VOC emissions from the production and the industrial use of paints, inks and adhesives in Flanders, Belgium: evaluation of the reduction potential and the implementation of the European Solvent Directive 1999/13/EG

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Abstract

The European Directive 1999/13/EG, better known as the ‘VOC Solvents Directive’, was transposed into legislation in Flanders (Belgium) in July 2001. By order of Aminal, the Flemish environmental administration, Vito (Flemish Institute for Technological Research) performed a study focusing on the effects of the Solvents Directive on the VOC-emissions and the economic impact on the production of paint, ink and glue and the industrial use of these products. The following industrial user sectors were part of this study: metal, wood, synthetic material, rubber, paper processing and paint shops.

By means of detailed inquiries and company visits we calculated the VOC emissions to be 13.3 ktons in 2001 in Flanders. Of this, 6.3 ktons can be attributed to metal coating and especially to the construction and machine production subsector, 1.5 ktons to wood coating from which 80% originating from furniture manufacturing, 1.8 ktons to synthetic material, 0.8 kton to rubber processing, 0.5 kton to paint shops and a negligibly small amount to paper processing.

Under the Solvents Directive we calculated that the VOC-emissions will decrease to 7.5 ktons in 2010 taking into account a maximum economic growth of 15% between 2001 and 2010. Furthermore, the feasibility and the economic effect of an implementation of primary reduction measures (switch to alternative environmentally friendly products such as high solids, water based, UV-cured, hot melts, etc.) and secondary reduction measures (end-of-pipe techniques like activated carbon filters and incinerators) was determined. A marginal cost curve was constructed in which the above mentioned reduction measures are included. A summation of the reductions with a marginal cost of less then 5000 €/ton could bring the remaining emissions at 6.6 kton in 2010. This emission reduction is sufficient to meet the conditions enforced by the solvent guideline and is a good step towards the national emission ceilings which have to be met by 2010.
1 Introduction

Significant for this study are the NMVOC, non-methane volatile organic compounds. Methane concentrations are a few hundred times higher than those of other VOC, but they have a very low reactivity in the atmosphere. Furthermore, methane emissions are negligible in the industrial sectors considered in this study.

The industrial sectors that are examined are:
- The production of paint, lacquer, varnish, ink and adhesives
- The industrial use of organic coatings and adhesives in the:
  - Metal sector
  - Wood sector
  - Synthetic and rubber sector
  - Paint shops
  - Paper sector

In Flanders, a strong industrialised region, 94% of the NMVOC emissions are anthropogenic through evaporation of solvents and fuels and through incineration processes. NMVOC are precursors in the formation of tropospheric ozone and other noxious photochemical substances [1].

NMVOC emissions bring on international air pollution problems and therefore several authorities have formulated objectives to deal with them. The first concrete agreement dealing on transboundary air emissions has been made in 1979 and is known as the “Convention of Geneva”. This convention was completed with eight protocols of which the last one, the Göteborg Protocol (1999), prescribes the national emission ceilings for the emissions of NO\textsubscript{x}, NMVOC, SO\textsubscript{x} and NH\textsubscript{3} in 2010. In July 2001 the European Directive 2001/81/EC on National Emission Ceilings (NEC) was approved and is even stricter than the Göteborg Protocol. The Belgian emission ceiling for NMVOC has been established at 139 kton by 2010. Belgium can be divided into three regions: Flanders, the Walloon and Brussels. This study is limited to Flanders and the emission ceilings for this region are established at 70.9 kton by 2010 [2].

In 1999 the European Solvent Emission Directive 1999/13/EG (SED) was approved and in 2001 it has been transposed into Flemish environmental legislation [3]. This directive specifies the reduction of VOC resulting from the use of organic solvents in the above mentioned industrial activities by October 2007 at the latest. Companies that are submitted to the directive need to comply with the sector dependant emission limits or can choose to follow a reduction programme.

2 Objective

Vito had three major objectives in this study: make an inventory of the VOC emissions, trace out scenarios for 2010 and formulate cost curves and economic feasibility of the reductions necessary to comply with the Solvent Emission Directive.
The results of the study will be used by the Flemish environmental administration in international negotiation on VOC emission reductions and they will lay the foundation for sectoral reduction programmes.

3 Methodology

3.1 Emission inventory

First a listing of companies was made to determine the number of firms that had to be observed. We held back 73 paint producers, 23 glue producers and 721 industrial users of coatings and/or adhesives. Because the industrial use of coatings and adhesives is very divergent, we classified the 721 companies into 5 sectors as mentioned in the introduction. Because of the mutual differences in used coatings, adhesives and application techniques between companies of the metal and wood sector we classified these companies into respectively 12 and 4 subsectors. A detailed survey of the users’ classification into sectors and subsectors is given in Figure 1.

Inquiries were sent to the companies in which following information was asked:

- coatings and adhesive production or use,
- solid and solvent content of the products,
- added thinners,
- production/application techniques,
- reduction measures (primary and secondary) and the year of implementation (past and/or nearby future).

VOC emissions of the coatings and adhesive production were calculated as follows:

- $E_{production} = TSC \times 4\% - RE$

  Where $TSC$ is the Total Solvent Content (in tons) of the annually produced coatings, $4\%$ is the emission factor for coatings production and $RE$ stands for the reduced emissions (in tons) by secondary reduction measures.

- $E_{adhesive} = TSC \times 1.25\% - RE$

  Where $TSC$ is the Total Solvent Content (in tons) of the annually produced adhesives, $1.25\%$ is the emission factor for adhesive production and $RE$ stands for the reduced emissions (in tons) by secondary reduction measures.

The emission factor for paint production is obtained from CEPE (Conseil Européen de l’industrie des Peintures, des Encres d’imprimerie et des Couleurs d’Art). The emission factor for adhesive production was determined by investigation of the producers.

The VOC emissions of the industrial use of coatings and adhesives were determined at a different way:

- $E_{production and adhesive use} = TU \times \%SC - R - RE$

  Where $TU$ is the Total Use of coatings or adhesives (in tons), $\%SC$ is the average Solvent Content (in %), $R$ is the removal of coatings, adhesives, solvents (in tons) and $RE$ stands for the reduced emissions (in tons) by secondary reduction measures.
Emission data of companies that did not respond to the inquiry after a second reminder were extrapolated on the basis of the subsector and the number of employees. A Monte Carlo statistical analysis was made to determine the under and upper limit of the obtained VOC emissions in the 95% confidence level.

![Figure 1](image)

**Figure 1:** Classification of the users of coatings and adhesives into sectors and subsectors. Automotive without car assembling and refinishing.

### 3.2 Scenarios

Besides an emission inventory of 2001, Vito made an evaluation of the future emissions until 2010, and developed therefore three scenarios.

In the “Economic growth scenario” VOC emissions are calculated for a (sub)sector dependant growth and without complying with the SED. The economic growth was determined by means of production statistics between 1995 and 2002 and data from business federations. In other words, this is a scenario in which the maximal emissions for 2010 are predicted without a switch over to environmentally friendly coatings, adhesives and without the use of other primary or secondary measures.

The second scenario is the “Alternative coatings/adhesives scenario”. We made an estimation of the remaining VOC emissions supposing that wherever possible the conventional solvent based coatings and/or adhesives are replaced by the best environmentally friendly alternatives for that (sub)sector.

In the “Solvent Directive scenario” we assume that companies strictly comply with the Directive. The emission reduction that has to be managed in 2010 is
calculated with 2001 as a starting point and taking the economic growth in consideration.

### 3.3 Cost curves

The last step of this study was to determine the economical impact of the SED and of further emission reduction till 2010. This was done by formulating total cost curves and marginal cost curves.

For each (sub) sector and by number of employees the possible primary and secondary reduction measures are evaluated. The following primary reduction measures are observed for the industrial users: switch over to high-solid coatings, water based coatings or adhesives, powder coatings, hot melts (glue), and UV curable coatings. The secondary measures that are taken into account for both producers and users are: activated carbon absorbers, incinerators, condensation, absorption, bio filtration, bio scrubbing, and photo oxidation.

Reduction efficiency, investment and operational cost and life span are examined for the above mentioned reduction techniques and subdivided into (sub) sectors and number of employees.

In the total cost curve a summation was made of the achieved VOC reductions and the prices for this reduction. In the marginal cost curve we calculated the price per ton emission reduction, so one can determine the price of an extra ton reduction at any given point of the cost curve.

### 4 Results

#### 4.1 Emission inventory and scenarios

The Flemish industry is characterised by the dominance of small and medium sized enterprises. Companies that emit more than 20 tons VOC on a year basis have to submit a yearly “emission report” to the Flemish environmental authorities. Companies with VOC emissions of less than 20 tons don’t have this obligation and therefore little is known of these companies. Consequently the inquiries were very important to achieve a detailed insight of the sectors total emissions. The overall response to the questionnaire was 35%.

In Table 1 an overview is given of the results of the emission inventory and of the different scenarios that are calculated. The emissions are aggregated per (sub) sector.

In the metal sector 97% of the VOC emissions originate from the use of solvent containing paints and varnishes and only 3% from the use of adhesives. When we analyse Table 1 and Figure 2 we see that for the metal sector the most important VOC emissions arise from the construction (43%) and the machinery (32%) subsector. On the one hand this is due to the fact that the construction and machinery subsectors cover the most companies, and on the other hand an average firm of these subsectors emits the second most VOCs of the metal sector in Flanders. Logically one would think that these subsectors will have to reduce...
The most to comply with the Solvent Directive. This is not entirely the case for the construction subsector.

Figure 2: VOC emissions in 2001 and predictions for 2010 with the Solvent Emissions Directive as assumption.

The construction subsector covers a large amount of small companies that use less than 5 tons of solvents per year. These firms are not submitted to the SED. Furthermore, the majority of the biggest companies already use powder coatings that don’t contain solvents. Figure 3 shows that 30% of the companies still can reduce VOC emissions. These are situated in the medium-sized business.

The VOC emissions of the machinery subsector can be particularly ascribed to 9 relatively big companies. The emission reduction has to be considerable to comply with the Directive. Possible measures are a switch to powder or waterbased coatings, activated carbon absorbers or incinerators for the bigger companies.

For the production and coating of metal barrels the majority of paints used nowadays contains 40% solvent. Just one company has switched to water based paint between 1990 and 2001. Emission reductions are achieved by implementation of incinerators by all large companies. The emissions in 2001 are still relatively high because one firm only put an incinerator in operation in 2002. By implementation of an incinerator the large companies already comply with legislation.

The 2 coil coat companies in Flanders already have catalytic incinerators and comply with legislation. Producers of metal furniture apply powder coatings in 99% of their total paint use and comply therefore to the Directive. The remaining subsectors of the metal sector have substantially lower VOC emissions.
Figure 3: Percentage of companies per subsector that does not yet comply with the Solvent Emission Directive and percentage of companies that already complies with or is not submitted to the SED.

The VOC emissions of the wood sector originate for 87% from the use of solvent containing paints and varnishes and for 13% from the use of adhesives. Only the plate and sheet subsector contribute to a great extent to the adhesive use. The glues used here are urea-formaldehyde based, of which 0,1% formaldehyde in a free form so that it can evaporate to the atmosphere. The greater part of the formaldehyde is chemically bound in the drying process. Urea-formaldehyde glues are not submitted to the Solvent Directive and therefore we expect the emissions are still going to increase by 2010.

The most important VOC emissions from the wood sector are emitted by the paint and varnish use of the furniture subsector. The common paint that is used here is on a nitro-cellulose basis and contains up to 80% solvents. Because the Flemish furniture subsector particularly uses hardwood e.g. oak the switch to water based paints is not easy. The surfaces would need more sanding and polishing to achieve the same smooth surface as with solvent based paints. To comply with the SED a VOC emission reduction of 50% has to be achieved towards 2010. Figure 3 shows that 31% of the companies have to reduce emissions to comply with the Directive.

In the synthetic sector (plastic) 64% of the VOC emissions originate from the use of solvent containing adhesives and 36% from the use of paints and inks. Solvent containing glues are especially used for the processing of polyurethane and polystyrene foams in mattresses, car seats, mats. These adhesives are also used for the production of laminates and gluing of PVC. As an environmentally friendly alternative hotmelts and sometimes waterbased adhesives can be used for these activities. A few large companies (more than 200 employees) have incinerators to reduce their VOC emissions. To comply with the SED, the synthetic sector has to reduce its emissions by 54%.
Table 1: Overview of the VOC emissions in 2001 and for the scenarios in 2010.

<table>
<thead>
<tr>
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<tr>
<td><strong>Metal sector:</strong></td>
<td></td>
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<tr>
<td>Automotive</td>
<td>498</td>
<td>579</td>
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<td>3129</td>
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<td>2330</td>
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<td>Barrels</td>
<td>578</td>
<td>636</td>
<td>293</td>
<td>383</td>
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<td>Heating</td>
<td>255</td>
<td>293</td>
<td>125</td>
<td>134</td>
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<td>Coil coat</td>
<td>16</td>
<td>38</td>
<td>3</td>
<td>38</td>
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<tr>
<td>Furniture</td>
<td>6</td>
<td>7</td>
<td>2</td>
<td>7</td>
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<tr>
<td>Bicycles</td>
<td>47</td>
<td>49</td>
<td>11</td>
<td>12</td>
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<td>Ships</td>
<td>17</td>
<td>17</td>
<td>11</td>
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<td>Trains</td>
<td>117</td>
<td>117</td>
<td>58</td>
<td>22</td>
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<tr>
<td>Other</td>
<td>53</td>
<td>61</td>
<td>18</td>
<td>43</td>
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<td><strong>Subtotal</strong></td>
<td>6342</td>
<td>± 679</td>
<td>7261</td>
<td>2598</td>
</tr>
<tr>
<td><strong>% compared to 2001</strong></td>
<td>/</td>
<td>+ 14.5</td>
<td>- 59.0</td>
<td>- 51.4</td>
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<tr>
<td><strong>Wood sector:</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Furniture</td>
<td>1221</td>
<td>1404</td>
<td>556</td>
<td>609</td>
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<tr>
<td>Cabinetwork</td>
<td>153</td>
<td>176</td>
<td>99</td>
<td>176</td>
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<tr>
<td>Plate/sheet</td>
<td>152</td>
<td>202</td>
<td>152</td>
<td>174</td>
</tr>
<tr>
<td>Other</td>
<td>20</td>
<td>20</td>
<td>3</td>
<td>20</td>
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<tr>
<td><strong>Subtotal</strong></td>
<td>1546</td>
<td>± 85</td>
<td>1802</td>
<td>809</td>
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<tr>
<td><strong>% compared to 2001</strong></td>
<td>/</td>
<td>+ 16.6</td>
<td>- 47.7</td>
<td>- 36.7</td>
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<td>Synthetic</td>
<td>1751</td>
<td>2014</td>
<td>532</td>
<td>808</td>
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<td>Rubber</td>
<td>819</td>
<td>942</td>
<td>819</td>
<td>236</td>
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<td>Paint shops</td>
<td>547</td>
<td>629</td>
<td>133</td>
<td>81</td>
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<td>Paper</td>
<td>37</td>
<td>42.5</td>
<td>35</td>
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<tr>
<td><strong>Subtotal industri. use</strong></td>
<td>11042</td>
<td>± 1241</td>
<td>12690</td>
<td>4926</td>
</tr>
<tr>
<td><strong>% compared to 2001</strong></td>
<td>/</td>
<td>+ 14.9</td>
<td>- 55.4</td>
<td>- 52.8</td>
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<tr>
<td>Production coatings, ink</td>
<td>2153</td>
<td>2476</td>
<td>2455</td>
<td>2202</td>
</tr>
<tr>
<td>Production adhesives</td>
<td>120</td>
<td>138</td>
<td>138</td>
<td>129</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>13315</td>
<td>± 1635</td>
<td>15304</td>
<td>7519</td>
</tr>
<tr>
<td><strong>% compared to 2001</strong></td>
<td>/</td>
<td>+ 14.9</td>
<td>- 43.5</td>
<td>- 43.3</td>
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</table>
The rubber sector uses solvent adhesives to a great extent for re-treading of tires. The use of paints is marginal in this sector. There is no alternative adhesive for this type of activity, so therefore the VOC emissions in the alternative adhesives scenario remain the same as in 2001. To comply with the SED an emission reduction of 71% has to be achieved with secondary measures like activated carbon adsorption or incinerators, depending on the amount of VOC.

Paint shops use a variety of coating types, going from solvent coatings to powder coatings. Mostly metal parts (steel, aluminium) are coated, but also components of plastic or wood belong in this sector. Therefore it is not easy to suggest measures to reduce the VOC emissions. For the use on metal parts (most important emissions) it should be possible to switch to electrostatic powder coatings.

The paper sector (except for the printing industry) uses almost exclusively waterbased inks with a very low organic solvent content. Moreover the use of adhesives is also limited to waterbased types and a small part hotmelts. VOC emissions are low, but nevertheless 25% of the companies are submitted to the SED and have to reduce the emissions of this sector with 27% compared to 2001.

To calculate the VOC emissions of the production of paints, inks and adhesives we used the above mentioned emission factors. To comply with the SED, companies have to achieve the total marginal emission value of 5% of the solvent input when the use of solvents is between 100 and 1000 tons per year. The total marginal emission value is 3% when the use of solvents is larger than 1000 tons. This means that adhesive producers already meet the SED and that only large paint and ink producers have to reduce their emissions. Therefore, the total VOC emissions are estimated to increase a little, taking the economic growth in consideration.

5 Cost curves and conclusion

In the previous chapter we calculated the VOC emission under the SED to be 43,3% lower than in 2001 or 7545 tons in 2010. Is it economically possible for the Flemish sectors to comply with the SED? For all subsectors we examined the possible primary and secondary reduction measures. Industrial examples proved that a reference value of € 5000 per ton VOC reduction is acceptable. This value points out the upper limit so that once exceeded, a measure is not cost-effective [4]. Although, if a measure costs less than € 5000 per ton this does not imply that it is feasible for all companies in a given subsector. Smaller firms have a limited turnover, gross profit, added value and the investments per year are lower than for large firms. When we look at the ratio of the reduction costs (< € 5000 per ton) and the turnover of the subsectors we see that for 6 of the 17 subsectors it is acceptable to take the suggested measures. For the remaining 11 subsectors the implementation of the measures is debatable and these should be examined at company level.
When all reduction measures with a marginal cost less than € 5000 per ton reduction will be implemented, an emission reduction of 51% compared with 2001 can be achieved. The remaining VOC emission is 6589 tons in 2010 so that can be complied with the Solvent Emission Directive at acceptable costs per ton reduction, Figure 4.

References