ENVIRONMENTAL ASSESSMENT OF PVC AND SELECTED ALTERNATIVE MATERIALS

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Abstract

A general method was developed to assess potential adverse environmental and health effects of materials during their whole lifecycle. Through a combination of life cycle steps and consequence elements comprising: consumption of energy and materials, occupational and ecological impact, and accidential risks, an environmental profile of the materials was developed. The method was used to evaluate PVC and eleven alternative materials. The alternative materials included were the polymers PE, PP, PET, PS, and PUR, synthetic rubbers (EPDM, CR, and SBR), paper, impregnated wood, and aluminium. The environmental profiles of the alternatives were finally compared to that of PVC.

Introduction

The Danish minister of environment in 1988 announced that in a very few years the manufacturing and use of polyvinyl chloride (PVC) products should be reduced as much as technically and economically possible due to the environmental impacts of production, use and disposal of PVC. This preventive environmental policy was mainly based upon the emission of hydrogen chloride and dioxins from the incineration of waste. In Denmark, PVC introduces some 50-80% of the chlorine content of the incinerated waste. A study of the technical, economical and environmental consequences of a substitution was initiated by the National Agency of Environmental Protection in order to collect background data for the upcoming negotiations between the environmental authorities and PVC-industry and manufacturers of PVC products in Denmark. The environmental assessment focused on PVC and eleven alternative materials i.e. polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), polyurethane (PUR), synthetic rubbers (EPDM, CR and SBR), paper, impregnated wood, and aluminium.

Assessment methodology

The assessment of each material was conducted in three steps. Firstly, a screening of the life cycle for the potentially most severe impacts of the material was accomplished by consulting experts in material-, health- and environmental sciences, and a chemical profile including 4 - 5 chemicals or chemical groups characterizing the material was established. Secondly, data on the key consequen-

ces were collected and evaluated from readily available literature and interviews with experts from Danish Technological Institute, the industry, and environmental authorities. Finally, the evaluation of each material was used to develop an impact profile for the material as such, and for each of the alternative materials a comparison to PVC was made.

The specific assessment matrix used for the screening and for the final evaluation combines six steps of the life cycle with six consequence elements as illustrated in figure 1 with PVC as an example. In the matrix, key impact areas are shown using a four-level scale indiation i.e. potential for severe impact (---), potential for impact (-), potentially no impact (0), and lack of knowledge or insufficient data (?). The data collection is concentrated on the severe impact potential areas of the screening, but also the question marks have to be given special attention.

Figure 1. Specific matrix for an environmental assessment of PVC

	Consumption of resources	Work Environment		External Environment		Accidents
		Exposure	Effect	Exposure	Effect	
Production of raw materials	60 GJ/T					
- polymer.		-	- - -	- - -	-	- - -
- compound.		-	-	-	-	-
Production of semi-products	9					
- injection		-	-	0	0	-
- extrusion		-	-	0	0	-
- blow extr.		-	-	0	0	-
- kalandr.		- - -	- - -	-	0	-
Manufacturing of final products	?	-	-	-	0	-
Use	0	-	-	0	0	- - -
Recovery	?	-	-	-	-	0
Waste						
- incinerat.	-10,8	?	?	-	-	-
- landfill.	?	0	0	-	-	0
- composting	?	0	0	- - -	- - -	0

In the final comparison of the alternative materials with PVC, the exposure and effect part of work and external environment are combined, resulting in a more simple relative assessment matrix. For the final relative assessment profile a scale going from potentially much lesser impact than PVC (+ + +) to potentially much greater impact than PVC (---) is used.

Some important limitations of the methodology shall be mentioned:

- Problems are seen retrospectively and are not assessed for individual products, industries, or countries. Through implementation of new abatement or cleaner technologies the described situation can be different from an average situation to a nationally specified situation.

- Especially for several of the alternative materials the amount of data is insufficient for a thorough evaluation, and despite the expert consultations some problems might have been overlooked or not selected for in-depth studies.

- The assessment does not include activities and impacts in the petrochemical industry (the plastics), in mining (aluminium), or in forestry (paper and wood), and for each material some specialized products introducing new or higher concentrations of additives can be envisaged but are not included in the material assessement.

- The assessment of energy and material consumption is limited to the amount of energy (or resources) used and does not include the type of energy e.g. coal-fired or water-based power plants, which do have substantially different impacts on the environment. Also, no risk analysis of probabilities and consequences of accidents at specified plants are included, and the assessment of accidents only indicates the possibility of severe events of fire, explosion or dispersal of toxic substances.

Results and discussion

The evaluation of PVC is based on a substantial amount of literature but almost excludes data from the involved industries, as only few data were available. The potentially severe impact areas of production and compounding of PVC were found to be the exposure to the carcinogenic vinyl chloride monomer in the work environment and the discharge of dioxins in waste water. Other major problems are exposures to vinylchloride, chlorine or hydrogen chloride, heavy metals, phosgene and dioxins generated in accidents (e.g. fires), or in the production and use of PVC. Finally incineration of PVC-containing waste generates hydrogen chloride, dioxins and heavy metals which are emitted to the atmosphere or contaminate incinerator ashes or filter residues.

Among the alternative materials evaluated only PE, PP, PET, and EPDM (ethylene-propylene-diene) represent environmentally acceptable materials preferable to PVC. Use of halogen-based flame retardents in special products as well as possible exposures to neurotoxic n-hexane and carcinogenic benzene at production and processing of EPDM could change this evaluation.

Through the life-cycles, polystyrene, impregnated wood, paper, and aluminium all represent both improvements and potential pollution problems compared to PVC. PS production requires more energy, some typical products are expanded with CFC (chloroflurocarbons) or azodicarbonamide (a sensitizing agent) with severe external and work environment impacts, respectively. Styrene is suspected to cause damage to reproduction. Manufacturing of impregnated wood involves high exposure to wood dust supposed to be carcinogenic, and accidential releases of tributyltin (wood preservatives) constitutes a major risk to the aquatic environment. Traditionally, paper production is dominated by sulfate-mass and chlorine-based bleaching resulting in waste water strained with oxygen-consuming pollutants and chloroorganics e.g. dioxins. Recently, serious problems in the work environment of waste paper processing industries have been reported in Denmark, where waste water discharges have been minimized through introduction of closed-loop water systems. Production of virgin aluminium involves a very high energy consumption, and the work environment includes severe potentials of exposures to carcinogenic polyaromatic hydrocarbons (PAH's). Furthermore, approximately only one fifth of the raw material ends up in the final product, and the production thus results in major amounts of solid waste and sludge to be disposed of.

PUR implies occupational exposure to highly toxic isocyanates in the production, processing, manufacturing, and in fires. Also, PUR is commonly expanded with CFC, and halogen-based flame retardents are frequently used. Thus, PUR is not a recommendable alternative material to PVC. A similar conclusion is drawn for the synthetic rubbers CR (chloroprene) and SBR (styrene-butadiene) involving carcinogenic substances in the work environment of production and processing (vulcanization). Also, CR probably generates hydrogen chloride and dioxins when incinerated or burned.

Conclusion

Of the selected alternatives only PE, PP, PET, and EPDM represent evident improvements when compared to PVC with respect to environmental effects. Polystyrene, impregnated wood, paper, and aluminium have some advantages when compared to PVC, but potential problems necessitate further evaluation on product level. Polyurethanes, CR, and SBR cannot be recommended as alternatives to PVC.