Eco-profiles of the European Plastics Industry

POLYMETHYL METHACRYLATE (PMMA)

A report by

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for

PlasticsEurope

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IMPORTANT NOTE

Before using the data contained in this report, you are strongly recommended to look at the following documents:

1. Methodology

This provides information about the analysis technique used and gives advice on the meaning of the results.

2. Data sources

This gives information about the number of plants examined, the date when the data were collected and information about up-stream operations.

In addition, you can also download data sets for most of the upstream operations used in this report. All of these documents can be found at: www.plasticseurope.org.

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POLYMETHYL METHACRYLATE

Polymethyl methacrylate (PMMA) is a transparent, colourless, thermoplastic polymer with a structure as shown in Figure 1. The structure of the polymer solid gives PMMA a distinctive optical clarity. It is commonly available in either sheet or bead form, is readily fabricated and can be coloured as required.

![Structure of polymethyl methacrylate. The brackets indicate the repeat unit.](image)

Its durability, plus its high quality finish, ensures that it is in demand for the longer lasting high quality products, such as baths, sinks and showers. Its mechanical properties of high softening point and high impact strength, when combined with its good weatherability and resistance to most aqueous inorganic reagents, favour its use in external applications. Illuminated signs, glazing and motor vehicle rear lights are only a few of the examples of the use to which it can be put. Because of its optical clarity and stability, PMMA has found uses in the medical field where special grades have long been successfully employed for intra-ocular lenses, contact lenses and implants.

Besides self-polymerisation, methyl methacrylate (MMA), will polymerise with a range of other materials, yielding co-polymers with properties tailored to specific applications. The mechanical properties and finishes of PMMA can be further optimised for specific applications by the addition of inert fillers and plasticisers.

THE PRODUCTION ROUTE TO PMMA

Unlike the polyolefins, the production route for polymethyl methacrylate requires the production of a significant number of intermediates as shown schematically in Figure 2. Essentially the processes produce acetone cyanohydrin which is then converted to methyl methacrylate. The monomer may be polymerised to produce beads which can then be extruded, or the monomer may be directly polymerised as in the production of cast sheet.
There are a number of different routes to acetone but the most commonly used is as a by-product in the manufacture of phenol and this route has been used in the present work. Hydrogen cyanide is mainly produced by the reaction of methane (natural gas) with ammonia. A small proportion of hydrogen cyanide, however, is obtained as a by-product from acrylonitrile production. For the purposes of this report, it has been assumed that all hydrogen cyanide is produced from the reaction of methane and ammonia. Acetone is then reacted with hydrogen cyanide to produce acetone cyanohydrin and this is converted to methyl methacrylate in an acid solution of sulphuric acid. The intermediate, methacrylamide sulphate is not isolated but the spent sulphuric acid from the process is recovered and regenerated for further use.
RECYCLABILITY OF PMMA

Physical recycling, in which off-cuts of PMMA are crushed and re-ground to be used again in conversion operations, is widely practised. A small proportion of this form of recycling is included in the data reported here but only when the scrap arises within the PMMA manufacturing process. In this respect, this report is no different from the earlier reports for other plastics.

It is, however, important to recognise that PMMA is different from virtually all other plastics in that it can be readily recycled back to the original monomer. Thermal cracking, the process by which PMMA is converted to MMA, can be carried out with almost 100% recovery. The resulting monomer can be separated from any fillers, distilled and decolourised, so that it is almost indistinguishable from virgin material. This important characteristic potentially has a great impact on the practicability of recycling products made from the polymer and may, therefore, significantly influence the life-cycle assessment of articles made from PMMA.

ECO-PROFILE OF PMMA

Table 1 shows the gross or cumulative energy to produce 1 kg of PMMA resin as beads for further conversion and Table 2 gives this same data expressed in terms of primary fuels. Table 3 shows the energy data expressed as masses of fuels. Table 4 shows the raw materials requirements and Table 5 shows the demand for water. Table 6 shows the gross air emissions and Table 7 shows the corresponding carbon dioxide equivalents of these air emissions. Table 8 shows the emissions to water. Table 9 shows the solid waste generated and Table 10 gives the solid waste in EU format.

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>Electricity</td>
<td>9.43</td>
<td>4.13</td>
<td>0.40</td>
<td>-</td>
<td>13.95</td>
</tr>
<tr>
<td>Oil fuels</td>
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<td>27.92</td>
<td>0.33</td>
<td>21.45</td>
<td>51.95</td>
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<tr>
<td>Other fuels</td>
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<td>26.27</td>
<td>0.08</td>
<td>21.63</td>
<td>50.24</td>
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<tr>
<td>Totals</td>
<td>13.93</td>
<td>58.31</td>
<td>0.81</td>
<td>43.08</td>
<td>116.14</td>
</tr>
</tbody>
</table>
Table 2
Gross primary fuels required to produce 1 kg of PMMA beads. (Totals may not agree because of rounding)

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Fuel prod'n &amp; delivery energy (MJ)</th>
<th>Energy content of delivered fuel (MJ)</th>
<th>Fuel use in transport (MJ)</th>
<th>Feedstock energy (MJ)</th>
<th>Total energy (MJ)</th>
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</thead>
<tbody>
<tr>
<td>Coal</td>
<td>3.59</td>
<td>4.60</td>
<td>0.12</td>
<td>&lt;0.01</td>
<td>8.32</td>
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<td>Oil</td>
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<td>28.13</td>
<td>0.48</td>
<td>21.45</td>
<td>52.11</td>
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<tr>
<td>Gas</td>
<td>4.23</td>
<td>40.93</td>
<td>0.11</td>
<td>21.32</td>
<td>66.59</td>
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<tr>
<td>Hydro</td>
<td>0.31</td>
<td>0.16</td>
<td>0.01</td>
<td>-</td>
<td>0.48</td>
</tr>
<tr>
<td>Nuclear</td>
<td>3.54</td>
<td>1.56</td>
<td>0.08</td>
<td>-</td>
<td>5.18</td>
</tr>
<tr>
<td>Lignite</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Wood</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Sulphur</td>
<td>&lt;0.01</td>
<td>0.09</td>
<td>&lt;0.01</td>
<td>0.30</td>
<td>0.49</td>
</tr>
<tr>
<td>Biomass (solid)</td>
<td>0.03</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>&lt;0.01</td>
<td>0.02</td>
<td>&lt;0.01</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>Recovered energy</td>
<td>&lt;0.01</td>
<td>-17.18</td>
<td>&lt;0.01</td>
<td>-</td>
<td>-17.18</td>
</tr>
<tr>
<td>Unspecified</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>-</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Peat</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>-</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.01</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>-</td>
<td>0.02</td>
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<tr>
<td>Solar</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>-</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Wave/tidal</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>-</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Biomass (liquid/gas)</td>
<td>0.05</td>
<td>0.02</td>
<td>&lt;0.01</td>
<td>-</td>
<td>0.07</td>
</tr>
<tr>
<td>Industrial waste</td>
<td>0.04</td>
<td>0.02</td>
<td>&lt;0.01</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>Municipal Waste</td>
<td>0.05</td>
<td>0.02</td>
<td>&lt;0.01</td>
<td>-</td>
<td>0.08</td>
</tr>
<tr>
<td>Wind</td>
<td>0.03</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>Totals</td>
<td>13.93</td>
<td>58.41</td>
<td>0.81</td>
<td>43.08</td>
<td>116.23</td>
</tr>
</tbody>
</table>

Table 3
Gross primary fuels used to produce 1 kg of PMMA beads expressed as mass.

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Input in mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil</td>
<td>1200000</td>
</tr>
<tr>
<td>Gas/condensate</td>
<td>1300000</td>
</tr>
<tr>
<td>Coal</td>
<td>2900000</td>
</tr>
<tr>
<td>Metallurgical coal</td>
<td>240</td>
</tr>
<tr>
<td>Lignite</td>
<td>5</td>
</tr>
<tr>
<td>Peat</td>
<td>150</td>
</tr>
<tr>
<td>Wood</td>
<td>99</td>
</tr>
</tbody>
</table>
Table 4
Gross raw materials required to produce 1 kg of PMMA beads.

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Input in mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>-150000</td>
</tr>
<tr>
<td>Animal matter</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Barytes</td>
<td>70</td>
</tr>
<tr>
<td>Bauxite</td>
<td>510</td>
</tr>
<tr>
<td>Bentonite</td>
<td>41</td>
</tr>
<tr>
<td>Biomass (including water)</td>
<td>13000</td>
</tr>
<tr>
<td>Calcium sulphate (CaSO4)</td>
<td>4</td>
</tr>
<tr>
<td>Chalk (CaCO3)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cr</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cu</td>
<td>1</td>
</tr>
<tr>
<td>Dolomite</td>
<td>7</td>
</tr>
<tr>
<td>Fe</td>
<td>600</td>
</tr>
<tr>
<td>Feldspar</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Ferromanganese</td>
<td>1</td>
</tr>
<tr>
<td>Fluorspar</td>
<td>12</td>
</tr>
<tr>
<td>Granite</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Gravel</td>
<td>2</td>
</tr>
<tr>
<td>Hg</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Limestone (CaCO3)</td>
<td>6800</td>
</tr>
<tr>
<td>Mg</td>
<td>&lt;1</td>
</tr>
<tr>
<td>N2</td>
<td>110000</td>
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<tr>
<td>Ni</td>
<td>&lt;1</td>
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<tr>
<td>O2</td>
<td>130000</td>
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<tr>
<td>Olivine</td>
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</tr>
<tr>
<td>Pb</td>
<td>4</td>
</tr>
<tr>
<td>Phosphate as P2O5</td>
<td>1900</td>
</tr>
<tr>
<td>Potassium chloride (KCl)</td>
<td>4</td>
</tr>
<tr>
<td>Quartz (SiO2)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Rutile</td>
<td>&lt;1</td>
</tr>
<tr>
<td>S (bonded)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>S (elemental)</td>
<td>33000</td>
</tr>
<tr>
<td>Sand (SiO2)</td>
<td>3300</td>
</tr>
<tr>
<td>Shale</td>
<td>12</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>32000</td>
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<tr>
<td>Sodium nitrate (NaNO3)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Talc</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Unspecified</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Zn</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Table 5
Gross water consumption required for the production of 1 kg of PMMA beads. (Totals may not agree because of rounding)

<table>
<thead>
<tr>
<th>Source</th>
<th>Use for processing (mg)</th>
<th>Use for cooling (mg)</th>
<th>Totals (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public supply</td>
<td>2000000</td>
<td>-</td>
<td>2000000</td>
</tr>
<tr>
<td>River canal</td>
<td>5300000</td>
<td>1300000</td>
<td>14000000</td>
</tr>
<tr>
<td>Sea</td>
<td>2400000</td>
<td>4700000</td>
<td>4900000</td>
</tr>
<tr>
<td>Well</td>
<td>1600000</td>
<td>330000</td>
<td>200000</td>
</tr>
<tr>
<td>Unspecified</td>
<td>4800000</td>
<td>50000000</td>
<td>55000000</td>
</tr>
<tr>
<td>Totals</td>
<td>7700000</td>
<td>68000000</td>
<td>76000000</td>
</tr>
</tbody>
</table>
Table 6
Gross air emissions associated with the production of 1 kg of PMMA beads.
(Totals may not agree because of rounding)

<table>
<thead>
<tr>
<th>Emission</th>
<th>From fuel prod'n (mg)</th>
<th>From fuel use (mg)</th>
<th>From transport (mg)</th>
<th>From process (mg)</th>
<th>From biomass (mg)</th>
<th>From fugitive (mg)</th>
<th>Totals (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dust (PM10)</td>
<td>1100</td>
<td>660</td>
<td>17</td>
<td>240</td>
<td>-</td>
<td>-</td>
<td>2000</td>
</tr>
<tr>
<td>CO</td>
<td>2800</td>
<td>1400</td>
<td>200</td>
<td>1100</td>
<td>-</td>
<td>-</td>
<td>5500</td>
</tr>
<tr>
<td>CO2</td>
<td>960000</td>
<td>3900000</td>
<td>280000</td>
<td>990000</td>
<td>-74</td>
<td>-</td>
<td>5900000</td>
</tr>
<tr>
<td>SOX as SO2</td>
<td>4100</td>
<td>21000</td>
<td>190</td>
<td>3200</td>
<td>-</td>
<td>-</td>
<td>29000</td>
</tr>
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<td>H2S</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
<td>-</td>
<td>&lt;1</td>
</tr>
<tr>
<td>mercaptan</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
<td>-</td>
<td>&lt;1</td>
</tr>
<tr>
<td>NOX as NO2</td>
<td>2900</td>
<td>830000</td>
<td>270</td>
<td>910</td>
<td>-</td>
<td>-</td>
<td>12000</td>
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<td>&lt;1</td>
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<td>HCl</td>
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<td>hydrocarbons not specified</td>
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<td>76</td>
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<td>1</td>
<td>12000</td>
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<td>aldehyde (-CHO)</td>
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<td>&lt;1</td>
<td>89</td>
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<td>89</td>
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<td>organics</td>
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<td>1900</td>
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<td>-</td>
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<td>Pb+compounds as Pb</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
<td>-</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Hg+compounds as Hg</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
<td>-</td>
<td>&lt;1</td>
</tr>
<tr>
<td>metals not specified elsewhere</td>
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<td>11</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
<td>-</td>
<td>12</td>
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<td>H2SO4</td>
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<td>&lt;1</td>
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<td>-</td>
<td>&lt;1</td>
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<tr>
<td>H2O</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
<td>-</td>
<td>&lt;1</td>
</tr>
<tr>
<td>dichloroethane (DCE) C2H4Cl2</td>
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<td>-</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
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<td>&lt;1</td>
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<td>vinyl chloride monomer (VCM)</td>
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<td>&lt;1</td>
<td>-</td>
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<td>&lt;1</td>
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<td>CFC/HCFC/HFC not specified</td>
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<td>-</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
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<td>organo-chlorine not specified</td>
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<td>-</td>
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<td>HCN</td>
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<td>48000</td>
</tr>
<tr>
<td>aromatic HC not specified</td>
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<td>1</td>
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<td>-</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>polycyclic hydrocarbons (PAH)</td>
<td>&lt;1</td>
<td>2</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>NMVOC</td>
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<td>&lt;1</td>
<td>19</td>
<td>-</td>
<td>-</td>
<td>19</td>
</tr>
<tr>
<td>CS2</td>
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<td>As+compounds as As</td>
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<td>-</td>
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<tr>
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<td>-</td>
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<td>&lt;1</td>
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<td>-</td>
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<td>dioxin/furan as Teq</td>
<td>-</td>
<td>-</td>
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<td>&lt;1</td>
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<td>-</td>
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<td>toluene C7H8</td>
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<td>&lt;1</td>
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<td>&lt;1</td>
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<td>-</td>
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pmma
Table 7  
Carbon dioxide equivalents corresponding to the gross air emissions for the production of 1 kg of PMMA beads. (Totals may not agree because of rounding)

<table>
<thead>
<tr>
<th>Type</th>
<th>From fuel prod'n (mg)</th>
<th>From fuel use (mg)</th>
<th>From transport (mg)</th>
<th>From process (mg)</th>
<th>From biomass (mg)</th>
<th>From fugitive (mg)</th>
<th>Totals (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 year equiv</td>
<td>3700000</td>
<td>4000000</td>
<td>29000</td>
<td>1200000</td>
<td>-174</td>
<td>14</td>
<td>8900000</td>
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<tr>
<td>100 year equiv</td>
<td>2000000</td>
<td>3900000</td>
<td>29000</td>
<td>1100000</td>
<td>-174</td>
<td>7</td>
<td>7000000</td>
</tr>
<tr>
<td>500 year equiv</td>
<td>1300000</td>
<td>3900000</td>
<td>29000</td>
<td>1000000</td>
<td>-174</td>
<td>4</td>
<td>6200000</td>
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Table 8
Gross emissions to water arising from the production of 1 kg of PMMA beads. (Totals may not agree because of rounding).

<table>
<thead>
<tr>
<th>Emission</th>
<th>From fuel prod'n (mg)</th>
<th>From fuel use (mg)</th>
<th>From transport (mg)</th>
<th>From process (mg)</th>
<th>Totals (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>7</td>
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<tr>
<td>BOD</td>
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<td>Pb+compounds as Pb</td>
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<td>&lt;1</td>
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<tr>
<td>Fe+compounds as Fe</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<td>Na+compounds as Na</td>
<td>1</td>
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<td>18000</td>
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<td>acid as H+</td>
<td>2</td>
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<td>76</td>
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<td>NO3-</td>
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<td>9</td>
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<td>Hg+compounds as Hg</td>
<td>&lt;1</td>
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<td>&lt;1</td>
<td>&lt;1</td>
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<td>F-</td>
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<td>dioxin/furan as Teq</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
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Table 9
Gross solid waste associated with the production of 1 kg of PMMA beads.
(Totals may not agree because of rounding)

<table>
<thead>
<tr>
<th>Emission</th>
<th>From fuel prod'n (mg)</th>
<th>From fuel use (mg)</th>
<th>From transport (mg)</th>
<th>From process (mg)</th>
<th>Totals (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic containers</td>
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<td>Plastics</td>
<td>&lt;1</td>
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<td>&lt;1</td>
<td>19</td>
<td>19</td>
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<tr>
<td>Metals</td>
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<td>-</td>
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<td>-</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<td>Unspecified refuse</td>
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<td>&lt;1</td>
<td>6700</td>
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<td>Mineral waste</td>
<td>43</td>
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<td>340</td>
<td>2800</td>
<td>3200</td>
</tr>
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<td>Slags &amp; ash</td>
<td>16000</td>
<td>5700</td>
<td>130</td>
<td>1400</td>
<td>23000</td>
</tr>
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<td>Mixed industrial</td>
<td>4000</td>
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<td>13</td>
<td>8100</td>
<td>12000</td>
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<td>Regulated chemicals</td>
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<td>760</td>
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<td>15</td>
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<td>290</td>
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<td>Inert chemical</td>
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<td>2</td>
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<td>Wooden pallets</td>
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<td>-</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<td>Waste to recycling</td>
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<td>160</td>
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<tr>
<td>Waste returned to mine</td>
<td>57000</td>
<td>-</td>
<td>12</td>
<td>600</td>
<td>57000</td>
</tr>
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<td>Tailings</td>
<td>1</td>
<td>-</td>
<td>11</td>
<td>50</td>
<td>63</td>
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<tr>
<td>Municipal solid waste</td>
<td>-7200</td>
<td>-</td>
<td>-</td>
<td>&lt;1</td>
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</table>

Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.
Table 10
Gross solid waste in EU format associated with the production of 1 kg of PMMA beads. Entries marked with an asterisk (*) are considered hazardous as defined by EU Directive 91/689/EEC

<table>
<thead>
<tr>
<th>Emission</th>
<th>Totals (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>010101 metallic min'l excav'n waste</td>
<td>1600</td>
</tr>
<tr>
<td>010102 non-metal min'l excav'n waste</td>
<td>58000</td>
</tr>
<tr>
<td>010306 non 010304/010305 tailings</td>
<td>17</td>
</tr>
<tr>
<td>010308 non-010307 powdery wastes</td>
<td>12</td>
</tr>
<tr>
<td>010399 unspecified met. min'l wastes</td>
<td>230</td>
</tr>
<tr>
<td>010408 non-010407 gravel/crushed rock</td>
<td>1</td>
</tr>
<tr>
<td>010410 non-010407 powdery wastes</td>
<td>&lt;1</td>
</tr>
<tr>
<td>010411 non-010407 potash/rock salt</td>
<td>57</td>
</tr>
<tr>
<td>010499 unsup'd non-met. waste</td>
<td>15</td>
</tr>
<tr>
<td>010505*oil-bearing drilling mud/waste</td>
<td>7900</td>
</tr>
<tr>
<td>010508 non-010504/010505 chloride mud</td>
<td>6200</td>
</tr>
<tr>
<td>010599 unspecified drilling mud/waste</td>
<td>6700</td>
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<td>020107 wastes from forestry</td>
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</tr>
<tr>
<td>050106*oil ind. oily mainn'f sludges</td>
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</tr>
<tr>
<td>050107*oil industry acid tars</td>
<td>150</td>
</tr>
<tr>
<td>050199 unspecified oil industry waste</td>
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</tr>
<tr>
<td>050999 coal pyrolysis unsup'd waste</td>
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</tr>
<tr>
<td>060101*H2SO4/H2SO3 MFSU waste</td>
<td>&lt;1</td>
</tr>
<tr>
<td>060102*HCl MFSU waste</td>
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</tr>
<tr>
<td>060106*other acidic MFSU waste</td>
<td>&lt;1</td>
</tr>
<tr>
<td>060199 unsup'd acid MFSU waste</td>
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</tr>
<tr>
<td>060204*NaOH/KOH MFSU waste</td>
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</tr>
<tr>
<td>060299 unsup'd base MFSU waste</td>
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<tr>
<td>060313*h. metal salt/sof'n MFSU waste</td>
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<td>060314 other salt/sof'n MFSU waste</td>
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<tr>
<td>060399 unsup'd salt/sof'n MFSU waste</td>
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</tr>
<tr>
<td>060404*Hg MSFU waste</td>
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<tr>
<td>060405*other h. metal MFSU waste</td>
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<tr>
<td>060499 unsup'd metallic MFSU waste</td>
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<tr>
<td>060602*dangerous sulphide MFSU waste</td>
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<tr>
<td>060603 non-060602 sulphide MFSU waste</td>
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<tr>
<td>060701*halogen electrol. asbestos waste</td>
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<tr>
<td>060702*Cl pr. activated C waste</td>
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<tr>
<td>060703*BaSO4 sludge with Hg</td>
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<td>060704*halogen pr. acids and sol'ns</td>
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<td>060799 unsup'd halogen pr. waste</td>
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<tr>
<td>061002*N ind. dangerous sub. waste</td>
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<tr>
<td>061099 unsup'd N industry waste</td>
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</tr>
<tr>
<td>070101*organic chem. aqueous washes</td>
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</tr>
<tr>
<td>070103*org. halogenated solv'ns/washes</td>
<td>&lt;1</td>
</tr>
<tr>
<td>070107*hal'd still bottoms/residues</td>
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</tr>
<tr>
<td>070108*other still bottoms/residues</td>
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<tr>
<td>070111*org. chem. dan. eff. sludge</td>
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<tr>
<td>070112 non-070111 effluent sludge</td>
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</table>

continued over …..
Table 10 - continued
Gross solid waste in EU format associated with the production of 1 kg of PMMA beads. Entries marked with an asterisk (*) are considered hazardous as defined by EU Directive 91/689/EEC

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>070199</td>
<td>unsp'd organic chem. waste</td>
<td>3500</td>
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<tr>
<td>070204*</td>
<td>polymer ind. other washes</td>
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<tr>
<td>070207*</td>
<td>polymer ind. half still waste</td>
<td>&lt;1</td>
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<tr>
<td>070208*</td>
<td>polymer ind. other still waste</td>
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<tr>
<td>070209*</td>
<td>polymer ind. half fil. cakes</td>
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<tr>
<td>070213</td>
<td>polymer ind. waste plastic</td>
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<td>070214*</td>
<td>polymer ind. dan. additives</td>
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<td>070216</td>
<td>polymer ind. silicone wastes</td>
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<tr>
<td>070299</td>
<td>unsp'd polymer ind. waste</td>
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<td>080199</td>
<td>unspecified paint/varnish waste</td>
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<tr>
<td>100101</td>
<td>non-100104 ash, slag &amp; dust</td>
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<td>100102</td>
<td>coal fly ash</td>
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<td>100104*</td>
<td>oil fly ash and boiler dust</td>
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<td>100105</td>
<td>FGD Ca-based reac. solid waste</td>
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<td>100113*</td>
<td>emulsified hydrocarbon fly ash</td>
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<td>dangerous co-incin'n ash/slag</td>
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<td>non-100115 co-incin'n ash/slag</td>
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<td>100116*</td>
<td>dangerous co-incin'n fly ash</td>
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<td>100199</td>
<td>unsp'd thermal process waste</td>
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<td>100202</td>
<td>unprocessed iron/steel slag</td>
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<td>iron/steel mill scales</td>
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<td>100501</td>
<td>primary/secondary zinc slags</td>
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<td>zinc pr. other dust</td>
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<td>non-100511 Zn pr. skimmings</td>
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<td>101304</td>
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<td>130208*</td>
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<td>150101</td>
<td>paper and cardboard packaging</td>
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<td>150102</td>
<td>plastic packaging</td>
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<td>150103</td>
<td>wooden packaging</td>
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<td>150106</td>
<td>mixed packaging</td>
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<td>170107</td>
<td>non-170106 con/debr/bric/til mix</td>
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<td>170904</td>
<td>non-170901/2/3 con/dem/n waste</td>
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<td>190905</td>
<td>sat./spent ion exchange resins</td>
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<td>paper and cardboard</td>
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<td>200108</td>
<td>biodeg. kitchen/canteen waste</td>
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<td>200138</td>
<td>non-200137 wood</td>
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<td>plastics</td>
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<td>other separately coll. frac'ns</td>
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<td>mixed municipal waste</td>
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</tr>
<tr>
<td>200399</td>
<td>unspecified municipal wastes</td>
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</tbody>
</table>

Note: Negative values correspond to consumption of waste e.g. recycling or...