) classified recycled crushed glass into three categories: fine recycled glass (<4.75mm), medium recycled glass (<9.5mm) and coarse recycled glass (<19mm). They have presented detailed
geotechnical properties as well as some chemical properties of those different sized recycled glasses.

Crushed recycled glass has the potential to be used as filler in applications such as cement and concrete manufacture or aggregates in road construction. It may also be mixed with virgin materials in the manufacture of whole glass products. However, use of such recycled glass may cause concern, if these materials are not washed properly and contain chemical and/or biological contaminants. There are potential risks of safety of the workers involved in the manufacture/construction of anything involving contaminated recycled glass. Moreover, there are risks of leaching of contaminants from the construction site and to the integrity of the final product itself should the contaminants act as a spoilage agent. To avoid any potential occupational health and safety concern for the workers involved with using recycled glass and to overcome any risk of contaminants leaching to the surrounding environment, it is necessary to thoroughly test the recycled glass, before its use as an aggregate in pavement sub-bases or other engineering applications.

Leachable chemicals from recycled glass stems mainly from contamination on the surface of glass particles rather than dissolution of chemicals entrained in the glass itself. Heavy metals may be inherently part of the glass crystal structure (when present as impurities or additives), but these normally remain permanently locked within the solid glass phase even after substantial mechanical processing and size reduction. Thus, these entrained chemicals are not considered
threats to public or environmental health. However, it is possible that glass materials can come into contact with water and in particular acidic water, both of which are likely to extract surface and soluble impurities from the crushed glass diverted via recycling programs.

Measurement of the sulphate content enables the foundation conditions to be classified according to potential sulphate attack. Appropriate precautionary measures, such as the use of sulphate-resisting cement of a richer, denser concrete mix, can be taken during construction.

The classic way of measuring sulphate is to add a soluble barium salt (e.g., barium chloride or barium nitrate) in excess in the solution (water, acid or base) containing sulphate with slight dilute hydrochloric acid. This will form white dense barium sulphate precipitate, which is then filtered, dried and weighed. Following the above mentioned procedure, sulphate concentration was determined gravimetrically by heating an acidified sample to boiling point (driving out CO₂) and precipitating with 2M BaCl₂. The weight proportions of sulphate in the samples were found to be:

Water Wash: 290 mg kg⁻¹

Acid Wash: 110 mg kg⁻¹

Base Wash: 420 mg kg⁻¹
The standard specifies a maximum limit of 3000 mg kg$^{-1}$ for inorganics. None of the samples tested exceed this limit. However, the Australian Standards (Standards Australia, 1992 and 1998) also requires chloride or sulphate levels in aggregates which exceed 0.01% to be reported if used for any practical applications. This indicates that the levels measured would be of concern if recycled glass concentration as filler is very high.

**Organics**

Organic material is usually easily extracted by either acid or alkaline extracts (and sometimes just by water). It is then difficult to quantify once extracted into solution. Commonly, therefore, the assumption is made that total organic content is required, not just the amount extracted. It is also commonly assumed that total organic content can be estimated by the weight loss on heating of a dried sample.

The weight percent mass loss of the glass was 0.29%. Disfani et al. (2011a) reported an organic content of 1.3% for fine recycled glass. The Australian Standard (Standards Australia, 1997) is for weight loss on heating to be less than 5%, thus the glass sample is well within the standard.

An alternative test for organics is to ensure that the colour of the extract is not darker than the colour of the solution being used to perform the extraction. Since the blank water, acid and base solutions were all colourless, this means that none of the extracts should show any colour.
Testing of the extracts by U.V. spectroscopy against the water blanks showed zero colour in all three extracts indicating the absence of any extractable organic material.

**Surfactant**

Surfactants are compounds that lower the surface tension of a liquid, allowing easier spreading, and lowering of the interfacial tension between two liquids, or between a liquid and a solid. Australian Standards does not require measurement of surfactant content for recycled crushed glass; however the presence of surfactants can be particularly problematic as they can act as enhancers for other contaminants. The surfactant level of water prior to contact with the samples was 72 mN m\(^{-1}\) and the same value was obtained in all the water, acid and base extracts; indicating that there was no significant surfactant levels extracted from the recycled glass samples.

**CONCLUSIONS**

Recycled crushed glass is a waste material that can be used for different engineering applications, particularly as a construction aggregate. In this paper the authors report on a study of possible environmental impacts from storing and using glass cullet in construction in the state of Victoria, Australia. Leachate from waste glass stockpiles was sampled and analyses conducted of selected contaminants; results were compared with state EPA Victoria Guidelines or national
Conductivity, pH values, most heavy metals, organic and inorganic material (sulphate and chloride) contents were found to be within acceptable limits for extracts into water, acid and base. However, iron content in acid extracted samples was above the acceptable limits and should be monitored if crushed glass is used for any practical applications where there is potential to contaminate the ambient environment. Iron content in normal water extracts remain well under acceptable limits. The inorganic content (chloride and sulphate) was also within the acceptable limits. There is no specified limit in Victoria for surfactant levels within crushed glass. However, surfactant levels of extracts (acid, water and base) after leaching were found to be same as surfactant levels of raw extracts before mixing. Therefore, there will be no issue with the use of recycled glass in regards to surface tension property of the ambient environment. A few of the measured values are noted to be near to the specified limits. The authors conclude that this does not necessarily mean that the same concentrations of contaminants will be leached out to the ambient environment, as often contaminants present are being diluted (as it spreads to a wider area/volume). Moreover, these levels of contaminant are expected only from the first flush. After couple of flushes, levels of contaminant are expected to be much lower because of wash-off effects. Therefore it can be concluded that recycled crushed glass is a viable material to be used as an aggregate in pavement sub-base without posing an undue risk of environmental contamination.
REFERENCES


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EPA Victoria, 2007. Publication 448: Classification of wastes, Environmental Protection Agency of Victoria, Melbourne, Australia.


Table 1: Heavy metals testing results with specified limits

<table>
<thead>
<tr>
<th>Metal</th>
<th>Limit (^a) (mg kg(^{-1}))</th>
<th>Water (mg kg(^{-1}))</th>
<th>Acid (mg kg(^{-1}))</th>
<th>Base (mg kg(^{-1}))</th>
<th>Disfani et al. (2001)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>50</td>
<td>0</td>
<td>74</td>
<td>3</td>
<td>NA</td>
</tr>
<tr>
<td>Magnesium</td>
<td>NA</td>
<td>9</td>
<td>54</td>
<td>35</td>
<td>NA</td>
</tr>
<tr>
<td>Lead</td>
<td>300</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Copper</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Manganese</td>
<td>NA</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>NA</td>
</tr>
<tr>
<td>Zinc</td>
<td>200</td>
<td>0</td>
<td>26</td>
<td>0</td>
<td>34</td>
</tr>
</tbody>
</table>

\(^a\)EPA Victoria (2007), NA: Not available
Figure 1: Recycled glass (<5 mm) used in this study (scale in mm)