Life Cycle Environmental Assessment of Paint Processes

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INTRODUCTION

The automotive painting operation is an energy-and materials intensive operation and contributes most to the environmental emissions, compared to any other manufacturing process of a vehicle. Environmental concerns along with economic considerations for cleaner technologies led to the transition from solventborne to waterborne to powder paint coatings over the past decade to reduce plant volatile organic compound (VOC) emissions and the need for abatement equipment.

Life Cycle Assessments (LCA) are widely used for the evaluation of the environmental emissions associated with the manufacturing, use, and end of life of materials and processes. 1,2 It is a useful tool in the long-term investment decision making of corporations that seek innovative solutions to their environmental and financial problems. 3 LCA provides a holistic view of the environmental emissions associated with the manufacturing of materials and processes because it is based on the inventory of all environmental emissions involved. The environmental LCA analysis is evaluated based on industrial ecology principles, taking into account all energy and material flows throughout the production, use, and end of life of a product. 4 This is the basis of the Design for the Environment (DFE) concept, on which many corporations base their decisions for the selection of environmentally reliable and cost effective materials and processes. 5

Previous studies that addressed environmental impact analysis of automotive painting did not consider an in-depth life cycle analysis evaluation of the materials and processes involved in a typical assembly plant. 6,7 For example, in a recent study 7 the LCA assessment of the General Motors Orion Assembly Center (Lake Orion, MI) was carried out by examining the facility and management operations. Harsch et. al 7 focused on the comparison of powder, waterborne, and solventborne clearcoats. Dobson 8 examined the environmental trade-offs associated with lowering the VOC content of a plant.

The major goal of this study was to thoroughly evaluate the environmental emissions of the traditional solvent-based coatings as compared to those for alternative coatings based on water or powder, all in a greenfield automotive plant. In order to evaluate the emissions based on the LCA approach we followed the EPA SETAC (Society of Environmental Toxicology and Chemistry) guidelines in which a complete inventory of all materials that
Three paint scenarios were compared as shown in Table 1:

1. solventborne primer-waterborne basecoat—solventborne clearcoat, which is considered the baseline;
2. powder primer surfacer-waterborne basecoat—solventborne clearcoat; and
3. powder primer surfacer-waterborne basecoat—powder clearcoat.

Within scenario (2) we looked at two different colors, white and pewter, as well as two powder primer formulations, acrylic and polyester. The nomenclature of each scenario is presented in Table 1 (column 1).

Although, scenarios (1) and (2) are common in the U.S., scenario (3) may be a potential arrangement for automotive paint in future operations. The powder clearcoat is currently being investigated by the Low Emission Paint Consortium (LEPC) of the United States Consortium for Automotive Research (USCAR).

For the purposes of this study it was assumed that each scenario operates in a greenfield plant following all the standard processes essential to the operation. The LCA of the paint process consists of: (a) LCA of the materials required to paint the vehicle, and (b) LCA of the paint operation in a plant. We did not consider the fate of the painted vehicle body at the end of its lifetime. The reason is that there are no quantifiable processes that account for the separation of the paint from the metal in the shredder. Often the paint is never separated from the parts and the metal is treated with the paint on it. More importantly, the end of life LCA will be similar for all scenarios.

We made the assumption that the phosphate and the electrodeposition processes were identical for all scenarios and thus they were not included in this study. The vehicles being studied were SUVs of typical size, such as Chevy Blazers.

We made this study a generic one based on assumptions that allow the comparison of the three scenarios to be possible. The results of the analysis provided the energy and water requirements as well as the air, water, and solid waste emissions per job.

In this paper we first provide a detailed discussion of the processes involved in the paint operation for each scenario and its corresponding LCA. This is followed by the LCA of the materials. The results from the total LCA of the entire paint operation, which includes the materials and the processes, are then provided, followed by the overall performance of the scenarios and the conclusions.