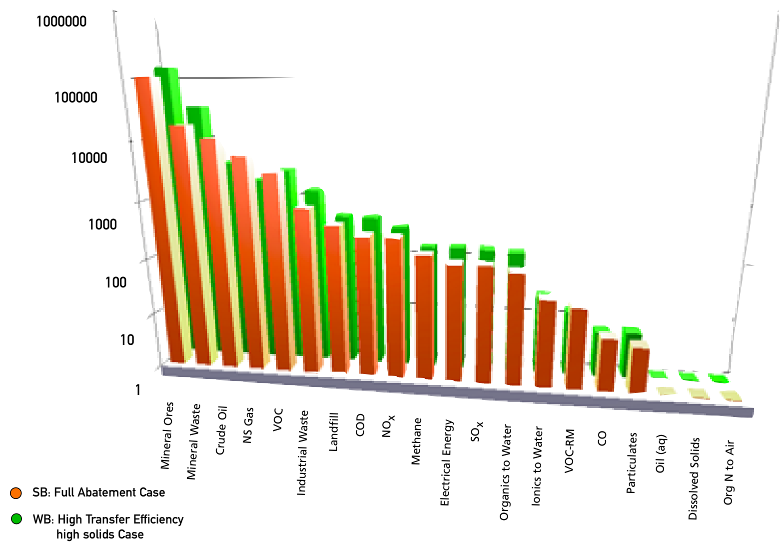
Case Study

Car Coating

A life-cycle assessment study of automotive basecoats

Functional excellence and environmental protection are guiding principles for the European solvents industry. As part of its commitment to environmental care the industry continuously explores opportunities to reduce impacts such as emissions and conserve resources by providing ever more efficient solutions for its customers. One area of focus is VOC reduction as part of Europe's broad commitment to reduce ground-level ozone peaks, a component of summertime smog.

However, the enormous array of applications and processes which rely on solvents means that it is impossible to generalise on how best progress can be made on the VOC agenda. The European Solvents Industry Group (ESIG) is a strong advocate of a flexible approach to VOC reduction. True understanding of the performance requirements, constraints, costs and environmental issues requires the expertise of those who actually operate an individual process.
This case study goes some way towards explaining this opinion. It describes work by ESIG and colleagues in both the paint making and motor industries.



Alternative coating strategies for automotive basecoats have been considered.
The results reinforce the need to take an integrated view of environmental impact and highlight the complexity of the issues; the environmental profiles of both the low and high solvent content (with abatement) systems cannot be distinguished.

Background

Life Cycle Assessment (LCA) is a technique which provides the user with a broader perspective on the environmental effects of the production and use of a product. It seeks to quantify the environmental burdens associated with a particular industrial process by taking into account activities connected with, say the manufacture of a product, from the extraction of raw materials through all process stages, use and disposal of that product.

Life cycle assessment has been used to examine the options for automotive OEM basecoats. It allows users to evaluate the environmental merits of water-based automotive basecoats compared to the traditional solvent based systems, but which can be abated, under conditions where the emission limits of the Solvent Emissions Directive will be met by both technologies.

The 'cradle-to-grave' life cycle assessment (LCA) provides comprehensive data that informs the debate for automotive basecoat painting.

The options assessed are:

Option 1: current solvent based system with abatement.

Option 2: water-based system (higher solids formulation with high transfer efficiency).

Option 3: water-based system (low solids formulation with low transfer efficiency).

Key findings

The study concludes:
there is no overall environmental benefit from either solvent based with abatement or water-based, since the emissions are about equally balanced for both.

Therefore, switching technology from unabated solvent based to either solvent based with abatement or water-based are equivalent options for VOC emission reduction.

Methodology

In comparative studies it is important to define the functional unit carefully to ensure equal or equivalent subsequent performance.

A single type of car and a single colour basecoat were selected. The same clearcoat was applied to each and is included in the scope. All coating manufacturing steps from earth resources (e.g. crude oil) to finished thinned paint are included. Both car shells are treated in the same way and with the same materials before and after the processes considered within this scope.

Functional Unit: This is defined as the paint required (base + clear system) to produce the shell of a typical sedan car. The car chosen is a popular model, a 'C' Class Sedan with $80M^2$ electrocoat area, painted in metallic silver. Systems were selected which are as close to state-of-the-art as possible while still reflecting commercial reality, allowing a fair basis for comparison. In particular this means that an identical clearcoat system for both basecoats is necessary.

Case Study Car Coating

Quality of Data: Much of the data used (for more than 60 unit chemical processes) is derived from operated plants for which actual usage data is available, as well as measured and estimated emissions data. This information has been used in preference to other sources (e.g. process economics evaluations). For a limited number of processes (including basic hydrocarbon feedstocks) published LCA studies have been used.

Formulations believed by the paint company to be representative of state-of-the-art paints have been used as the basis for the comparison. The need for commercial confidentiality has meant that guide formulations have been used, but the quality implications of this approach are only slight.

A cut-off rule of 2% has generally been applied unless there is an identifiable environmental reason to include individual minor components. A target of 96% of all raw-material mass has been achieved.

Paint usage and effluent data from two motor car assembly plants has been used as the detailed base case. However, in order to reflect variation within the industry, such as the use of different solids levels, electrostatic charging methods (particularly for water-based), further data provided by the paint company has been used. This allows the study to explore the range of current practice through defining two extra WB cases: The lowest emissions case was one employing higher solids paint with a high transfer efficiency. The other case employed low solids coating at a low transfer efficiency.

Engineering data has been used to define the energy consumptions in the study; this is justified for two reasons: Both technologies can be compared on an equal basis without reference to the particular type and age of equipment used in specific factories. Also, the difficulties (with limited metering) and cost associated with making detailed measurements on complex running lines would have been excessive.

Results

The complete inventory data is presented in Figure 1. The striking similarity between the profiles is very important since it illustrates the lack of difference in the overall environmental picture. In fact, many emissions are not significantly different at all.

A comprehensive analysis by category and impact has not been undertaken since we believe the method is still being developed and is not universally accepted. However, an overall assessment and identification of the options for improvement are assisted by some data reduction: It is important to consider only emissions where significant differences between the control measures exist.

Significant differences:
The range of current practice implies that about half the emission data can be set to one side, including CO_2 and car plant VOC. Of the remaining significantly different emissions nine are lower for the solvent based case, and a further nine are lower for the water-based system.

Emissions higher for water-based:
There are three underlying causes here.

Firstly, a more intensive use of electrical energy in the water-based cases gives higher emissions or consumptions of Total fossil energy, ashes, NOx and SOx as well as mineral ores and mineral waste. The need for an infra-red flash-off zone, which uses electrical energy for heating and air movement uses about an extra 110 MJ/car. Ultimately the kinetics of water evaporation, due to its high latent heat of vaporisation is the problem. Consumption of fossil fuel does not show a significant difference because the electrical use is balanced by the fossil fuel requirement for the solvent based system abatement unit. Secondly, amines from water-based paint give rise to ammonia and amine emissions, largely from production and application respectively. Thirdly, the lower material efficiencies achieved with the water-based system makes a significant contribution to mineral waste from the manufacture of aluminium, the main pigment.

Emissions higher for solvent based:
The higher solvent content of this system (which is not completely counterbalanced by the lower transfer efficiencies of WB) means higher emissions or consumptions of crude oil, natural gas, VOC emitted remote from car plants, oil to water, metals to water, dissolved solids, phosphates and nitrates, biocides and aqueous nitrogen. All of these arise from chemicals manufacture (including solvents) and are emitted at sites remote to the car plant.

It is interesting that (all other things being equal) one would expect all the emissions differences to reduce in size if the solids level of the coatings were increased (e.g. to US levels). This would result in more of the emissions being set aside, as not being significantly different, and so converge the environmental profiles.

Conclusion:

Recent developments in paint application technology and solvent abatement techniques make both water-based and abated solvent based coatings viable methods to meet European VOC Emission regulations. However, the results show that neither control technology has the environmental high ground.

If the two VOC control measures cannot be differentiated on environmental grounds, then performance and cost factors should be used. Realistically, cost and performance measures must always go hand in hand with environmental criteria in management decisions.

Where one of the technologies is already installed, the best approach is to prioritise options for improvement of that process: Energy demand reduction and better material usage are the two most important here.

Energy demand reduction and conservation measures that can be applied to either technology include carefully matching demand and capacity of major units such as air fans and ovens. Reformulation of clear-coats (while taking time for approval) may allow less severe cure schedules. It may be an option to take advantage of an oversized oven to explore curing at lower temperatures.

Improved material usage would include reducing the paint requirement through the use of coloured primers (if not already in use), avoiding the need to paint so much of the shell with the basecoat. Some improvements in transfer efficiency, particularly through choice of electrostatic charging method, and first run capabilities (first-time OK rates) may yet be possible with both technologies.

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