Life Cycle Assessment (LCA) as a tool to evaluate the environmental impact of water-based, solvent-based and Hot Melt Road Marking Materials
Index

- LCA Principles
- Preamble
- Objective of Study
- Key measures
- Fundamental Unit
- Process flow
- Base compositions
- Source of Data
- Results
- Discussion
- Conclusion
LCA is a method used to quantify the effects of a product or a service from the extraction of raw materials to disposal.

Performed in accordance to International (ISO 14040 to 14043) standards
Preamble

• Paper based on an amalgam of 2 separate reports
  » Solvent vs Water
  » Water vs Hot Melt

• Data based on absolute statistics
  Consistent measurement to international standards
  Audited by Independent Accounting Firms
  Peer Reviewed
  Data presented based on stated assumptions

• No commentary on the suitability of products for specific purposes
Objective of the LCA Study

Evaluate the **environmental** and **human health impact** of water based and solvent based acrylic, and hot-melt road markings over the proposed life cycle

**Impact on 19 factors across 6 categories**

- Air Pollution
- Water Pollution
- Ground Pollution
- Toxicity to Humans
- Toxicity to the Environment
- Use of Earth Resources
## Environmental impact categories and indicators assessed

<table>
<thead>
<tr>
<th>Areas</th>
<th>Indicators</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources</td>
<td>Primary energy</td>
<td>MegaJoule</td>
</tr>
<tr>
<td></td>
<td>Depletion of non-renewable resources</td>
<td>Year-1</td>
</tr>
<tr>
<td>Air Pollution</td>
<td>Acidification of air</td>
<td>g eq. H+</td>
</tr>
<tr>
<td></td>
<td>Greenhouse effect (CO2 release)</td>
<td>g eq. CO2</td>
</tr>
<tr>
<td></td>
<td>Metal in air</td>
<td>g</td>
</tr>
<tr>
<td></td>
<td>VOC in air</td>
<td>g</td>
</tr>
<tr>
<td>Water Pollution</td>
<td>Eutrophication</td>
<td>g eq. PO4</td>
</tr>
<tr>
<td></td>
<td>Metals in water</td>
<td>g</td>
</tr>
<tr>
<td></td>
<td>Organic matter in water</td>
<td>g</td>
</tr>
<tr>
<td></td>
<td>Suspended solid oxidizable matter</td>
<td>g</td>
</tr>
<tr>
<td>Soil Pollution</td>
<td>Metals in soil</td>
<td>g</td>
</tr>
<tr>
<td></td>
<td>Paint waste emitted to soil</td>
<td>g</td>
</tr>
<tr>
<td>Waste</td>
<td>Hazardous industrial waste (Class I)</td>
<td>kg</td>
</tr>
<tr>
<td></td>
<td>Municipal and industrial waste (Class II)</td>
<td>kg</td>
</tr>
<tr>
<td></td>
<td>Inert waste (Class III)</td>
<td>kg</td>
</tr>
<tr>
<td>Toxic risks</td>
<td>Aquatic ecotoxicity</td>
<td>g eq. 1,4-DCB</td>
</tr>
<tr>
<td></td>
<td>Human toxicity</td>
<td>g eq. 1,4-DCB</td>
</tr>
<tr>
<td></td>
<td>Sediment ecotoxicity</td>
<td>g eq. 1,4-DCB</td>
</tr>
<tr>
<td></td>
<td>Terrestrial ecotoxicity</td>
<td>g eq. 1,4-DCB</td>
</tr>
</tbody>
</table>
3. Functional Unit

To cover 1 m\(^2\) of highway with white colour reflective traffic markings for 10 years (performing to defined standards*)

Life cycle calculations are based on a function or service rendered by a product

- For the purpose of the consistency, it is assumed that all materials have an in-service life of 1 year.
  - *retroreflectivity, skid resistance, wear, luminance
Process Flow

- Production of raw materials
  - Packaging 1 (Packaging for raw materials)
    - Transport 2
    - Paint preparation
  - Packaging 2 (Packaging for finished products)
    - Transport 4
    - Application to road surface
    - Use and disposal

- Production of the packaging materials used for raw materials
  - Transport 1

- Production of the packaging materials used for finished products
  - Transport 3
    - Transport to the place of application or
    - Delivery to the customer
  - Transport 5
    - Disposal of packaging materials
Rohm and Haas Formulation TP-27-1

(Based on Rohm and Haas Paraloid B66 traffic paint formulation).

(Generic formulation sourced from various inputs).
Base Compositions

Commercial water-based acrylic paint
Base components: all acrylic emulsion polymer, titanium dioxide, filler, water, coalescent, ammonium, thixotropic agent and wetting agent. The paint contains 42% water and less than 4% solvent. 400 gm/m² glass beads on application. (Rohm and Haas formulation TP-27-1)

Commercial solvent-based acrylic paint
Base components: solvent based acrylic polymer, titanium dioxide, filler, toluene, plasticizer, thixotropic agent and wetting agent. Contains approximately 30% toluene. 400 gm/m² glass beads on application. (Based on Rohm and Haas Paraloid B66 traffic paint formulation).

Commercial Hot-melt Roadmarking
Base components: C5 Resin, PE resin, plasticizer, TiO2 and fillers. (Various inputs).

<table>
<thead>
<tr>
<th>Component</th>
<th>Waterbased</th>
<th>Solventbased</th>
<th>Hot Melt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binders</td>
<td>267</td>
<td>139</td>
<td>195</td>
</tr>
<tr>
<td>Titanium Dioxide</td>
<td>56</td>
<td>125</td>
<td>50</td>
</tr>
<tr>
<td>Fillers</td>
<td>415</td>
<td>254</td>
<td>530</td>
</tr>
<tr>
<td>Solvents</td>
<td>24</td>
<td>251</td>
<td></td>
</tr>
<tr>
<td>Glass Beads *</td>
<td>216</td>
<td>216</td>
<td>200</td>
</tr>
<tr>
<td>Other</td>
<td>22</td>
<td>15</td>
<td>25</td>
</tr>
</tbody>
</table>

* Glass Beads added on application
Source of data

• The data of this LCA study is obtained from multiple sources, include:

  – Direct data collected from Dows Manufacturing and Technical Facilities (limited to binders for water-borne and solvent-based traffic paint);

  – Literature research of academic papers and national/sectoral standards;

  – Interviews with research institutes and regulatory authorities;

  – Interviews with major paint/hot-melt producers and applicators in Europe, Asia and North America.
Impact Sources

Energy Use

VOC

Total Solid Waste

Greenhouse Release

Water Pollution

Human Toxicity
Summary of impacts

• **Water Based**
  - Binders contribute the most significant impacts except water and VOC
  - TiO2 contributes most water consumption and impact on many other categories, reflecting its environmental impact
  - The production process contributes relatively small impact compared to RM inputs

• **Solvent Based**
  - Binders and VOC as per water based
  - Solvents contribute most VOC, energy input and environmental and Human toxicity
  - The production process contributes relatively small impact compared to RM inputs

• **Hot Melt**
  - Similar to water based paint, production for repaint contributes the most impact for all impact categories.
  - The thickness of application is also a major factor relative to paint
  - Application stages also contribute the most significant proportion to greenhouse effect
## LCA Balance Sheet

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Unit</th>
<th>Water-based</th>
<th>Hot-Melt</th>
<th>Solvent-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Energy consumption (Non Renewable)</td>
<td>Mj</td>
<td>300</td>
<td>1,639</td>
<td>1,430</td>
</tr>
<tr>
<td>Total water Consumption</td>
<td>Litre</td>
<td>83</td>
<td>305</td>
<td>115</td>
</tr>
<tr>
<td>Chemical Oxygen in Demand (COD)</td>
<td>gm</td>
<td>5</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>VOC</td>
<td>gm</td>
<td>326</td>
<td>350</td>
<td>3,440</td>
</tr>
<tr>
<td>Total Solid Waste</td>
<td>Kg</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Greenhouse effect</td>
<td>g CO2e</td>
<td>18,053</td>
<td>54,068</td>
<td>58,640</td>
</tr>
<tr>
<td>Depletion of Non Abiotic Resources</td>
<td>Kg Antimony Equiv</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Acidification Potential</td>
<td>g SO2e</td>
<td>94</td>
<td>386</td>
<td>130</td>
</tr>
<tr>
<td>Eutrophication Potential</td>
<td>g Phosphate equiv</td>
<td>6</td>
<td>34</td>
<td>33</td>
</tr>
<tr>
<td>Human Toxicity</td>
<td>g Hematolocical Tox equiv</td>
<td>1,344</td>
<td>3,972</td>
<td>3,000</td>
</tr>
</tbody>
</table>
Conclusions

• Water based road marking paints present the best LCA balance sheet based on the defined standards
• All impact factors studied are in favor of the water based technology
• With solvent based paints in particular the application phase is of concern with respect to human health and greenhouse release sourced from VOC’s.

In conclusion, WB paints offer the best results in minimising the Environmental and Safety impacts of the three systems tested