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GREEN PAPER

Environmental issues of PVC

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1. INTRODUCTION

The Commission has committed itself to assess the impact of PVC on the environment, including related human health issues, in an integrated approach. In the Proposal for a Directive on end of life vehicles¹, it is stated that “*the Commission will consider the evidence regarding the environmental aspects relating to the presence of PVC in waste streams; on the basis of the evidence, the Commission will review its policy regarding the presence of PVC in waste streams and will come forward with proposals to address problems which may arise in this regard.*” In the Council Common Position on that Proposal², it is further stated that “*the Commission is currently examining the environmental impacts of PVC. The Commission will, on the basis of this work, make proposals as appropriate as to the use of PVC including considerations for vehicles*”.

PVC has been at the centre of a controversial debate during much of the last decades. A number of diverging scientific, technical and economic opinions have been expressed on the question of PVC and its effects on human health and the environment. Some Member States have recommended or adopted measures related to specific aspects of the PVC life cycle. These measures are not identical and some of them may have consequences for the internal market. An integrated approach is therefore necessary to assess the whole life cycle of PVC in order to develop the necessary measures to ensure a high level of protection of human health and the environment as well as the proper functioning of the internal market.

The two objectives of this document are, firstly, to present and assess on a scientific basis, the various environmental issues including related human health aspects that occur during the life cycle of PVC and, secondly, to consider, in view of sustainable development, a number of options to reduce those impacts that need to be addressed. This should serve as a basis for a consultation with stakeholders in order to identify practical solutions to health and environmental issues raised by PVC.

2. THE PVC INDUSTRY AND ITS PRODUCTS

2.1. *PVC material and its applications*

Polyvinyl chloride (PVC) is a synthetic polymer material (or resin), which is built up by the repetitive addition of the monomer vinyl chloride (VCM) with the formula $\text{CH}_2\text{-CHCl}$. PVC has thus the same structure as polyethylene except for the presence of chlorine. The chlorine in PVC represents 57% of the weight of the pure polymer resin. 35% of chlorine from the chloralkali electrolysis eventually ends up in PVC, which thus constitutes the largest single use.

¹ COM (97) 358 final
² EC 39/1999

Pure PVC is a rigid material, which is mechanically tough, fairly good weather resistant, water and chemicals resistant, electrically insulating, but relatively unstable to heat and light. Heat and ultraviolet light lead to a loss of chlorine in the form of hydrogen chloride (HCl). This can be avoided through the addition of stabilisers. Stabilisers are often composed of salts of metals like lead, barium, calcium or cadmium, or organotin compounds³.

The mechanical properties of PVC can be modified through the addition of low molecular weight compounds that mix with the polymer matrix. Addition of these so-called plasticisers in various amounts generates materials with an important versatility of properties that has led to the use of PVC in a vast range of applications. The main types of plasticisers used are esters of organic acids, mainly phthalates and adipates⁴.

The main distinction between the numerous applications is between « rigid PVC » (accounting for about two thirds of total use) and « flexible PVC » (accounting for about one third).

The following table presents the main applications of PVC in Europe and the percentage of overall use. The great number of applications is characterised by a wide range of lifetimes ranging from several months to more than 50 years for some construction products. The main applications of PVC in Europe are in the building sector, which accounts for 57% of all uses and where products also have the longest average lifetimes.

Table 1: Main use categories of PVC in Europe (1999)⁵

Use / application	Percentage	Average life-time (years)
Building	57	10 to 50
Packaging	9	1
Furniture	1	17
Other household appliances	18	11
Electric/Electronic	7	21
Automotive	7	12
Others	1	2-10

2.2. *Production processes of PVC and PVC compounds*

Mass production and use of PVC took off in the 1950s and 1960s, whereas the first industrial production started in the 1930s.

World production of PVC today is at more than 20 million tonnes per year - up from 3 million tonnes in 1965 - which corresponds to about one fifth of the total plastic production. PVC is thus one of the most important synthetic materials. Production is mainly located in the US, Western Europe and Asia. Production in Western Europe in 1998 was 5.5 million tonnes (about 26% of the world production). Average growth rates of PVC production in recent years have been between 2 and 10%, with

³ More details and quantities will be discussed in section 3.

⁴ More details and quantities will be discussed in section 3.

⁵ Prognos, Mechanical recycling of PVC wastes, Study for DG XI, January 2000

differences per region (higher in Asia, lower in Europe) and per application (higher for rigid, lower for flexible). Prices for virgin PVC are extremely cyclical due to variations in supply and demand and prices for the raw materials.

Two main processes are used to produce PVC: suspension polymerisation of VCM (80%) and emulsion polymerisation (10%).

The production of VCM from ethylene and chlorine, or ethylene and HCl respectively, takes place to a great extent in closed industrial processes. Emissions of chlorine, ethylene, ethylene dichloride, HCl, VCM and chlorinated by-products including dioxines to the working environment or the outdoor environment can occur (air and water). Several of these chemicals are well known toxic substances⁶ and strict emission control measures are therefore necessary. Several Community Directives apply to PVC and VCM production processes⁷.

As in other sectors of the chemical industry, continuous improvements in the production processes have taken place over the years. Best available technologies for the production of VCM and suspension PVC have been established, which have led to the adoption of a number of relevant emission limits in OSPAR Decisions (Convention for the protection of the marine environment of the north-east Atlantic)⁸. A voluntary commitment was already signed in 1995 by the Association of European PVC producers (ECVM). In this industry charter for production of VCM and PVC (suspension), strict emission limits for a number of chemicals were set, which had to be complied with by 1998. Compliance was verified through an independent audit, which attested an overall compliance of 88% with all standards. ECVM has expressed its intention to achieve full compliance as soon as possible. In addition to the charter for VCM and suspension PVC production, ECVM signed in 1998 a charter for the production of emulsion PVC with strict emission limits for VCM to air and water, and VCM content of the final polymer. Those companies, which, although already complying with existing national and local regulations or requirements, do not yet comply with the stricter limits of the voluntary charter, committed themselves to do so by 2003. An independent external verification is scheduled for early 2004.

Raw PVC is processed into finished products in several steps. The addition of the necessary additives is called PVC-compounding. PVC is a thermoplastic material, i.e. upon heating it melts and can then be brought into many forms and shapes through various processes. After cooling, the material regains its original properties.

⁶ According to Dir. 67/548/EEC, VCM is classified as carcinogenic category 1, EDC as carcinogenic category 2, HCl as corrosive and irritant to the respiratory system,

⁷ Protection of the health of workers exposed to vinyl chloride monomer. Council Directive 78/610/EEC of 29.6.78 (OJ L 197 of 22.7.1978, p. 12)

The provisions of Directive 96/61/EC concerning integrated prevention and reduction of pollution, Directive 76/464/EEC and 86/280/EEC on discharges of certain dangerous substances and Directive 84/360/EEC on the combating of air pollution from industrial plants apply to PVC and VCM production processes. Directive 91/61/EC establishes the application of best available techniques (BAT) as the general rule for emission limits. Information concerning BAT for large volume organic chemicals will be published by the Commission in 2001/2002, as part of the BAT information exchange being organised pursuant to Article 16 (2) of Directive 96/61/EC. It is possible that new emission limits will then be adopted in accordance with Article 18 of the Directive.

⁸ Decisions 98/4 and 98/5 enter into force on 9 February 1999 for new plants and on 1 January 2006 for existing plants. The Commission, in its Proposal for a Council Decision [COM(1999) 190 final], proposes that these Decisions are approved on behalf of the Community

A large number of different methods that use this principle are employed in the transformation of PVC, notably extrusion, calendaring, injection moulding, blow moulding, rotation moulding, thermoforming, and film blowing.

During compounding and further transformation, emissions of a number of dangerous substances and therefore exposure of workers can occur. Compounding of PVC powder and additives (also in powder form or liquid) is usually carried out in closed equipment. Exposure of workers can occur when dosing the compounds in the mixer. This can be eliminated or reduced to a minimum in accordance with the provisions of Council Directive 98/24/EC⁹ on the protection of the health and safety of workers from the risks related to chemical agents at work.

In cases of over-heating during conversion of PVC through heating, forming and cooling, there is a risk of emission of a number of degradation compounds, where HCl is the most important one. However, the amounts generated are small and have a low potential of adverse effects on the environment. The amounts of VCM rest monomer emitted during the conversion are considered to be very low¹⁰. The emissions of stabilisers and plasticisers are also small if appropriate measures are taken. In general, workforce protection measures have to be taken, in order to comply with the existing legislation on workers and environment protection¹¹.

2.3. *Structure and description of the PVC industry*

Recent statistics produced by the PVC industry estimate that the total PVC producing and transforming industry in Western Europe comprises more than 21.000 companies with more than 530.000 jobs and a turnover of more than 72 billion €. The industry can be roughly divided into four groups: PVC polymer producers, stabiliser producers, plasticiser producers, and PVC transformers.

PVC polymer is produced by a relatively small number of companies, mostly located in Europe, the US, and Japan. Production capacity in developing countries is growing steadily as well. Annual consumption in Western Europe is slightly higher than production, and since the early 1990s, imports have been higher than exports leading to a small net import of about 230.000 tonnes in 1998 (when domestic production was around 5.5 million tonnes)¹². Several manufacturers are integrated in the chlorine or petrochemical industry and also produce ethylene, chlorine and VCM monomer. In 1999, there were 10 companies producing VCM and PVC, operating 52 plants on 40 sites in 10 Member States and Norway and employing about 10,000 people.

Eleven European companies (22 plants) produce more than 98% of the stabilisers sold in Europe. They employ around 5.000 people for a production of 160.000 tonnes of stabiliser formulations and a turnover of about 380 million €.

In 1999 there were about 20 companies producing about 1 million tonnes of plasticisers in Europe, the three biggest accounting for about 40% of overall

⁹ JO L 131 of 5.5.1998, p. 11

¹⁰ Danish Environmental Protection Agency, Environmental Project No. 313, Environmental Aspects of PVC, 1995.

¹¹ Danish Environmental Protection Agency, op.cit.

¹² Source: ECVM, based on data provided by EUROSTAT.

capacity¹³. The number is decreasing: smaller companies are abandoning the products or are being bought by big companies. It is estimated that about 6,500 people are employed by this industry. The production trend from 1990 to 1995 was an annual increase of 1.5%. Western Europe is a net exporter of plasticisers.

The transformation of PVC into final products, which requires two or three different manufacturing operations, is essentially done in more than 21,000 small and medium sized enterprises. Ninety per cent of these SMEs have less than 100 employees, 5% have between 100 and 500 employees, and 5% have more than 500 employees. Table 2 summarises the information regarding the number of companies, production and employment of the whole PVC industry chain.

Table 2: PVC industry: companies, production, employment¹⁴

Products	Companies	Production (tonnes)	Employment
Total PVC	21,199	7,900,000	530,000
Flexible products	10,321	3,700,000	260,000
Rigid products	10,878	4,200,000	270,000

3. THE USE OF ADDITIVES IN PVC

3.1. *Range and types of additives*

In order to provide the range of properties needed in the finished products, PVC polymer is mixed with a number of additives. Depending on the intended application, the composition of the PVC compound (i.e. resin + additives) can vary largely due to the different quantities of additives that are incorporated into the polymer as fillers, stabilisers, lubricants, plasticisers, pigments or flame retardant. A very large number of different formulations of PVC compounds are used to manufacture products. The use of plasticisers (mainly phthalates) and stabilisers in rather high quantities constitutes a specific characteristic of PVC manufacturing compared to other types of plastics. All other types of additives are also used to varying extent with other plastic materials.

The most important categories of additives, which need to be assessed scientifically in terms of hazardous characteristics and risks to human health and the environment, are stabilisers, in particular those containing heavy metals such as lead and cadmium, and plasticisers, mainly the phthalates.

3.2. *Stabilisers*

Stabilisers are added to the PVC polymer in order to prevent degradation by heat and light. Different types of stabilisers are used and their content in the final product varies according to the technical requirements of the intended application.

¹³ Information received from the European Council for Plasticisers and Intermediates
¹⁴ Information received from the association of European Plastic Converters (EuPC)

Lead stabilisers are currently the most widely used, in particular lead sulphate and lead phosphite. About 112,000 tonnes¹⁵ of lead stabilisers were used in Europe in 1998, containing about 51.000 t of lead metal and representing 70%¹⁶ of the overall stabiliser consumption. With an overall consumption of lead of about 1.6 million tonnes in Europe in 1995¹⁷, lead stabilisers thus account for about 3% of the total consumption. Lead stabilisers are used mainly in pipes, profiles and cables.

Cadmium stabilisers are still being used by some producers as stabilisers in PVC window frames, where their use is still permitted by Community legislation. In Europe, use of cadmium has largely decreased from about 600 t/a in 1992¹⁸ to 100 t/a in 1997 and 50 t/a in 1998.

About 14,500 tonnes of mixed metal solid stabilisers and 16,400 tonnes of liquid stabilisers were used in 1998 in Europe^{19,20}. Among these types of stabilisers, calcium/zinc and barium/zinc systems are the most commonly used.

Organotin compounds represent, with a consumption of 15,000 tonnes²¹ about 9.3% of the European consumption of stabilisers. Various types of organotins, in particular mixtures of mono- and di-organotin compounds, are used as stabilisers, mostly in rigid packaging film, bottles, roofing, and clear rigid construction sheeting.

According to Council Directive 67/548/EEC on the classification and labelling of dangerous substances as amended²², most lead compounds including those used in PVC are classified as toxic to reproduction, harmful, dangerous for the environment (ecotoxic) and presenting a danger of cumulative effects. Lead is persistent and certain lead compounds accumulate in certain organisms.

Most cadmium compounds are classified according to Council Directive 67/548/EEC as harmful and dangerous for the environment (ecotoxic). Other cadmium compounds are classified as being harmful, toxic or very toxic. Some compounds are also classified as carcinogens (category 2). Cadmium is persistent and certain cadmium compounds accumulate in certain organisms.

Data on the organotin compounds used as stabilisers in PVC show that dioctyl tin is toxic to the immune system. Such immunotoxic effects have not been observed for the other organotin compounds used as PVC stabilisers (dimethyl tin, dodecyl tin, monobutyl tin). Dioctyltin compounds present a possible environmental risk locally in the aquatic environment.

A distinction has to be made between the hazards and risks from chemical substances. At present, no comprehensive risk assessments have been completed on

¹⁵ Donnelly, J.P. (1999): Risk Assessment of PVC Stabilisers during Production and the Product Life Cycle. Proceedings of OSPARCOM workshop

¹⁶ European Industry Position Paper on PVC and Stabilisers. ECVM. Document produced by the ECVM in conjunction with ELSA and ORTEP, 1997

¹⁷ Eurometaux, Annual report 1999.

¹⁸ OSPARCOM workshop on cadmium 1997

¹⁹ Figures provided by the European Stabilisers Producers Association (ESPA)

²⁰ Donnelly, J.P. (1999): Risk Assessment of PVC Stabilisers during Production and the Product Life Cycle. Proceedings of OSPARCOM workshop

²¹ Donnelly, J.P. (1999): Risk Assessment of PVC Stabilisers during Production and the Product Life Cycle. Proceedings of OSPARCOM workshop

²² OJ L 196, 16/08/1967, p. 1.

the use of cadmium and lead compounds as stabilisers in PVC products. Under Council Regulation 793/93 of 23 March 1993 on the evaluation and control of the risks of existing substances²³, a risk assessment is being finalised on cadmium and cadmium oxide. For lead, the Scientific Committee on Toxicity, Ecotoxicity, and the Environment (CSTEE) has recently adopted an opinion regarding a draft ban on the use of lead in products in Denmark²⁴. The CSTEE is currently working on the issue of risks from the use of lead in general and an opinion, building *inter alia* on a study to be commissioned by the services of the Commission, should be adopted by mid-2001 on both the environmental and human health risks of lead.

As for most heavy metals, cadmium and lead are emitted to the environment by many sources other than their use in products, that contribute significantly more to the dispersion of these heavy metals in the environment, e.g. industrial activities, petrol, fertilisers and sewage sludge. Also, both heavy metals are used in numerous products. The most important uses for lead and cadmium in terms of quantity are in batteries and accumulators. Apart from the use in batteries, PVC stabilisers represent one of the main applications of lead.

The main points of interest for the discussion of the potential risks from lead or cadmium stabilisers in PVC are the following:

- Lead and cadmium stabilisers in PVC will most probably remain bound in PVC during the use phase and thus will not contribute significantly to exposure. A potential contamination of the environment by the use of lead or cadmium stabilisers in PVC can take place during the production and waste phase.
- During the phases of production and of waste treatment, a number of specific protection and prevention measures need to be taken in order to eliminate or reduce to a minimum the exposure of workers, in accordance with the EU's legislation on workers health and safety.
- No exact data are available on the contribution of lead stabilisers in PVC to the overall lead load in municipal solid waste being landfilled or incinerated. Various calculations and estimates have led to widely varying results: 1%, 3%, 6%, 10%²⁵ and 28%²⁶. For cadmium it is estimated that about 10% of cadmium in waste incinerators or landfill originate from PVC²⁷.
- Few experimental investigations have been carried out on the behaviour in landfills of PVC waste containing lead and cadmium. It can be expected that lead and cadmium compounds would stay encapsulated in rigid PVC waste. For lead in flexible PVC, the situation is less certain. In particular, one study²⁸ has shown a 10% release of lead stabiliser from one type of *flexible* PVC cable containing a

²³ OJ L 84, 05/04/193, p.1

²⁴ CSTEE opinion on lead – notification 98/595/DK. Opinion expressed at the 15th CSTEE plenary meeting. Brussels, 5th of May 2000.

²⁵ Bertin Technologies, The influence of PVC on quantity and hazardousness of flue gas residues from incineration, Study for DG XI, April 2000

²⁶ The Behaviour of PVC in Landfill, Study for DG ENV, Argus in association with University Rostock, 1999

²⁷ Bertin Technologies, cit. op.

²⁸ Mersiowski et al. Long-Term Behaviour of PVC Products under Soil-Buried and Landfill Conditions, Technical University Hamburg-Harburg, July 1999.

mixture of various plasticisers. The contribution of PVC to the lead content found in landfill leachates has not been investigated.

- During the incineration of PVC and other wastes, practically all lead and cadmium ends up in the bottom and fly ashes of the incinerators. Due to a high contamination with heavy metals, fly ashes and residues, which are generally mixed, have to be disposed of in controlled landfills. Bottom ashes are either re-used or landfilled. A dispersion of heavy metals into the environment therefore cannot be excluded but this seems unlikely in the short term.

Given the scientific uncertainties described above, the effect of substitution of lead or cadmium to the overall environmental emissions cannot be precisely quantified at present. However, it is questionable whether a general substitution of these stabilisers would have a major effect on the overall emissions of lead or cadmium to the environment. On the other hand, according to some analyses, the long term use of lead stabilisers would contribute to an increase of lead concentrations in the environment²⁹ through the waste management phase.

Due to the issues raised by the presence of hazardous substances in waste, the Community waste management strategy³⁰ has stated that *“preventive measures might lead to the need for EC-wide rules to limit the presence of heavy metals in products or in the production process or ban specific substances, in order to prevent, at later stage, the generation of hazardous waste. This might be the case where neither the reuse nor the recovery or the safe disposal of that substance is an environmentally acceptable solution.”*

The protection of man and the environment from risks related to exposure to cadmium has been an issue in Community policy for several years. On 25 January 1988 the Council of the European Communities adopted a Resolution³¹ on a Community action programme to combat environmental pollution by cadmium. The Council stresses that the uses of cadmium should be limited to cases where suitable alternatives do not exist.

With regard to the use of cadmium in stabilisers for PVC, Directive 91/338/EEC already restricts the use of cadmium as a stabiliser in a number of PVC applications. However, the use of cadmium in PVC profiles is still allowed. Sweden, Austria and the Netherlands have banned all the uses of cadmium in stabilisers and Directive 1999/51/EC provides for a general derogation to Sweden and Austria to apply stricter rules concerning cadmium.

No Community legislation exists on the use of lead compounds as stabilisers. Denmark³², Sweden³³, Austria³⁴ and Germany³⁵, have called for further restrictions,

²⁹ Swedish National Chemicals Inspectorate, Additives in PVC, Marking of PVC, report of a Government Commission, 1997

³⁰ COM(96)399

³¹ OJ No C 30, 4. 2. 1988, p. 1.

³² Notification of Denmark of a draft legislation on the restriction of the use of lead in products

³³ Swedish National Chemicals Inspectorate, Additives in PVC, Marking of PVC, report of a Government Commission, 1997

³⁴ Austrian national legislation on the ban of cadmium in PVC

³⁵ Kommission Human-Biomonitoring des Deutschen Umweltbundesamts “Bleireferenz und Human-Biomonitoring-Werte”, 1996

mandatory or voluntary, on the use of lead and cadmium, in particular as stabilisers in PVC.

Moreover, as previously mentioned, a risk assessment is being carried out on cadmium as well as a scientific evaluation on lead by the CSTEE. Decisions on potential risk reduction measures should be based on all existing scientific evaluations. They should be reviewed in the light of new scientific developments, including the results of potential future risk assessments.

Potential substitutes of lead and cadmium are already being used, the main substitutes being calcium-zinc stabilisers and tin organic stabilisers. Calcium/Zinc compounds do have a more advantageous hazard profile than lead and cadmium compounds and are currently not classified as dangerous. Technical reasons (product quality, standards, testing requirements) and economic grounds (higher costs) currently prevent the general substitution of lead stabilisers. It is expected that in the coming years the price difference between lead stabilisers and calcium/zinc stabilisers will decrease due to new production capacities being currently installed. Tin stabilisers have less favourable properties with regard to the environment and humans.

In March 2000, the PVC industry (PVC manufacturers, PVC additive producers and PVC converters represented by their European associations (ECVM, ECPI, ESPA, EuPC³⁶) combined to sign a voluntary commitment with the declared objective to “*meet the challenge of sustainable development*” though adopting “*an integrated approach to deliver the concept of responsible cradle to grave management.*”

The signatories represent more than 98% of PVC polymer, additives and compound producers, and between 60 to 80% of the transformers of window frames and pipes.

The voluntary commitment addresses different impacts of PVC on the environment, and includes a plan for the various actions envisaged reduction of emissions at the production stage, limitations on the use of cadmium, progressive implementation of recycling targets, as well as financial commitments involving the creation of a fund designed to finance relevant research projects. The main actions envisaged relate to:

- specific obligations, details of which are indicated at appropriate points in this document, covering the period 2000-2010.
- quantitative and progressive objectives for recycling certain waste streams and phasing out cadmium.
- publication of an annual report to be made available to interested parties.
- verification and evaluation of the results by an independent third party, first in 2003, and later in 2008.

Report of the Bundestag Enquête Kommission “The products of industrial society; Perspectives on sustainability management of material streams”, recommendations regarding PVC, July 1994
ECVM is the European Council of Vinyl Manufacturers; ECPI the European Council for Plasticisers and Intermediates; ESPA the European Stabilisers Producers Association and EuPC the European Plastics Converters.

³⁶

- revision of objectives in order to take into account technical and scientific progress as well as the suggestions of interested parties.

The signing and entry into force of this commitment represents an important step which need to be assessed in function of the effectiveness criteria mentioned in the Communication of the Commission to the Council and to the European Parliament concerning agreements in the area of the environment (COM(96)561 final).

The success of this approach will require a constant progression in the efforts realised in the specific areas covered by the agreement and, in particular, reduction in the production and use of certain additives, more ambitious target quantities for recycling, industry's contribution to added costs of incineration, and a fully operational funding mechanism.

As regards cadmium, industry has committed itself to phase out the use of cadmium stabilisers in 2001. This commitment does not cover the imports of PVC from third countries, which might still contain cadmium.

Concerning the use of lead, the European Stabilisers Producers Association (ESPA) has committed itself to carry out "*initial risk assessments on lead-based stabilisers under the CEFIC and ICCA programmes 'confidence in chemicals' by 2004*".

ESPA has committed itself to produce yearly statistics showing which stabilisers are purchased by converters. ESPA anticipates that the 120,000 tonnes of lead used in PVC in 1999 will decrease to 80,000 tonnes in 2010 and has stated that it "*will support this trend by developing suitable alternatives*". The PVC stabiliser industry does not at present take measures to phase out the use of lead in PVC, other than to "*continue to research and develop alternative stabilisers to the lead-based systems*".

Issues for consideration

The Commission considers, on the basis of the above-mentioned analysis, that the contamination of the environment by lead and cadmium should be avoided as much as possible. The Commission is in favour of a reduction of the use of cadmium and lead as stabilisers in PVC products. A number of measures could be envisaged and should be assessed in the light of their potential environmental and economic implications.

- 1. Legislative phase-out or other risk reduction measures for cadmium and/or lead with the possibility of temporary derogations***
- 2. Implementation of the voluntary commitment of the PVC industry on cadmium***
- 3. Development of further voluntary commitments for lead.***

Question n°1:

Which set of measures should be implemented to address the issue of the use of lead and cadmium in new PVC? According to which timeframe?

3.3. *Plasticisers*

Plasticisers are necessary to manufacture flexible PVC products. In Western Europe about one million tonnes of phthalates are produced each year, of which approximately 900,000 tonnes are used to plasticise PVC. In 1997, 93% of the PVC plasticisers were phthalates. The most common phthalates are: bis-2-ethylhexyl phthalate (DEHP), diisodecyl phthalate (DIDP) and diisononyl phthalate (DINP). In recent years the use of DEHP has decreased, while that of DIDP and DINP has increased. The quantities of plasticisers added to the PVC polymer vary depending on required properties. Depending on the final use, plasticiser contents vary between 15 and 60%, with typical ranges for most flexible applications around 35 to 40%.

Other plasticisers, in particular adipates, trimellitates, organophosphates and epoxidised soybean oil can also be used as softeners in PVC. These plasticisers represent only a small fraction of the use of plasticisers. Information on the impact of these plasticisers on the environment and on human health from their use in PVC is limited and further data would need to be acquired for a proper assessment. This section will therefore concentrate on phthalates, the most important plasticisers in term of quantity and the main plasticisers currently assessed in term of environmental and health risks.

Phthalates are high production volume chemicals, five of which have been put, due to their potential risks to human health and the environment, on the first three priority lists for risk assessment in accordance with Regulation 793/93 on existing substances. The risk assessments on these five substances are carried out by Member

State rapporteurs³⁷. The risk assessments on DEHP, DIDP, DINP, DBP have been or are expected to be completed in 2000 and in 2001 for BBP.

DEHP, DINP and DIDP have a potential for bioaccumulation. The risk assessments under Regulation 793/93 have concluded that no concern exists for the accumulation potential of DBP, DINP and DIDP, whereas the potential effects on the environment are still being assessed for DEHP and BBP. Long-chain length phthalates have a low biodegradability under normal conditions of sewage treatment and are only partly degraded in usual leachate and sewage treatment plants, where they accumulate on suspended solids. Certain phthalates as well as their metabolites and degradation products can cause adverse effects on human health (in particular on liver and kidney for DINP and on testicles for DEHP). Potential endocrine disrupting properties are being evaluated.

All the phthalates used in large quantities in PVC applications are ubiquitous in the environment today. Transport in the air and leaching out from certain applications seem to be the major routes by which phthalates enter the environment. Phthalates are found in high concentrations mostly in sediments and in sewage sludge. In Denmark, it has been reported that the concentrations of certain phthalates can exceed the national limit values fixed for the use of sewage sludge in agriculture.

The risks due to the use of phthalates in certain soft PVC toys and childcare articles have been assessed by the Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE). Phthalates leach out from toys and child care articles, when sucked by small children. In its opinions, the Scientific Committee on Toxicity, Ecotoxicity and Environment has expressed its concern about the risks resulting from the exposure of small children to two phthalates (DINP and DEHP) used in these products, due to the potential adverse effects on liver, kidney and testicles. The Commission has adopted on 10 November 1999 a Proposal for a Directive and on 7 December 1999 a Decision under the emergency procedure of Directive 92/59/EEC in order to ban of the use of phthalates in certain toys and childcare articles intended to be put in the mouth.

Without waiting for the final stage of the above mentioned risk assessment process, three Member States have already started to draw up risk management strategies based on the global objective to reduce the use of phthalates. The Swedish Government has presented a bill on "Swedish environmental quality objectives" which aims at reducing the use of the main phthalate DEHP³⁸. The Danish government has adopted an action plan to reduce the use of phthalates by 50% over the next 10 years. The sustainability of flexible PVC has also been assessed by the German Umweltbundesamt³⁹, which recommends a phase-out of flexible PVC, for

³⁷ The five phthalates are : Bis(2-ethylhexyl) phthalate (DEHP), rapporteur Sweden; Di-'isononyl''phthalate (DINP), rapporteur France; Di-'isodecyl''phthalate (DIDP), rapporteur France; Dibutylphthalate (DBP), rapporteur the Netherlands; Butyl Benzyl Phthalates (BBP), rapporteur Norway

³⁸ The Swedish Government states that "the use of DEHP and other plasticizers with harmful effects in PVC for outdoor use in coated woven fabrics and coated plate and for corrosion protection in cars should be phased out on a voluntary basis by 2001. Other uses of DEHP as a plasticizer in PVC, with the exception of medical products and drugs, should be phased out on a voluntary basis by 2001."

³⁹ Deutsches Umweltbundesamt, Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC, 1999

those applications where safer alternatives are available, due to the permanent loss of softeners, in particular phthalates, into the environment.

Issues for consideration

The use of phthalates in PVC applications raises issues, described above, which could be addressed through a number of measures, including legislative or voluntary risk reduction measures. These potential measures should be assessed in the light of their environmental and economic implications.

Question n°2:

Should specific measures be taken for the use of phthalates as plasticisers in PVC? If so, when and through which instruments?

4. THE WASTE MANAGEMENT OF PVC

Four studies have been commissioned by the services of the Commission in order to assess the technical aspects of the main waste management options for PVC waste: mechanical recycling⁴⁰, chemical recycling⁴¹, incineration⁴² and landfilling⁴³.

The management of PVC waste should be assessed in the context of the European waste management policy. The Communication from the Commission on the review of the Community strategy for waste management⁴⁴ has confirmed “*the hierarchy of principles that prevention of waste shall remain the first priority, followed by recovery and finally by the safe disposal of waste*”. It is further stated that “*preference should be given, where environmentally sound, to the recovery of material over energy recovery operations. This general rule is based on the fact that material recovery has a greater effect on waste prevention than energy recovery. It will nevertheless be necessary to take into account the environmental, economic, and scientific effects of either option. The evaluation of these effects could lead, in certain cases, to preference being given to the energy recovery option.*” In its Resolution⁴⁵ of 24 February 1997, the Council has endorsed this hierarchy of principles.

4.1. Current situation and future developments

Current situation

The total quantity of PVC waste is a function of PVC consumption. However, due to lifespans, which can reach up to 50 years and more for some applications such as pipes and profiles, there is a “time-lag” between PVC consumption and PVC presence in the waste stream. PVC products reached significant market share in the 1960’s. Considering lifespans of about 30 years and more, a significant increase of PVC waste quantities is expected to start around 2010.

⁴⁰ Prognos, Mechanical recycling of PVC wastes, Study for DG XI, January 2000

⁴¹ TNO, Chemical recycling of plastics waste (PVC and other resins), Study for DG III, December 1999

⁴² Bertin Technologies, The influence of PVC on quantity and hazardousness of flue gas residues from incineration, Study for DG XI, April 2000

⁴³ Argus in association with University Rostock, cit. op.

⁴⁴ COM(96) 399 final

⁴⁵ 97/C 76/01

Due to the fact that PVC is used in a wide range of applications, data on PVC waste arisings in the EU are uncertain. The most recent and detailed data available on PVC waste quantities are estimations carried out by industry and are based on calculations using production quantities per year and average lifespan of products.

It is estimated that in 1999 the total annual PVC waste quantity was about 4.1 million tonnes in the Community, which can be divided into 3.6 million tonnes of post-consumer PVC waste and 0.5 million tonnes of pre-consumer PVC waste. Pre-consumer wastes are generated during the production of intermediate and final PVC products as well as during the handling and installation of PVC products. The present composition of PVC waste is two thirds flexible PVC and one third rigid PVC.

About one million tonnes of PVC is present in the construction and demolition waste stream. One million tonnes of PVC can be found in the municipal solid waste stream, which comprises wastes collected from households as well as similar wastes collected from commercial and industrial operations. About 700,000 tonnes of PVC packaging waste are generated and about 700,000 tonnes of PVC are found in end of life vehicles and electrical and electronic equipment.

At present the main waste management route in the Community for all types of post-consumer waste is landfilling. This is therefore also the case for post-consumer PVC waste. About 2.6 to 2.9 million tonnes of PVC waste are currently landfilled every year. Mechanical recycling is applied to only a small fraction of the post-consumer waste (about 100,000 tonnes). Approximately 600,000 tonnes of PVC are incinerated per year in the Community.

Future developments: baseline scenario

This scenario⁴⁶ describes the situation with regard to the quantities of PVC waste and the main waste management routes expected in the years 2000, 2010 and 2020, with the assumption that no PVC-specific measures will be taken except for those legal, administrative and voluntary measures in force or in preparation at Community and at national levels. It is assumed under this scenario that existing and future Directives on landfilling, incineration, packaging, end of life vehicles and electric and electronic waste will be implemented.

The key element in the management of post-consumer PVC waste is the expected increase in PVC waste quantities. Predictions of future PVC waste arisings are subject to uncertainties but it is expected that the volume of PVC waste will increase significantly by 30% in 2010 and by 80% in 2020, in particular due to the important increase of waste quantities from long lifespan products. Post-consumer wastes will increase from about 3.6 million tonnes at present to about 4.7 million tonnes in 2010 and 6.2 million tonnes in 2020. PVC pre-consumer wastes will increase from 0.5 to 0.9 million tonnes.

Compared to the current situation, it is expected that the composition of PVC post-consumer waste arisings by product group will change. The share of PVC building waste and waste from household and commercial products will increase, whereas the contribution of packaging is expected to decrease significantly. The proportion of flexible PVC waste will also decrease.

⁴⁶ Prognos, cit. op.

In the context of the baseline PVC waste scenario, changes in waste management legislation and practices are expected to have the following effects:

- The landfill Directive will bring some important changes to waste management mainly due to the expected increasing landfill costs. Some Member States, in particular Germany, Austria, the Netherlands and Denmark have announced national policies for banning the landfilling of untreated organic wastes, including plastics, with the exception of PVC waste for Denmark.
- Recycling is expected to increase significantly over the next decades, in particular for those waste streams for which recycling targets will be set. Energy recovery is also expected to increase for waste, which cannot be recycled.

How this will affect the treatment of PVC waste will be discussed in more detail in the following sections on the main waste management options.

4.2. *Mechanical recycling*

Mechanical recycling refers to recycling processes where PVC waste is treated only mechanically, mainly through shredding, sieving, and grinding. The resulting recyclates (in powder form) can be processed into new products. Depending on the degree of contamination and the composition of the collected material, the quality of the PVC recyclates can vary a lot. The quality of the recyclates determines the degree, to which virgin material can be substituted by recyclates: “high-quality” recyclates can be re-used in the same types of PVC applications, whereas “low-quality” recyclates from mixed waste fractions can only be “down-cycled” into products usually made from other material.

Recycling of post-consumer waste is still at a low level in the EU and the quantities recycled represent less than 3% of the total⁴⁷. About 100,000 tonnes are currently recycled per year in the EU. A major part of the post-consumer PVC waste recycling (about 70%) is down-cycling in the area of cable wastes (about 38,000 tonnes) and packaging waste (about 19,000 tonnes).

High-quality mechanical recycling for post-consumer wastes is still in a preliminary stage and exists only for few product groups and with low quantities (about 3.600 tonnes of rigid profiles, 5,500 tonnes of PVC pipes and 550 tonnes of flooring).

There appears to be no Member States where the recycling rate of post-consumer waste is significantly higher than the EU average. In some countries, collection schemes have been established, usually through voluntary approaches. However, the recycling rate is usually below 5% and is largely based on the down-cycling of packaging and cables.

As far as pre-consumer wastes are concerned, about 420,000 tonnes of PVC were recycled in 1998, representing about 85% of pre-consumer PVC waste arising. Mechanical recycling of pre-consumer waste exists in all Member States and can be considered as a profitable economic activity.

⁴⁷ Prognos, cit. op.

A number of life cycle assessments⁴⁸ on some specific PVC products have shown that mechanical recycling provides an environmental advantage for production waste, cut-offs and post-consumer PVC waste, which can be separated. The environmental advantages of the down-cycling of mixed plastics for the production of products which substitute concrete, wood or other non-plastic applications are less certain.

However, the presence of additives classified as hazardous, such as lead, cadmium and PCBs, in large PVC waste streams raises specific issues during their potential recycling. The recycling of PVC waste containing heavy metals results in a dilution of these substances in a greater quantity of PVC, since it is necessary to add virgin material. The heavy metals are not directly released into the environment during the recycling process and the renewed service life. The recycling of PVC material containing these heavy metals postpones the final disposal to a later stage. Although it could be difficult to control the use of recycled PVC containing lead and cadmium, for technical reasons it is unlikely that PVC waste from various applications would be recycled together in case of high quality recycling. Due to the product-specific additives formulations, recyclers would prefer recycling into similar applications. Additional measures, such as restrictions of the uncontrolled sale of recyclates containing heavy metals or its down-cycling, could be envisaged. A prohibition of the recycling of PVC waste containing heavy metals would eliminate the mechanical recycling of post-consumer PVC wastes from building applications - the waste stream with the highest potential for high-quality recycling - as they virtually all contain lead or cadmium. It should be noted that, except for Denmark, Member States, which have banned the use of cadmium as stabilisers, allow the recycling of PVC waste containing cadmium. The problem of PCBs in PVC cable waste has been addressed in Directive EC/96/59 on the disposal of PCB and PCT, which provides that cables containing more than 50 ppm of PCBs are considered as PCBs and have therefore to be decontaminated or disposed of in accordance with the provisions established under this Directive.

PVC can have a negative influence on the recycling of other plastics in mixed plastic waste. When PVC is processed with other plastics, such as in the packaging waste stream, the processing temperature is limited to the range of PVC-processing, which is a relatively low range compared to other plastics. Due to similar densities, polyethylene terephthalate (PET) and PVC waste are difficult to separate and the presence of PVC puts additional costs on some PET recycling schemes such as the PET bottles. In some cases, the PVC industry has recognised this issue and contributes to this additional cost.

As in the case of other materials, the recycling of PVC is also limited by the overall recycling costs. Economic profitability is reached when the net recycling costs (i.e. the overall costs for collection, separation and processing minus the revenues from sale of the recyclates) are lower than the prices for alternative waste management routes for related PVC wastes. If economic profitability cannot be reached, the recycling of PVC waste will not take place under free market conditions, unless there are legal obligations or voluntary measures enforcing or promoting the recycling of PVC. Collection represents the major bottleneck regarding the availability of waste and costs.

⁴⁸

Prognos, cit. op.

High-quality recycling of post-consumer waste (in particular pipes, profiles, flooring) is at present not profitable, as the net recycling costs are well above the costs for landfilling or incineration. In addition, there are further costs for the waste owner for separation of wastes at the construction sites.

Low-quality recycling of post-consumer PVC waste, such as for packaging waste, is not economically profitable. Economic profitability is not likely to be reached for other waste streams suitable for low-quality recycling, such as office supplies, printing films. Cable insulation is the only post-consumer waste, which can be recycled at competitive costs, due to the presence of valuable metals, such as copper.

In conclusion, the recycling of pre-consumer waste can, in principle, be profitable. However, post-consumer PVC waste recycling is far from reaching economic competitiveness. In addition to the establishment of recycling schemes with a broad regional coverage, financial incentives are necessary for a separate collection of PVC wastes. Also, PVC is often present as a component in composite materials, or mixed in contaminated waste streams, which require specific collection and sorting operations. The price of virgin material, which is highly volatile (between 0.5 and 0.8 €/kg), has a large influence on the profitability of recycling. In addition, the prices for landfilling and incineration are low. Nevertheless, in the coming years, it can be expected that the economic conditions for recycling are likely to improve, in particular due to the increasing costs for landfilling and incineration.

Future developments and policy orientations

In the baseline scenario about 9% of the total PVC waste could be mechanically recycled in 2010 and 2020, representing about 400,000 tonnes of PVC waste in 2010 and 550,000 tonnes in 2020⁴⁹. The recycling rates vary according to the specific waste streams considered.

- For high quality recycling, the following recycling rates could be reached for construction and demolition PVC wastes: about 25% for pipes, about 40% for window profiles and about 12% for flooring.
- For low-quality recycling, the recycling rates would be about 65% for cables present in the construction and demolition waste stream, about 30% for waste from electronic and electronic equipment and about 20% for packaging.
- Other waste streams such as household and commercial wastes are not likely to be recycled according to the assumptions made in this scenario.

Compared to this baseline scenario, maximum recycling potentials have been estimated⁵⁰, which represent the PVC quantities, which can be recycled, taking into account the technical and economic limits of PVC recycling. According to this scenario, the potential for post-consumer waste is about 800,000 tonnes in 2010 and 1.2 millions tonnes in 2020, representing a recycling rate of about 18%. This means that the mechanical recycling of PVC waste could contribute only to the management of about one fifth of PVC post-consumer waste. Other waste management routes will therefore remain important.

⁴⁹ Prognos, op. cit.

⁵⁰ Prognos, op. cit.

In its commitment of March 2000, the PVC industry has made quantified commitments regarding the mechanical recycling of pipes, fittings and window frames. For pipes, the commitment is “to recycle at least 50% of the collected available quantity of pipes and fitting waste by 2005”. For window profiles, the commitment is “to recycle at least 50% of the collectable available quantity of window profiles waste by 2005”. These targets are not based on waste generated but on waste collected.

According to the PVC industry, in 2005 the annually recycled quantities are estimated as follows: 15,000 tonnes for pipes and 15,000 tonnes for window profiles. However, the following large PVC waste streams, which could be used for high quality recycling, are not covered by the commitment: rigid profiles other than window profiles (about 240,000 tonnes in 2005), flooring calandered (about 240,000 tonnes in 2005) and flexible profiles and hoses (about 120,000 tonnes in 2005). Nonetheless, in its commitment, the PVC industry has stated that in the case of other potential applications such as PVC cables, flooring and roofing membranes, “*more work is needed in developing suitable logistics, technologies and reuse applications*”. In addition, the industry has committed itself to supporting these developments including the achievement of higher mechanical recycling targets “*as soon as possible.*”

Issues for consideration:

The Commission considers, on the basis of the above-mentioned analysis and given the present low recycling rate, that recycling of PVC should be increased. This could be achieved through a range of measures, which could be used separately or in combination. Their potential environmental and economic implications should be assessed. These potential measures include:

- 1. Mandatory collection and recycling targets for some relevant PVC waste streams***
- 2. Voluntary commitment of the industry to improve and finance, totally or partially, the collection and the recycling of some relevant PVC waste streams***
- 3. Recommendations to Member States with the objective of establishing and developing separate collection of PVC waste and other demolition waste***
- 4. Development of appropriate standards that allow the use of recycled PVC materials***
- 5. Marking of plastic products as a useful tool to facilitate the separation of PVC waste from the general waste stream and development of other methods for plastic identification and sorting.***
- 6. Development of innovative recycling processes for certain post-consumer PVC waste***

Question n°3:

Which set of measures would be the most effective to reach the objective of an increase of PVC recycling?

The recycling of PVC waste containing heavy metals raises specific issues due to the potential dilution of heavy metals into new and possibly wider range of products. Some potential measures could be envisaged to address these issues. These measures should be assessed in the light of their potential environmental and economic implications. They include:

- 1. Legislative instruments to restrict the mechanical recycling of PVC waste containing lead and cadmium***
- 2. Specific conditions for this recycling, such as recycling in the same type of application, the control of the placing on the market of recyclates, the marking of the recycled products and the control of the use of heavy metals***
- 3. No specific conditions for this recycling.***

Question n°4:

Should specific measures be attached to the mechanical recycling of PVC waste containing lead and cadmium? If so, which ones?

4.3. *Chemical recycling*

Chemical recycling denotes a number of processes, by which the polymer molecules that constitute plastic materials are broken up into smaller molecules. These can either be monomers that can be used directly to produce new polymers or other substances that can be used elsewhere as starting materials in processes of the basic chemical industry.

In the case of PVC, in addition to the breaking up of the backbone of the polymer molecules, the chlorine attached to the chains is set free in the form of hydrogen chloride (HCl). Depending on process technology, HCl can be re-used after purification or has to be neutralised to form various products that either can be used or have to be disposed of.

In practice, during the last 5 years, there have been only a limited number of initiatives that have resulted in the construction of industrial plants, or may lead to the realisation of such plants in the near future. Chemical recycling processes can be categorised according to their capacity to handle waste with high or low chlorine content, 4 to 5% being the maximum PVC content that can be handled by technologies for low chlorine content. Of the three operational purpose-built chemical recycling plants for waste with low chlorine content, two have been shut down due to economic and supply reasons. For PVC-rich waste there is currently one incineration-based technology with HCl recovery operational, two pilots will become operational in the coming years.

According to several life cycle assessments (LCA), some chemical recycling processes would score considerably better with regards to energy use and global warming than municipal solid waste incineration and landfilling. In addition, in some processes chlorine is recovered, thus avoiding new production through energy-intensive chloralkali-electrolysis. The available LCAs did not allow a clear preference to be made for one of the chemical recycling technologies analysed. Direct mechanical recycling of PVC-rich waste is preferable in environmental terms, particularly if it concerns recycling to high-quality products, and does not involve extensive sorting and pre-treatment⁵¹

Together with the organic parts in PVC, plasticisers are transformed into feedstock material as well. Stabilisers containing heavy metals mostly end up in solid residues that will most probably have to be landfilled. For most of the dedicated chemical recycling technologies, emissions of problematic substances other than solid residues are low⁵². No firm conclusions can be drawn with regard to the formation of dioxins. As a general rule, reducing conditions and high temperatures promote the breakdown and prevent the formation of dioxines, which is the case in some processes where the operating conditions avoid the formation of dioxins.

It seems that chemical recycling of PVC-rich waste is unattractive in economic terms in those situations where mechanical recycling has proven already to be technically feasible, with the possible exception of flooring. This would imply that chemical recycling plants for PVC-rich waste would have to concentrate on those flows for which mechanical recycling is not feasible, e.g. for types of waste that cannot be

⁵¹ TNO, Chemical recycling of plastics waste (PVC and other resins), Study for DG III, December 1999
⁵² TNO, op.cit.

mechanically recycled as they would require additional separation steps, contain too many problematic impurities, or because of other restrictions linked to environmental concerns.

Chemical recycling has to compete with other waste management practices in the EU, mainly based on landfill and incineration. Landfill and incineration have the lowest gate fees. Purpose-built chemical recycling plants will also face an important competition from blast furnace operations and cement kilns, which could absorb a large quantity of mixed plastics waste with limited PVC content.

When looking at the various waste streams, it appears that in the current situation for categories like agricultural waste, industrial waste and non-packaging household waste, chemical recycling, although technically feasible, will have problems to compete in the absence of legal or other steering instruments. As for automotive and electrical and electronic waste, the PVC content in the mixed plastics waste seem to be too high to make them suitable for most chemical recycling options for mixed plastics waste with low chlorine content, but too low for economically viable separation and subsequent treatment in plants for PVC-rich waste.

Overall, it can be concluded that the successful operation of dedicated chemical recycling plants is mainly dependent on the economic aspects and in present circumstances there are important question marks over the viability of such operations.

Future developments and policy orientations

Chemical recycling has a potential mostly for those wastes for which mechanical recycling is not an option, and when legal or other instruments are effective in steering the waste away from the most cost-effective competitors (such as cement kilns, municipal solid waste incinerators and landfill).

For 2010, the total PVC waste quantities, which could be chemically recycled in the baseline scenario, are about 80,000 tonnes as a fraction in mixed plastics waste with low chlorine content (mostly from packaging) and about 160.000 tonnes in mixed plastics fractions with higher PVC content, mostly from automotive and electric and electronic waste.

Industry committed to invest 3 million € by 2001 in a pilot plant, with the objective to recover the chlorine and hydrocarbons content of PVC coated fabrics. The outcome of this pilot will be known by mid 2002, when the decision to build a commercial plant will be made.

Issues for consideration:

The Commission notes with interest the efforts described above to develop further chemical recycling technologies. In this context, potential measures could be envisaged in order to encourage these developments. Their potential environmental and economic implications should be assessed. Such measures include:

- 1. Further voluntary initiatives from the PVC industry***
- 2. Recommendations for targets for chemical recycling for those waste streams where mechanical recycling is not possible***
- 3. Setting of mandatory targets for chemical recycling.***

Question n°5:

Which set of measures would be most appropriate for chemical recycling of PVC waste?

4.4. Other recycling and recovery technologies including co-incineration

A newly developed dissolution-precipitation process is based on physical principles without destruction of the polymer molecules to feedstock compounds. The process was developed specifically for composite materials containing PVC and other components. PVC is separated from the components that make up the composite through selective dissolution, and then the entire PVC compound is regenerated through precipitation. PVC and the other components can then be re-used.

Currently, an experimental installation is operational and a pilot plant is planned to be operational in 2001. The technology works in a closed circuit system, where the solvent is recycled.

The process deals with selectively collected PVC products. The quality has to be about the same as for mechanical recycling, which means that the costs of making the material available are comparable. The developers of this process expect that the technology could deal with rather complicated formulations, such as tarpaulins, cables, pharmaceutical blister packs, floor coatings, car dashboards, and could compete financially with some of the other recycling options.

Mixed plastic waste is used by one German steel producer as a reducing agent in blast furnaces in the production of raw iron. Mixed plastic waste is also used in cement kilns as a substitute to coal, oil or gas for the generation of heat.

The evaluation of the environmental performance of the use of mixed plastic waste in blast furnaces and cement kilns is somewhat controversial. According to some life cycle analyses, blast furnaces and cement kilns score better with regards to energy used and global warming than municipal solid waste incineration. With regards to the potential contribution of PVC to the emissions of dioxins, it is rather difficult to draw firm conclusions and further research would be necessary.

Blast furnaces and cement kilns can treat mixed plastic waste without the need for high capital investment, thus offering low gate fees. The use of mixed plastic waste in cement kilns and blast furnaces represents serious competition for other waste management installations. On the other hand, the use of mixed plastic waste in cement kilns and blast furnaces is restricted by its content in chlorine, as chlorine can have negative effects on the quality of the produced cement or iron and the potential corrosion of the equipment due to the formation of HCl. A tolerance of some 2-3% or less is possible⁵³. Theoretically, co-combustion in cement kilns of mixed plastic waste with low PVC content could, however, become important in the future.

4.5. *Incineration*

PVC waste, if incinerated, is mainly treated in municipal waste incinerators. PVC waste is also present in hospital waste incinerators since PVC applications are used in hospitals. Approximately 600,000 tonnes of PVC are incinerated per year in the Community. PVC represents about 10% of the plastic fraction incinerated and about 0.7% of the total quantity of waste incinerated⁵⁴.

PVC waste contributes between 38% and 66% of the chlorine content in waste streams being incinerated. The other main sources of chlorine are putrescibles (about 17%) and paper (10%). On average it can be estimated that about 50% of the chlorine input into the incinerators are due to the presence of PVC.

Upon incineration, PVC waste generates hydrochloric acid (HCl) in the flue gas, which needs to be neutralised except when a special technology is employed where HCl is reused. At the moment, this specific technology is used only in 5 plants in Germany and 3 plants are in construction. All acid gases generated during the incineration of municipal solid waste (in addition to HCl mainly sulphur oxides) have to be neutralised prior to emission of the remaining gas to the atmosphere. Community legislation⁵⁵ already requires emission limit values for hydrochloric acid. These limits are currently being revised into more stringent limits⁵⁶.

In order to reach these emission limit values for HCl, neutralisation agents, in particular lime, are injected in order to neutralise the acidic components of the flue gas. The four main neutralisation processes are the dry, semi-dry, semi-wet wet and wet processes, which are presented in more details in annex 1.

An assessment⁵⁷ of the quantities of flue gas cleaning residues resulting from the incineration of PVC waste concluded that the incineration of 1kg of PVC generates on average⁵⁸ between 1 and 1.4 kg of residues for the dry process with lime, semi-dry

⁵³ Or some 1-1.5% chlorine. Values may vary per installation, and legal demands may vary per country.

⁵⁴ Bertin Technologies, cit. op.

⁵⁵ Directive 89/369/EEC on the prevention of air pollution from new municipal waste incineration plants requires emission limit values for hydrochloric acid between 50 and 250 mg/Nm³ depending on the capacity of the incineration plant.

⁵⁶ The Proposal for a Directive on the incineration of waste [COM(1998) 558 final] as well as the Common Position on this Proposal [98/289 COD of 25 November 1999] foresees a strict emission limit value for HCl of 10 mg/Nm³, which will become in 2005 the emission limit value for existing and new incinerators in the Community.

⁵⁷ Bertin Technologies, cit. op.

⁵⁸ The average figure apply to a PVC material mix with 45% chlorine, i.e. composed of 70% rigid PVC (containing 53% chlorine) and 30% flexible PVC (containing 25% chlorine)

and semi-wet wet processes. With the use of sodium hydrogen-carbonate as neutralisation agents in semi-dry process, 1 kg of PVC generates about 0.8 kg of residues. In case of wet processes, between 0.4 and 0.9 kg of liquid effluent is generated. There is an important difference between the amounts of neutralisation agent required and residues produced between soft and rigid PVC. Flexible PVC contains less chlorine than rigid PVC. The amounts of neutralisation agents required and of residues generated are therefore lower for flexible PVC than for rigid PVC (1 kg of soft PVC⁵⁹ generates between 0.5 and 0.78 kg of residues). More details can be found in the following table.

Table 3: Estimated quantities of residues generated by the incineration of 1 kg of PVC waste⁶⁰

		DRY		SEMI-DRY	WET	SEMI WET – WET
Neutralisation Agent		Lime	BICAR	Lime	Lime	Lime
Cl kg per kg of PVC	Min	0.25				
	Max	0.53				
	Average	0.45				
Residues (kg) (per kg PVC)	Min	0,78	0,46	0,70	0	0.54
	Max	1.65	0.97	1.48	0	1.15
	Average	1,40	0,82	1,26	0	1
Liquid effluent (dry material) (kg per kg PVC)		0	0	0	0.42 to 0.88	0

The flue gas cleaning residues are classified as **hazardous waste⁶¹**. The residues are generated separately (in particular in semi-wet and wet systems) or mixed with fly ash. The residues contain the neutralisation salts, the excess neutralisation agent as well as pollutants such as heavy metals and dioxins that were not destroyed. Landfilling of the residues is, with some exceptions, the only option used within the Member States.

Several processes have been devised to recover calcium chloride and sodium chloride from the residues of the dry and semidry processes, but few of them are currently used commercially. Except in some specific cases, it is uncertain whether such technologies can be commonly used in order to recover a substantial quantity of residues. These technologies would be “end of the pipe” solutions, less preferable than a preventive measure aimed at reducing at source the quantity of residues generated.

⁵⁹ For these calculations, soft PVC contain 0.25% of chlorine

⁶⁰ Bertin Technologies, The influence of PVC on quantity and hazardousness of flue gas residues from incineration, Study for DG XI, April 2000

⁶¹ According to Council Decision 94/904/EC establishing a list of hazardous waste, OJ L 356 , 31/12/1994 p.14-22, all solid waste from gas treatment are classified as hazardous (code 190107).

PVC at current levels in the municipal solid waste stream has the following effects on the flue gas cleaning residues in comparison to incineration of municipal solid waste without PVC⁶²:

- PVC incineration contributes to an increase of the quantity of flue gas cleaning residues (about 37% for the dry systems, 34% for semi dry systems and 42% for semi wet-wet⁶³).
- PVC incineration contributes to an increase of the content of leachable salts in the residues by a factor of two. These are primarily chlorides of calcium, sodium, and potassium.
- The incineration of PVC increases the amount of leachates from the residues put into landfill (about 19% for dry systems, 18% for semi dry systems, 15% for the semi wet-wet systems and 4% for wet systems). The leachates need to be treated prior to any discharge.
- There is a theoretical possibility that the leaching of, for example cadmium, may increase due to increased chloride complexation caused by PVC incineration but data would be needed to substantiate this.
- In the current temperature range of combustion steps for municipal solid waste incineration, the higher chlorine content has no significant effects on the transfer of heavy metals and trace elements from bottom ash to gas treatment residues.

The potential influence of the incineration of PVC waste on the emissions of dioxins has been at the centre of a major scientific debate since PVC is currently the largest contributor of chlorine into incinerators. The contribution of incinerators to the total emissions of dioxins in the Community was about 40% between 1993 and 1995⁶⁴.

It has been suggested that the reduction of the chlorine content in the waste can contribute to the reduction of dioxin formation, even though the actual mechanism is not fully understood. The influence on the reduction is also expected to be a second or third order relationship⁶⁵. It is most likely that the main incineration parameters, such as the temperature and the oxygen concentration, have a major influence on the dioxin formation.

Whilst at the current levels of chlorine in municipal waste, there does not seem to be a direct quantitative relationship between chlorine content and dioxin formation, it is possible that an increase of chlorine content in the waste stream above a certain threshold could contribute to an increase of the dioxin formation in incinerators. The threshold of 1% of chlorine has been suggested⁶⁶ but uncertainties remain on the

⁶² Bertin Technologies, op. cit.
The scenario considered is based on the incineration of 1 million tonnes of waste with and without PVC, respectively, and the landfilling of the resulting residues.

⁶³ Bertin Technologies, op. cit.

⁶⁴ Identification of relevant industrial sources of dioxins and furans in Europe, Landesumweltamt Nordrhein-Westfalen, Essen, 1997

⁶⁵ Danish Environmental Protection Agency, Environmental aspects of PVC, 1996

⁶⁶ Wikstrom, 1996, influence of level and form of chlorine on the formation of chlorinated dioxins, dibenzofurans and benzenes during the combustion of an artificial fuel in a laboratory reactor.

level of this threshold⁶⁷. Further assessment should be carried out in order to assess the threshold above which the chlorine content would influence the formation of dioxins. This threshold could be exceeded due to increasing quantities of waste containing chlorine.

At present, not all incinerators in the Community are already operating according to state-of-the-art air-emission standards for dioxins. The Proposal for a Directive on the incineration of waste⁶⁸ foresees an emission limit value of 0,1 ng/m³. This shall decrease the emissions of dioxins from incinerators.

The potential link between the incineration of PVC and the corrosion of the equipment of incinerators has also been debated. Some operators claim that the steam pressure and consequently the energy efficiency could be higher with a lower chlorine presence in the waste stream. The absence of PVC could therefore enable a higher efficiency of the energy recovery system. This question needs further research. It should be noted that the incineration with energy recovery of PVC waste generates higher energy than the incineration of general municipal solid waste since the calorific value of PVC waste is higher⁶⁹.

PVC waste incineration increases the operating costs of the incinerators due to the use of neutralisation agents to neutralise the acid flue gas and the additional costs for the waste management of the resulting residues. The total additional financial costs related to the incineration of PVC vary depending on the Member State, the neutralisation processes and the waste management of the residues. It is estimated that the additional costs of incinerating PVC compared to municipal solid waste is from about 20 € per tonne for wet systems to more than 300 € per tonne for dry systems⁷⁰. Differences depend upon the technology used and the type of PVC incinerated (flexible or rigid). More details on these costs can be found in annex 2. These additional costs are at present not borne specifically by new PVC products or by PVC waste, but are included in the overall incineration cost of waste.

A study⁷¹ has been commissioned to assess the economic implications of diverting PVC waste away from incineration. The report analyses three scenarios in comparison to the baseline scenario (see annex 3 for details). In the first and the second scenarios, recycling rates increase to 15% and 22% respectively in 2020, with a proportionate decrease in the amount of PVC sent to incineration and landfill. With

⁶⁷ Danish Environmental Protection Agency, Dioxins emissions from waste incineration, Environmental Project 117, 1989

Danish Environmental Protection Agency, The effects of chlorine content on the formation of dioxin, Project 118, 1989

Danish Environmental Protection Agency, Dioxins – sources, levels and exposures in Denmark, Working report N°50/1997

⁶⁸ COM(1998) 558 final

⁶⁹ The average caloric value for flexible PVC is about 20 GJ/tonne, about 16 <GJ/tonne for rigid PVC and about 10 GJ/tonne for municipal solid waste.

⁷⁰ Bertin Technologies, op. cit.

⁷¹ AEA Technology, Economic evaluation of PVC waste management, a report produced for the European Commission Environment Directorate-General, June 2000. The study encompasses EU Member States + 6 Candidate countries. The reported figures relate to the average between the “high” and the “low” incineration scenarios. These scenarios are based on the assumption that landfilling of PVC waste would be significantly reduced in some countries such as Sweden, Austria, Germany and the Netherlands. The difference relates to the degree of reduction achieved. Values shown refer to a 4% discount rate.

regard to incineration this means a cumulative diversion of about 1,700 ktonnes for scenario 1 (mainly construction waste) and 3,800 ktonnes for scenario 2 in the time period 2000 to 2020. In the third scenario recycling rates are unchanged against the baseline scenario, but the incineration rate is estimated as 28% in 2020 instead of 45% as forecasted in the baseline scenario as a result of the diversion of construction waste to landfill. This corresponds to the diversion of about 10,300 ktonnes in the time period 2000 to 2020.

The financial costs considered for scenarios 1 and 2 include the avoided cost of incineration (including “specific costs”⁷²) and the incurred net cost of the recycling process which depends on the waste stream diverted. The specific costs of incineration vary considerably depending upon the types of flue gas cleaning systems. Calculations in the report have been carried out for an “average” system distribution consisting of 25% semi dry-systems, 25% wet systems and 50% semi-wet wet systems. The results show that except in the case of rigid construction products (pipes, windows, cable trays and other rigid profiles) and cables, diversion of PVC waste from incineration to recycling results in a net increase in costs. The costs per tonne diverted have been estimated to be about 50 €/tonne for scenario 1 and about 190 €/tonne for scenario 2. Scenario 3 results in a net saving of about 90 €/tonne. These latter savings are mainly due to the lower cost of landfill and to the assumption that segregation of construction waste is generally carried out on site at the expense of the waste generator. Diversion of other waste streams to landfill (e.g. household and commercial waste) would result in much higher costs.

The main environmental burdens including the related human health impacts of the three scenarios have been assessed. To the extent possible, and therefore with a bias towards impacts of air pollution, the external costs associated to each scenario have been evaluated. The calculations for all the scenarios show environmental benefits. Considering what is regarded in the study as being the “best” estimate for each of the burdens evaluated, benefits have been estimated for the three scenarios to be respectively about 190, 140 and 50 € per tonne of waste diverted for the period 2000-2020. The major contribution to these results comes firstly from the avoided emissions from the manufacture of virgin PVC (in the case of high quality recycling) and secondly from the avoided emissions from incineration (including indirect emissions associated with the manufacture of neutralisation agents).

It can be seen from the comparison between the financial and the environmental analyses based on the best estimate that scenario 1 and scenario 3 show an overall benefit, as the costs per tonne diverted are lower than the benefits. The contrary is true for scenario 2, where the environmental benefit (although higher than in scenario 1 and 3) is nevertheless exceeded by the estimated cost.

A number of assumptions have been made to carry out these calculations. In particular, concerning the financial aspects, the cost elements were necessarily based on very few experiences of existing PVC post-consumer waste recycling schemes, which are still at a preliminary stage. These uncertainties are higher for scenario 2.

⁷²

Incineration of PVC with municipal solid waste (MSW) incurs additional operating costs for the incinerator in terms of reagents to abate acid gas emissions and for the treatment and disposal of residues, although these are partly offset by increased energy sales due to the higher calorific value of PVC compared to MSW.

As the price of recyclates is closely linked to the price of virgin PVC, increasing prices of the latter would lead to lower overall costs.

As indicated, the environmental analysis is biased towards the impacts of air pollution. However, it is likely that most of the externalities omitted (e.g. residues disposal) would increase the benefits of the diversion of PVC from incineration. The main exception relates to phthalate plasticisers. Landfilled flexible PVC would form a reservoir of these chemicals that could slowly leach out over time, whilst incineration presents the advantage of destroying them. Incineration also allows the recovery of the calorific value of phthalates. This factor has been included in the environmental analysis.

Future developments and policy orientations

In the baseline scenario, the incineration of PVC waste would increase to about 2.5 millions tonnes in 2020 compared to about 600,000 tonnes at present. The number and capacity of incinerators employing wet, semi-wet wet and semi-dry flue gas neutralisation technologies will increase at the expense of those employing dry technologies.

Issues for consideration:

The Commission considers, on the basis of the above-mentioned analysis, that the incineration of PVC waste raises a number of issues. A range of measures could be envisaged to address these issues and should be assessed in the light of their potential environmental and economic implications. Such measures include:

- 1. Diversion of PVC waste, mandatory or not, as far as economically feasible, from incineration to preferably recycling or landfilling. This would require the introduction of collection schemes to ensure separate collection of PVC to be diverted***
- 2. Similar diversion only for rigid PVC***
- 3. Meeting the additional costs related to the incineration of (totally or partially), e.g. through internalisation of these costs in the price of new PVC products or direct financial contribution to operators of incineration plants***
- 4. Encouragement of the conversion of the flue gas cleaning technologies that reduce the amounts of residues generated or allow the recycling of HCl instead of its neutralisation***
- 5. Further research on the potential relation between PVC incineration and dioxin formation should be carried out.***

Question n°6:

Which set of measures would be most effective to address the issues linked to the incineration of PVC waste?

4.6. *Landfill*

Landfilling is the most common waste management route for PVC waste. Exact figures on the landfilling of PVC waste are not known and there are large differences between various estimations ranging up to 2.9 million tonnes of PVC waste being landfilled every year. It can be estimated that several tens of million tonnes of PVC waste have already been landfilled during the past 30 years.

Member States will have to bring into force the provisions of Directive 1999/31/EC on the landfilling of waste in 2001. The Directive requires that landfill installations comply with a number of technical standards regarding the protection of soil and water including leachate collection, bottom sealing and gas emission control.

All materials in landfill including PVC are subject to different reactive conditions, which are determined by the parameters such as temperature, moisture, presence of oxygen, activity of micro-organisms and the interactions between parameters at different stages of the ageing process of landfills. Four main phases can be distinguished: short initial aerobic phase, anaerobic acidogenic phase (variable duration, longer than aerobic phase), anaerobic methanogenic phase (up to several centuries), final aerobic phase.

Investigations⁷³ have been carried out on both rigid and soft PVC samples mainly through laboratory equipment studies, examination of the effects of a biological treatment, and of microbiological tests.

The PVC polymer is generally regarded as being resistant under soil-buried and landfill conditions⁷⁴. However, an attack on the PVC polymer of a thin packaging foil has been detected⁷⁵. This remains an isolated result and the attack was observed under aerobic conditions and at 80°C, conditions which, if they occur in landfills, are transient.

Losses of plasticisers, especially phthalates, from flexible PVC are widely recognised in the literature. Results from studies on the degradability of phthalates under landfill conditions show that degradation of phthalates occurs, but may not be complete depending on conditions and type of phthalate. Both, phthalates and their degradation substances can be detected in landfill leachates. In addition, long-chain phthalates, such as DEHPs, are only partly degraded in usual leachate and sewage treatment plants and accumulate on suspended solids. Losses of phthalates could also contribute to gaseous emissions from landfills. As for other emissions from landfill, emissions resulting from the presence of PVC in landfills can last longer than the guarantee of the technical barrier and there is no evidence that the release of phthalates will come to a standstill after a given period of time.

Stabilisers are encapsulated in the matrix of rigid PVC waste. Hence, migration is expected to be low and would affect the surface of the PVC but not the bulk of the material. Concerning stabilisers in flexible PVC waste, a study⁷⁶ into the long-term

⁷³ Argus in association with University Rotstock, op. cit.

⁷⁴ Mersiowski et al. 1999, Behaviour of PVC in landfills, ECVM, Technical University Hamburg-Harburg

⁷⁵ Argus in association with University Rotstock, op. cit.

⁷⁶ Mersiowski et al., op. cit.

behaviour of PVC waste under landfill condition showed a release of lead stabiliser from one specific PVC cable containing a combination of several plasticisers.

PVC products disposed of in landfills will certainly contribute to the formation of dioxins and furans during accidental landfill fires, but the quantitative contribution cannot currently be estimated due to the inherent difficulties in obtaining the necessary data.

In order to further assess and quantify the environmental impacts of the landfilling of PVC, further research would be necessary to study the potential degradation of PVC polymer, the release of stabilisers and plasticisers, as well as the environmental contribution of phthalates to the leachates and gaseous emissions from landfills.

The costs for landfilling PVC waste in Member States are those for landfilling municipal solid waste and show a wide range of tariffs⁷⁷. The prices or tariffs for landfills are influenced by a number of factors such as the standard of the landfill, the competition between different disposal routes, the type and nature of waste being accepted. Generally, no influence on prices or tariffs could be related or is expected due to the presence of PVC in municipal solid waste being landfilled.

Future developments and policy orientations

In the baseline scenario, it is expected that the quantities of PVC waste landfilled would remain constant at about 2.8 millions tonnes in 2020.

Issues for consideration:

The Commission considers, on the basis of the previous analysis, that the landfilling of flexible PVC waste raises some issues. A range of measures could be envisaged to address these issues. Environmental and economic implications of these measures should be considered. Such measures include:

- 1. Disposal of flexible PVC waste in controlled landfill sites with high emission standards as foreseen in the landfill Directive***
- 2. Further research on the leaching or emissions of additives.***

Question n°7:

***Are specific measures concerning the landfilling of PVC waste necessary?
If so, which ones?***

5. OTHER HORIZONTAL ASPECTS ON PVC

The analysis in this document focuses on two main aspects : the use of additives in PVC and the management of PVC waste. In addition, more general and horizontal aspects arise in the context of a broad consultation on PVC.

⁷⁷ At present, the costs for landfilling municipal solid waste range from 8 € per tonne in Spain up to 200 € per tonne in Germany. The cost for landfilling mixed waste, such as unsorted construction and demolition waste containing organic components, is usually higher than for landfilling of inert waste. An average price of about 50 € per tonne is usual.

Regarding the type of instruments to implement a horizontal Community strategy on PVC, a range of measures, mandatory and voluntary, is available:

- Voluntary approaches, including the implementation of existing voluntary commitments, at national and Community levels, as well as the development of new voluntary approaches. As mentioned previously, the European PVC industry has signed a voluntary commitment on the sustainable development of PVC. And while this can be seen as a first step there is still work to be done to ensure an effective participation by industry in achieving Community goals in this area. It should be underlined that the services of the Commission are currently preparing a Proposal for a framework Regulation concerning Community environmental agreements to be adopted by Council and Parliament.
- Legislative measures, such as a Proposal for a Directive on PVC, could be proposed in order to address issues related to management of PVC waste and other legislative measures to deal with the use of additives on the basis of all existing scientific evaluation, including the results of risk assessments. Recommendations could also be adopted to develop the implementation of a Community strategy.
- A mix of instruments could be proposed, integrating voluntary commitments, recommendations and regulations including the adaptation of existing legislation. Such a set of instruments would be in line with an approach, which aims at combining voluntary and binding instruments.

Apart from an approach based on PVC waste management and additives, the question of a potential substitution policy for certain PVC applications has been raised in the context of promoting more sustainable products as part of an Integrated Product Policy. Such a substitution policy could be considered for specific applications, which can not be separated from the general waste stream and therefore are difficult to recycle such as in packaging, motor vehicles, electric and electronic equipment. A potential substitution policy would need to be underpinned by a comprehensive and objective assessment of the main environmental impacts both of PVC and of potential substitutes during their whole life cycle. The approach outlined in this document focuses on dealing with the environmental issues of PVC mainly through policies on additives and waste management.

Issues for consideration:

A number of issues regarding the environmental impacts of PVC have been identified, including the question of a horizontal approach and of appropriate instruments to address these issues. The Commission sees merit in developing a horizontal strategy on PVC. A number of instruments are available to implement such an approach. Environmental and economic implications, as well as the compatibility with the international obligations of the Community should be assessed.

Question 8:

Which are the appropriate instruments for developing a horizontal strategy on PVC? Should a PVC substitution policy for some specific applications be envisaged? If so, how?

6. CONCLUSION

A number of concerns regarding the impact of PVC on the environment, including related human health issues, have been identified and explained in this document. These are mostly related to the use of certain additives and to the management of PVC waste. In the light of the analysis, a number of options have been identified, which could ensure an effective approach on waste management and additives, to be based on an assessment of the environmental and economic implications, with a view to reducing the impact on human health and the environment of PVC throughout its life cycle.

A public consultation on PVC is proposed on the basis of these options. The Commission hereby invites all interested parties to discuss and comment on this document. A public hearing will be organised in October 2000.

Comments may be sent directly to the Commission at the latest on 30 November 2000. Submissions should be sent to Mr Krämer, Head of the waste management unit (DG ENV) and Mr Schulte Braucks, Head of the chemicals unit (DG ENTR), 200 rue de la Loi / Wetstraat 200, B-1049 Bruxelles/Brussel, Belgium. Comments may alternatively be sent by e-mail to the following address: ENV-PVC@cec.eu.int. The various language versions of the Green Paper, the studies commissioned by the Commission as well as the comments on the Green Paper can be found at the following internet address: <http://europa.eu.int/comm/environment/pvc/index.htm>.

On the basis of the analyses developed in this document and the outcome of this consultation process, the Commission will present at the beginning of 2001 a Communication setting out a comprehensive Community strategy on the environmental issues of PVC.

ANNEX 1

Description of the various flue gas cleaning processes

Flue gas cleaning processes	Main characteristics
Dry process	<p>The neutralisation process consists of the injection of solid neutralisation agents. The most common neutralisation agent is lime ($\text{Ca}(\text{OH})_2$). Other agents are also used, in particular sodium hydrogen-carbonate (Bicar, NaHCO_3) or spongiacal hydrated lime.</p> <p>A chemical reaction transforms the acidic components of the flue gas into salts. The resulting residues of the neutralisation process are solid residues mainly composed of neutralisation salt: calcium chloride (CaCl_2), sodium chloride (NaCl), sulphates (CaSO_4, Na_2SO_4), excess of the neutralisation agents and heavy metals in various chemical forms. These residues are classified as hazardous waste.</p> <p>The dry process with classical lime is not likely to be able to comply with the strict emission limit value of 10 mg/Nm^3. The dry processes using specific neutralisation agents such as spongiacal hydrated lime and Bicar can comply with this limit.</p>
Semi-dry process	<p>The neutralisation process consists of the injection of a solution or a suspension of the neutralisation agent (lime) in water. The resulting reaction products are solid residues. They are composed of calcium chloride, sulphates and heavy metals, as well as unreacted lime added in excess. The residues are classified as hazardous waste.</p>
Wet process	<p>In this process, two successive scrubbers are operating. In the first (acid scrubber), most of the HCl is absorbed in water. The remaining HCl and SO_x are absorbed and neutralised in the second scrubber (neutral scrubber), which is generally fed with a soda (NaOH) solution.</p> <p>The resulting liquid effluents need to be treated prior to release into the environment. In the water treatment unit, heavy metals and sulphates are precipitated by the addition of lime. The precipitated heavy metals are separated by filtration (and need to be landfilled), while the treated saline wastewater is discharged. The effluent of the acidic scrubber is either neutralised and treated together with the effluent of the neutral scrubber or is purified and HCl reused.</p>
Semi-wet wet process	<p>Due to stricter regulations on the discharge of saline wastewater, many incineration plants are introducing evaporation to eliminate liquid discharges completely⁷⁸. Wet processes are therefore being converted to semi wet-wet processes generating dry solid residues. This is already the case for German and Austrian plants. This process is similar to the wet technique but the liquid effluent is then sprayed in the gas and the liquid evaporated. This system produces dry residues classified as hazardous waste.</p>

⁷⁸

Economic evaluation of the Draft Incineration Directive, a report produced for the European Commission, DG XI, AEA Technology, December 1996

It is difficult to present a detailed repartition of the various types of incinerators currently in activity. The following statistics⁷⁹ present the situation for the period 1993-1996 and for plants with a rather large capacity. About 15% of the total capacity use a dry process for gas treatment, for 25% a semi-dry process is employed, for about 20% semi-wet wet processes are in use and about 40% wet processes are used. The distribution of treatment capacities is different in the various Member States. In general, the capacities for dry processes have decreased to the advantage of other processes. The stricter emission requirements for incinerators as proposed in the Directive on waste incineration are likely to enhance this trend.

⁷⁹ European Energy from Waste Coalition, Energy from Waste Plants: Databook of European Sites, Report prepared by Juniper Consultancy Services Ltd, November 1997. This figure refers to plants with a capacity of more than 30,000 t/year

ANNEX 2

Additional cost for PVC incineration

The figures in the following table⁸⁰ represent the range of additional costs for the incineration of PVC in comparison to municipal solid waste. The lower figures apply to flexible PVC containing 25% chlorine, the higher figures to rigid PVC containing 53% chlorine. The average figures apply to a PVC material mix with 45% chlorine, i.e. composed of 70% rigid PVC and 30% flexible PVC.

Average and range of additional cost for PVC incineration €/ton of PVC	Dry System		Semi-Dry	Wet	Semi-Wet, Wet
	Lime	Sodium Bicarbonate	Lime	Lime / NaOH	Lime / NaOH
Without stabilisation of the residues average and min/max value	196 95 – 234	274 144 – 327	165 84 – 206	19 -1 – 29	121 57 – 147
With stabilisation of the residues average and min/max value	290 154 – 347	334 172 – 396	244 127 – 305	19 -1 – 29	186 96 – 226

⁸⁰ Bertin Technologies, The influence of PVC on quantity and hazardousness of flue gas residues from incineration, Study for DG XI, April 2000

ANNEX 3

PVC waste management scenarios established for the economic and environmental analysis⁸¹

Scenarios of future waste management across the EU and six of the applicant countries have been developed in order to carry out the economic and environmental analysis. **The business as usual (BAU) scenario** is based on current destination of PVC waste across Western Europe as made available by EuPC and the present rate of MSW incineration. The present day incineration rate of main PVC waste streams is assumed to be in proportion to the general rate for MSW incineration. To estimate future destinations, a distinction has been made between Member States which will limit themselves to the strict implementation of the landfill directive and Member States which are likely to go beyond EU rules, substantially reducing the landfilling of raw organic waste (e.g. Austria, Germany, the Netherlands, Sweden) by increasing incineration. The first group of Member States are also expected to increase incineration capacity over the next two decades, but the final rate achieved is assumed to be lower because of the lower starting point and the poorer economic circumstances of some of the countries concerned. Accession countries have been included in this first group.

The obtained incineration rates have been applied to the remaining quantities after deduction of PVC waste that is mechanically recycled. Given the current limited state of its development, feedstock recycling has not been considered in the study. Mechanical recycling has been assumed to develop as predicted under the baseline scenario developed in the mechanical recycling study⁸². Thus recycling of post-consumer PVC waste will increase from about 3 per cent today to about 9 per cent by 2020.

Three alternative scenarios for diversion of PVC from incineration have then been elaborated. The first two are based on the assumption that PVC diverted from incineration will go to mechanical recycling. In the third scenario, diverted waste is sent to landfill.

Scenario 1: This scenario is partly based on the “selective improvement scenario” proposed in the mechanical recycling study. It is assumed that recycling of most construction wastes suitable for high quality recycling is encouraged so that the average potential calculated in the mechanical recycling study is reached. Although suitable for high quality recycling, PVC in the household and commercial waste category as well as flexible profiles and hoses (construction category) have however been excluded as no precise cost estimate was available. It is reasonable to assume that development of recycling potential for these wastes is therefore further away than for the remaining wastes for which cost estimates were provided.

Scenario 2: This scenario models mechanical recycling for all suitable types of waste (construction, household and commercial, packaging, electric and electronic waste) achieving its absolute full potential in 2010 and continues at this rate until 2020. All waste streams are recycled at the *maximum* of recycling potential estimated in the mechanical recycling study.

Scenario 3: In this scenario recycling rates remain unchanged compared to the baseline scenario. PVC waste diverted from incineration is therefore sent to landfill. The analysis is limited to the diversion of construction waste to identify the main economic and

⁸¹ AEA Technology, Economic evaluation of PVC waste management, draft report produced for the European Commission Environment Directorate-General, May 2000

⁸² Prognos, op.cit.

environmental impacts of diverting from incineration to landfill. Segregation of PVC from the other waste streams considered in the study is likely to be more problematic from an economic and technical perspective.