PVC Plastic: a Looming Waste Crisis

PVC Recycling - Solving a Problem or Selling a Poison?

PVC has been under severe pressure since the 1980s, on environmental grounds. In order to maintain its market position, the PVC industry has had to react against this pressure, and it therefore launched a public campaign to "green" PVC, with recycling at its centre.

The role of recycling in "greening" the PVC industry is best illustrated by the leaked minutes of a Solvay meeting held in Brussels in 1990. The minutes state: "After, M. Brouillot, a trade union representative remarked that this project (PVC recycling) is not economically viable. It is necessary, however, for its publicity and educational value". M. Bonny, a senior manager, added that the PVC recycling operation is 'for enhancing the public profile of PVC which is now under frequent attack' (Solvay 1990). Another leaked Solvay document, dated April 1992, outlines a strategy for a proposed public relations campaign to restore the image of PVC. This strategic plan includes recycling demonstrations, reports, workshops, conferences and a "media attack on journals read by opinion leaders" as a key strategy (Solvay 1992).

This strategy, as outlined by Europe's market leader in PVC, Solvay, seems to be a guiding principle for the industry world-wide. The industry is involved in all major PVC recycling schemes, and claims that they demonstrate PVC can be, and is being, recycled: " The steadily increasing number of PVC recycling projects around Europe, however, provide a very adequate demonstration that PVC can be recycled as safely and as readily as the other commodity plastics" (Norsk Hydro 1995). "PVC can readily be recycled, and can also be separated from mixed plastic wastes" (PACIA 1996). "Demand for recycled vinyl far outstrips supply" (Vinyl Institute 1993).

This recycling "strategy" seems to be paying off for the PVC industry. Governments, local authorities, PVC product manufacturers and consumers are now involved in recycling projects; in the countries which have the most advanced policies on PVC, like Germany, Denmark, the Netherlands and Austria, recycling is the centrepiece of these policies. The key role of PVC recycling for decision-makers is illustrated in the Dutch EPA's position on PVC (Zoeteman 1993): "The main feature of this policy is that PVC applications for which no feasible system of recycling and re-use can be established, the use of more environmental-sound alternative material is to be preferred." The Dutch government recently reconfirmed this policy in a PVC position paper (VROM 1997)

But does PVC recycling solve an environmental problem, or is it an empty claim which merely prevents or postpones the adoption of more stringent measures?

This report examines the latest advances in PVC recycling, and analyses the looming PVC waste crisis.

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PVC Recycling: a Cycle of Problems

For safe and useful materials, recycling is a beneficial activity, which governments and industry should promote and undertake. However, in the case of toxic materials, it simply perpetuates the toxic production of environmental poisons. Promotion of PVC recycling is a prime example.

A distinction should be made between 'post-consumer recycling' - the recycling of used products - and 'pre-consumer recycling' - the recycling of production waste. Pre-consumer recycling can be seen as optimising the efficiency of material use in manufacturing processes, while post-consumer recycling is the popular definition of recycling to conserve resources. Mechanical recycling in this report refers exclusively to post-consumer recycling. However in reality, most of the PVC recycling figures reported include pre-consumer PVC waste, which is recycled in the production process.

The recycling of post-consumer PVC poses particular technical and financial problems. More than half of the mass of pure PVC consists of chlorine, which affects its disposal in general. Final PVC products can also contain up to 60% of additives in all kinds of different combinations, (depending on their application and manufacturer) which also affects their disposal and recyclability. In addition, its melting point makes PVC incompatible in mixed plastics recycling.

PVC has the lowest recycling rate of all commodity plastics. At present, according to the plastics industry, only 6% of all plastics use in western Europe is mechanically recycled (APME 1996b). PVC has the lowest recycling rate of any commonly-used plastic: only 0.6% of consumption in western Europe (Sofres 1995). In the USA, only 0.6% of PVC in packaging is recycled (RW Beck 1996). In the same study, total post-consumer PVC recycling was estimated at 4,300 tonnes in 1995 (RW Beck 1996) - around 0.1% of the total US PVC consumption of approximately 4,300,000 tonnes. In Australia, only 0.25% of PVC consumption is recycled (Bie 1994). The European, US and Australian figures show a lower recycling rate for PVC than for any other of the commonly-used plastics.

PVC is incompatible with the potential recycling of other plastics in mixed plastic recycling. PVC cannot be mechanically recycled with other common thermoplastics like PE and PP (polyethylene and polypropylene) because of the differences in moulding temperatures. The moulding temperature of PVC is between 180 and 210 degrees

centigrade, whereas all the others (PE, PP, PS (polystyrene)) can be processed together within the temperature range of 220 to 260 degrees centigrade (Moller and Jeske 1995). At these temperatures, PVC starts to decompose (a process known as dehydrohalogenation), forming hydrochloric acid (HCl), which is highly corrosive to the equipment. Consequently PVC effectively sabotages the potential recycling of other plastics.

A common problem is the incompatibility of PVC with PET (polyethylene terephthalate) recycling. At the high PET processing temperature of 250 degrees centigrade or above, PVC degrades. If the PET is contaminated with PVC, it will leave black particles in the otherwise clean resin. As little as 20 parts per million - around one PVC bottle for every 50,000 PET bottles - can ruin recycled PET (Nir et al. 1993). PET and PVC cannot be separated by normal flotation methods, because they have similar densities, so special techniques have had to be developed to remove PVC in PET recycling, such as automated sorting based on colour, and detection of the chlorine atom in PVC using X-ray analysis (Nir et al. 1993). PVC thus makes the recycling of PET and other plastics more expensive.

High collection and separation costs. European experience shows that mixtures of lightly and heavily soiled plastic waste containing PVC can only be separated at great expense. This creates, on the one hand, a more or less clean PVC fraction, and on the other, a recyclable fraction of other plastics. In Germany, experience with packaging waste has shown that separation for recycling costs about DM 800 per ton, not including logistical costs (Menges 1996), which is very expensive. For this reason, PVC recycling basically focuses on products that can be collected separately, such as windows and pipes, and to some extent bottles. It appears, at present, that only PET and HDPE (high density polyethylene) recyclate is of a high enough standard to be used for high quality products. The physical properties of recompounded HDPE may be in the same range as the virgin polymer (Howell 1992). Currently, about 90% of mechanical plastic recycling in Europe involves the polyolefins (PP, PE) and PET. In the USA, PET recycling has been the most successful of all plastics and manufacturers are substituting PET for other resins in a number of packaging products (Nir et al. 1993).

Recycled PVC more expensive than virgin PVC, but lower quality. Recycled PVC from packaging and construction materials is a mixture of different grades, additives, plasticisers, and some fillers. It never achieves the performance given when specifically selected grades and additives are formulated together to meet a well-defined and specific purpose. The market value of recycled PVC will therefore always be well below that of primary PVC (SRI International 1993).

In Germany, the market value of regranulate is roughly 70% that of virgin PVC. But the cost of mechanical recycling (including collection and transportation) is estimated at DM 3-4 per kilogram of PVC, while the cost of virgin PVC fluctuated between DM 1.00 and 1.80 /kg in 1990-1992 (Pohle 1997). This means that in Germany PVC recyclate can only be sold at 70% of the price of virgin PVC even though it is some 200-300% more expensive.

Virgin PVC is mixed with additives to produce materials with physical properties suited to specific applications. There are literally thousands of formulations available (Ehrig 1992). Anyone wishing to use recycled PVC will therefore inevitably require a quality profile that comes as close as possible to that of a specific virgin material. Since this is unlikely to be achieved in practice, two options remain open, depending on the quality of the product (Menges 1996): remelt it directly into 100% recyclate and create products of lower quality with little market value; or mix it with virgin PVC into a compound material. The first option spreads toxic additives into new areas while creating low quality products; the other generally requires the input of large quantities of new material. This is not recycling.

Downcycling

Direct remelting in the form of 100% recyclate usually results in low quality products. Examples include plastic park benches and bird cages, products which have traditionally been made from other materials. This form of recycling may simply shift the disposal problem into another, more unmanageable waste stream. A good example is the recycling of PVC bottles into pullovers, made of 70% PVC recyclate. This recycling scheme replaces a chlorine-free material with a chlorinated material, with all the associated waste management problems (Pohle 1997). PVC recycling also helps to spread toxic additives into new areas and products. For example, dangerous levels of PCBs, dioxins and other hazardous substances were found in products made from recycled PVC cables, such as bird cages, in Germany in 1994 (Die Zeit 1994).

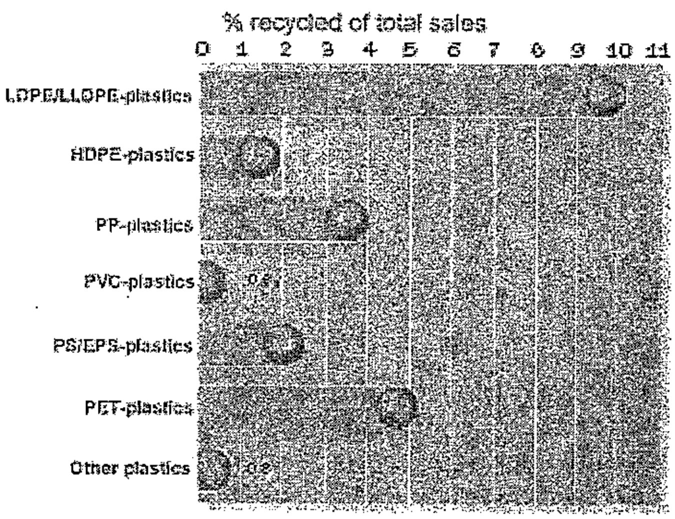
New markets for downcycling are booming in developing countries. There, plastic scrap is being downcycled into shoes and other short-life products that may end up in the waste stream in a few years' time.

Recycled PVC wrapped up in virgin PVC. To produce high quality products from PVC recyclate, like windows and pipes, virgin PVC is needed. It is therefore highly doubtful whether PVC recycling will result in a decrease in PVC production. Pipes can contain up to 60% of regranulate, according to the industry, and need at least 40% virgin PVC. According to the industry, recycled window frames can contain up to 80% of PVC recyclate from used windows, but need additional virgin PVC to achieve the required quality. However, in practice even this is not happening to any significant degree, as can be seen in the example of the German 'recycled' window frames (see Chapter 4).

Another obstacle for PVC recycling is that old material can contain relatively high levels of additives, such as lead and cadmium stabilisers and PCB's, which would contaminate new products in which thoses additives have been reduced or eliminated (SRI International 1993, Kaiser et al. 1993). For this reason, PVC recycling of cables and old windows may be restricted in countries where these additives are regulated, banned or restricted. A prime example is Austria, that does not use post consumer PVC windows regranulate because of the lead and cadmium content of old windows (see next chapter). More additives are likely to be classified as hazardous, such as chlorinated paraffins (OSPAR) and phthalates (Denmark), and this may further restrict the potential for PVC recycling in future.

Chemical recycling - an expensive, polluting and energy consuming attempt to convert plastic waste into raw materials: chlorine in PVC makes it all the more dangerous. Chemical recycling (or feedstock or raw material recycling) of plastics is a growing area of research. The aim is to recycle mixed plastics into hydrocarbons, which are raw material for the petrochemicals industry. The energy used to produce and manufacture the product is destroyed in chemical recycling; therefore, from a energy perspective, it is less advisable than mechanical recycling. Chemical recycling processes take place at high temperatures - 500-900 degrees centigrade - and dioxin may form in some stages if PVC or other chlorine sources are present.

PVC also creates problems in chemical recycling because of the formation of hydrochloric acid. This is corrosive to process equipment and poses a problem when released into the environment. Depending on the facility, the chlorine content in the mixed plastics feedstock may range from parts per million (ppm) up to a few per cent. Also, too much chlorine in the hydrocarbon end product can pose a problem for refineries because it may disrupt catalytic processes (Pohle 1997).



Post-consumer plastic recycling in Europe

Pyrolysis is a thermal process that takes place at 500-900 degrees centigrade, without oxygen. Mixed plastics can be pyrolysed into hydrocarbons (oil), soot, etc. If PVC is present, hydrochloric acid and chlorinated hydrocarbons are also produced; hydrochloric acid needs to be removed from the pyrolysis gas, but this removal process can result in the formation of dioxins (Pohle 1997). The main end product of pyrolysis is oil for the oil industry. The chlorine content in this end product needs to be kept low - below 10 ppm - otherwise it will disrupt the cobalt/molybdenum catalysts in the refinery. Mixed plastic waste that contains PVC needs to be pre-treated by removing PVC and other halogenated plastics from the feed or by degradative extrusion. However, dioxin formation cannot be excluded and it is expensive (Pohle 1997). Oil from the pyrolysis of soft PVC may contain up to 60% softeners (Pohle 1997). The only pyrolysis plant currently in use is the Fuji-Recycling pilot plant in Aioi, Japan, with a capacity of 1000 t/a (Pohle 1997). In the hydration process, mixed plastics are reprocessed into hydrocarbons and hydrochloric acid by hydration under pressure of 200-400 bar, at about 500 degrees centigrade. A 90% oil recovery is possible from mixed plastics, which can contain up to 1% PVC (Pohle 1997). According to a rough estimate, the energy balance for PVC may be negative (Pohle 1997).

Chemical recycling is more expensive then mechanical recycling: DM 1.00-1.50 /kg compared to DM 0.70-1.00/kg (excluding logistical costs, Pohle 1997). BASF spent DM 40 million in the development of a pilot plant in Ludwigshafen based on hydration. However, it had to cancel its upgrading because of competition from the steel industry, which uses plastic waste as a chemical reducing agent, to replace fuel at half the price BASF charges (Chemical Week 1996). In December 1996, BASF announced it was calling a halt to the entire project (European Chemical News 1996).

Environmental and worker health impacts of recycling. The hazards associated with mechanical recycling are similar to those for primary plastics processing, which may include air emissions, water discharges and worker exposure. Hydrogen chloride can be released during crushing and grinding of PVC (Kollmann et al. 1990).

More emissions are generated by extrusion-based processes than by those involving injection moulding (Forrest et al. 1995). Elevated levels of dioxins and furans were also found in a German workplace where post-chlorinated PVC was being extruded. The dioxins were thought to originate from the PVC resin (BF Goodrich 1992). However, the few available data indicate that there is a low dioxin formation (0,0001 - 0,037 ng TE/m3) in PVC product manufacturing (Länderausschusses für Immissionsschutz 1993). Elevated dioxin levels in soils were also found near four PVC product manufacturers in Baden-Württemberg, though the level of background contamination was not established in this study (LFUBW 1993). However, these are strong indications that these PVC product manufacturing plants may be significant dioxin sources, and more research is needed. It should not be ignored, either, that dioxins can form as a result of overheating during malfunctioning of the recycling processes (Pohle 1997).

In a recent case-control study in Sweden among workers in plastic product manufacturing, an increased risk of testicular cancer was found among PVC workers. Exposure to other plastics than PVC did not significantly increase the risk of testicular cancer (Hardell et al. 1997).

PVC increases toxic emissions in other recycling processes such as steel smelting, car reclamation and cable recycling. PVC can be a source of contamination in the recycling processes of other materials. A Finnish study found that a large amount of chlorinated aromatic compounds - such as dioxins, furans, PCBs and pentachlorophenol - are formed because of PVC plastic in cables and car compounds in metal reclamation (Aittola et al. 1993). From the available data, it can be concluded that, in steel melting processes, dioxin emissions increase as contamination from chlorinated compounds (of which PVC was identified as a significant source) increase. Substitution of alternatives to PVCin cars' undercoating could significantly reduce this chlorine input (Pohle 1997).

There is an increase in contamination before and after shredding cables into PVC fraction and copper fraction. High amounts of PCBs, chlorobenzenes and PAH were found. This contamination is primarily associated with PVC cables: PE cables only contained negligible amounts of the hazardous substances (Kaiser et al. 1993). Because of laws limiting the PCB content of products, this will seriously affect the possibility of re-using PVC cable shredding waste.

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