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Committee of Experts
"Healthy Building and Housing"
with the
Federal Minister for Environmental Planning,
the Building and Construction Industry and
Urban Development

PVC Products in the Building and Construction Industry

Answers to Questions on Health and the Environment

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Committee of Experts "Healthy Building And Housing"
with The Federal Minister for Environmental Planning,
the Building and Construction Industry and Urban Development

P V C P R O D U C T S I N T H E B U I L D I N G A N D C O N S T R U C T I O N I N D U S T R Y

Answers to Questions on Health and the Environment

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1. General Information

1.1 Reasons and Targets

The application of PVC (polyvinylchloride) is mentioned over and over again in the discussion about our environmental pollution, coupled with damage to people's health.

In order to be able to make statements on this, it is imperative to investigate all the health aspects, such as the manufacture, use and waste management of the material, in respect of the health hazard and environmental pollution.

In the following, however, only the area of the application of PVC in the building and construction industry will be singled out.

1.2 Application in the Building and Construction Industry and Production Quantities

In the Federal Republic of Germany around 8.0 million t plastic per year are manufactured currently; of that around 1.2 million t is PVC. About 50% of that, i.e. around 600,000 t PVC, is used for the building sector.

The reason for the versatile application of PVC in the building and construction industry lies in it's technical characteristics and in the fact that it is inexpensive. PVC is resistant to many chemicals, to weathering influences and to signs of corrosion. It has a low weight, is easy to process, can be welded, glued and dyed. In addition, it has low flammability and, owing to it's low conductivity of heat and noise, it has good performance characteristics.

A total of over 3,000 industrial and trade businesses, with more than 100,000 employees, deal with the manufacture and processing of PVC products in the Federal Republic of Germany.

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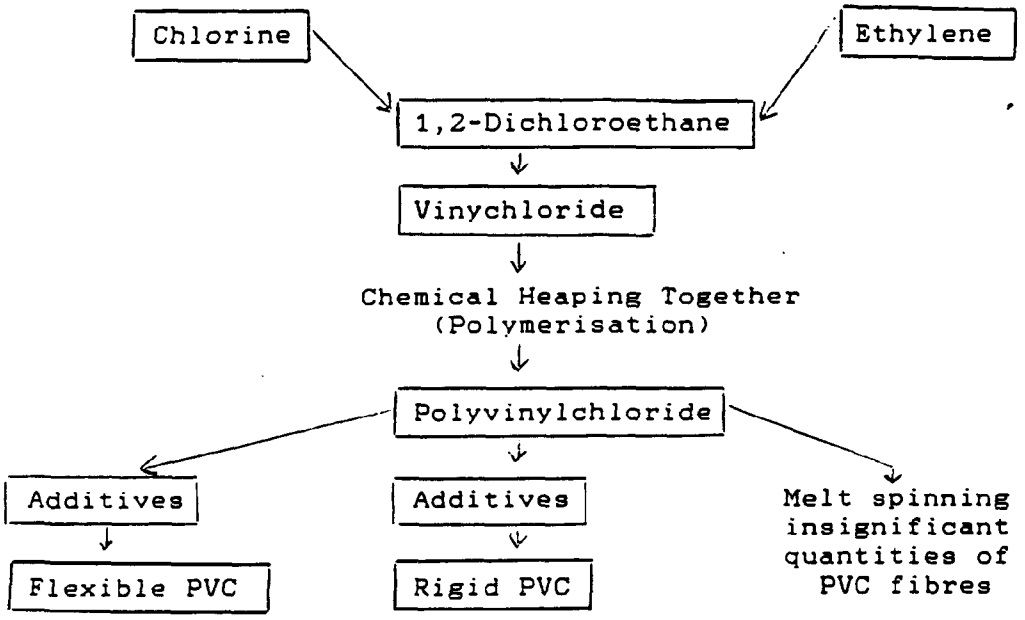
The portion of PVC materials produced from coal (acetylene) amounts to about 15%, and the portion produced from petroleum and natural gas (ethylene) about 85%. The chemical action is represented as follows:

HC = CH	+	HCl	→ H_2C = CHCl
Acetylene	+	Hydrogen chloride	→ Vinylchloride
H_2C = CH_2	+	Cl_2	→ H_2C = CHCl + HCl
Ethylene	+	Chlorine	→ Vinylchloride + Hydrogen chloride

The monomer vinylchloride is a colourless gas, which, through polymerisation (= chemical heaping together/ crosslinking), becomes polyvinylchloride = PVC.

Using the example of the application of ethylene, the following diagram occurs for the origination of PVC:



Depending on the application later, different additives are added to the white powder, which arises through the polymerisation of the vinylchloride.

1.4 Additives

Stabilizers, dyestuffs (pigments), lubricants, plasticizers, flame retardants and fillers are used as additives.

Before processing, the primary plastic PVC is mixed through the use of various **stabilizers**, some of which contain metals, depending on the intended purpose of application, in order to prevent thermal damage during processing and use, as well as to prevent oxidation and degradation through the influences of weathering - in particular through UV irradiation. In the end, stabilizers are decisive for the resistance of products to aging.

The normal stabilizers in the manufacture of PVC are:
- Calcium, zinc, magnesium soaps
- Barium, cadmium soaps
- Tin octyl combinations
- Basic lead combinations
- Epoxidized soya bean oils
- Pentaethritol ester
- Sorbitol

Sometimes, systems containing cadmium are used for PVC products, which are to be exposed to the weather, such as window profiles and shutters, for example. Interior products made from PVC, such as floor coverings, wallpapers, and also packaging materials, no longer contain cadmium stabilizers these days.

The PVC manufacturing and processing industry in the Federal Republic of Germany is striving to replace cadmium, step by step, with other stabilizers. Ten years ago, the cadmium consumption during the manufacture of PVC amounted to around 500 t per year. Despite a considerable increase in the overall production of PVC, it is currently only around 270 t per year.

Only lead compounds are used as stabilizers in pipe production these days. According to stipulations from the Federal Public Health Department, the lead content in PVC drinking water pipes must not exceed a value of two weight percent.

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In the Federal Republic the following combinations are normally used as **dyestuffs** (pigments) during the manufacture of PVC to colour the products:

- Titanium dioxide = white
- Iron oxide = yellow, black, brown, red
- Carbon black = black
- Cobalt = blue
- Organic pigments

There are no pigments containing cadmium in PVC products.

Lubricants reduce the viscosity of the moulding material for processing, or act as a lubricator between the melting plastic and the metal walls of the machines, tools and calibrator. They are processing aids.

The usual lubricants in the manufacture of PVC are:

- Metal soaps (stearates)
- Lignite wax and paraffin wax
- Types of polyethylene which are similar to wax
- Fatty alcohols and ester
- Silicons
- Glycerine ester

Plasticizers serve to make certain PVC products flexible (depending on the requirement) in broad ranges of temperatures.

Plasticizers are organic substances, which go into a physical interaction with high polymer materials, and form a homogeneous system with them. They are used to reduce the modulus of elasticity, the rigidity and the brittleness of thermoplastics (these soften in heat, in contrast with duroplastics, which remain stiff in heat).

The usual plasticizers in the manufacture of PVC are:

- Phthalates (among which is Diethylhexylphthalate DEHP, the most often used)
- Phosphates, epoxidized fatty acid ester
- Alkylic sulfonic acid ester
- Adipic - azelaic and sebascic acid ester
- Trimellite acid ester

Flame retardants are chemcial combinations, which reduce the inflammability of burning materials, prevent the formation of flames or delay incineration, to a large extent. They are used in the manufacture of PVC, e.g. for cable sheathing compounds.

The usual flame retardants in the manufacture of PVC are:
- Aluminium / magnesium oxide hydrate
- Phosphoric acid derivatives

In the literature, the possibility of using brominated aromatics as flame retardants for PVC products in the electrical sector (cables and cable sheathings) is often mentioned, in particular the use of penta-brominated diphenyl ether, which is controversial. Based on it's comprehensive knowledge of cable production in the Federal Republic of Germany, the Specialist Association Cable and Insulated Wires, belonging to the Central Association Electro-Technology and Electrical Industry (ZVEI), Registered Association, states that it is absolutely not usual to use that type of flame retardant in compositions for PVC insulations or coverings.

Fillers are intented to improve the processibility and the physical performance characteristics of products. Mineral fillers, marbles and fibres are used, besides organic natural materials.

The usual fillers in the manufacture of PVC are:
- Chalk
- Mica
- Talc
- Limestone - Marble
- Calcium sulphate (Gypsum)
- Quarz powder
- Kaolin
- Magnesium oxide

The following table gives a general overall view of the percentages of additives in PVC building products:

Groups of Products	Stabilizers in %	Plasticizers in %	Flame retardants in %	Lubricants in %	Fillers in %	Pigments in %
Window profiles	2 - 5	---	---	2	---	2 - 5
Pipes, rigid films, formers	2 - 3	---	---	2 - 3	---	2
Floor coverings	0.5-1	10-20	---	1	25-50	1
Wallpapers, flexible films	2 - 3	25-45	---	---	10-50	1 - 3
Cable sheathing compounds	1 - 3	25-40	0 - 5	1 - 2	10-50	1 - 3

2. Questions on Health and the Environment During Manufacture and Processing

The intermediary product vinylchloride arises during the manufacture of PVC. This material has a high carcinogenic potential, which can lead to changes in the skin and bones.

In the Federal Republic of Germany these days, so-called "intensive degassing" is used during the manufacture of PVC, which greatly reduces the content of monomeric vinylchloride in PVC. These days only 0.0001% vinylchloride is permitted in the final product, compared with 0.01% in compliance with previous regulations.

As a rule, residual vinylchloride which occurs is put back into the production process again through recycling. Incidentally, plants manufacturing PVC are subject to a licence from the authorities, in accordance with the Federal Law on Protection from the Effects of Emissions. This is only granted, if, among other things, it is guaranteed that no harmful effects on the environment can be caused by the plant. The requirements to restrict the vinylchloride emissions are laid down in detail in the Technical Instructions for Maintaining the Purity of the Air (TA-Air).

Consequently, through compliance with the legal regulations governing industrial health and safety standards, it can be assumed that damage to the health of those persons employed in the manufacture and processing of PVC in the Federal Republic of Germany today can be ruled out.

3. Questions on Health and the Environment During Use

Hardly any substances, which endanger health, are contained in PVC building products produced in the Federal Republic of Germany through modern methods, and/or the contents can hardly be released in dangerous concentrations. Thus, for example, investigations carried out at the Rheinland-Westphalia Technical College in Aachen have shown that, under normal room and atmospheric conditions, no emissions of vinylchloride or DEHP can be detected from the PVC coverings tested, which were manufactured in the Federal Republic of Germany.*

Animal experiments were carried out in the USA in respect of the plasticizer DEHP, using extremely high concentrations. The results showed a carcinogenic effect. In connection with this, the Advisory Committee for Waste Materials Relevant to the Environment (BUA), attached to the Society of German Chemists, to which experts from authorities, scientific institutes and industrial concerns belong, stated: "The current level of knowledge provides a solid basis for the assumption that carcinogenic effects, or effects damaging to the foetus, only occur with very high doses of DEHP, which are not usual in the environment, and the carcinogenic effect of DEHP, which has been established in rodents, is not relevant to people."

Older PVC floor coverings can also contain cadmium. Cadmium can enrich itself in plants and animals, but also in the human body. Damage to the lungs and kidneys arises from continuous cadmium pollution. In higher concentrations, cadmium inhibits the growth of plants.

A certain amount of cadmium pollution in household dust, casued through rubbing-down floor coverings, cannot be ruled out in traces, although this is extremely low owing to the special characteristics of the material. These days, cadmium stabilizers are no longer used in floor coverings.

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* Report dated 13 October 1986 by Prof. Einbrodt M.D.

4. Questions on Health and the Environment in the Event of Fire

PVC, which has low flammability and is self-extinguishing, can also burn during fires in buildings. It releases hydrogen chloride, which combines with water to form hydrochloric acid. In high quantities hydrochloric acid is a health hazard for people.

However, as varied fire tests have shown, in the event of a fire the hydrogen chloride arising from PVC products does not play a decisive role in the danger to people, in comparison with the quantity of the highly poisonous carbon monoxide (CO) originating from surrounding materials during the fire.

In the event of fire, however, PVC is an important source of chlorine, which promotes the formation of dioxins and furans. It is suspected that the fire residues are similarly as toxic as the corresponding chlorinated compounds. Tests carried out on this have not produced any results to date. In any case, PVC building components play a subordinate role in the overall emission of dioxins and furans during fires in buildings.

5. Questions on Health and the Environment During Waste Management

5.1. Waste in the Building and Construction Industry

Approx. 2 million t plastic waste occur in the Federal Republic of Germany annually. Of that, approx. 1.6 million t end up in domestic waste. The total quantity of PVC waste amounts to about 12% to 15% of all plastic refuse, i.e. a maximum of 300,000 t. It is estimated that 50% of that, at the most, i.e. 150,000 t, can be allocated to the building sector. In relation to the accompanying, current production, that is 25%. A certain balanced situation between production and waste management will take place only gradually in the next 50 years.

The total quantity of building rubble arising from house modernization, new buildings and demolition amounts to about 15 million t annually in the Federal Republic of Germany. In addition, 13 million t occurs from breaking up roads and 110 million t from deposits of soil.

Building refuse, and therefore it's PVC products too, end up for the most part on building rubble disposal sites.

5.2 Recycling

With regard to environmental pollution, it would be most sensible to prepare products which cannot be used any more, so that they can be put back into the production cycle. However, the prerequisiste for re-use is that plastic waste is collected separately from normal domestic waste and building rubble (see glass containers and paper containers).

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The advantages of recycling would be:
- The avoidance of waste arisings.
- Energy savings, because with recycling the amount of energy required is usually significantly lower than for a new production.
- Saving of disposal space.
- Easing the burden on municipal solid waste incineration plants and, thus, on the environment.

Up to now the recycling of plastic waste is carried out mostly just for industrial waste. However, this only represents a small easing of the burden for the whole of waste management of plastics.

In 1984 the environmental sign was allocated for products made from plastics which can be recycled (RAL - UZ 30). Finished products, which are manufactured from at least 85% of mixed and polluted plastic waste, can be equipped with this sign. These products are used primarily in the construction of roads and horticulture (e.g. as plinths for signs and signposts, seat fastners, bollards, manhole covers).

Quantitatively, this regeneration currently represents, only an insignificant factor for waste management, because there is only a low demand for the group of products which originate in this way. Consequently, in the PVC manufacturing and processing industry a stronger willingness must be adopted to participate in the recycling of PVC refuse from building rubble. The first signs of this are beginning to appear. A list of 58 PVC valorisation companies is available, who also accept PVC waste from elsewhere. In addition, in 1988 an "Association PVC and the Environment, Reg. Assn.** was formed, which, through it's work, intends to help to avoid PVC waste, to intensify the valorisation and/or recycling of PVC waste, and to promote the waste management of PVC refuse in a manner which is forward-looking and environmentally friendly.

** Arbeitsgemeinschaft PVC und Umwelt e.V. (AgPU), Adenauerallee 45, 5300 Bonn 1

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5.3 Landfills

As approx. 70% of the PVC products in the Federal Republic of Germany are put into landfills, the question arises of how these durable products should continue to be waste managed. Certainly it will not be possible to make disposal sites available on a larger scale in future. Consequently, the quantity of accumulating durable plastic products, must be reduced - where possible.

In the manufacturing of PVC, cadmium stabilizers are only used for durable, weather resistant products, such as window profiles. As a rule, these go to a landfill. As far as a landfill is concerned, the framework of the polymer is not degradable.

There are no scientifically substantiated statements on whether cadmium would be released in the conditions on a disposal site and whether it could get into the seepage water. Some additives in PVC, such as plasticizers, fillers, lubricants, are degraded microbially.

5.4 Municipal Solid Waste Incineration

Like all plastics, PVC consists of a carbon chain and, therefore, is combustible. Plastics have a high calorific value, which lies above that of the overall waste. The percentage of PVC refuse from the building sector, which currently ends up in domestic waste, is estimated to be about 15%. That is around 22,500 t in the Federal Republic of Germany. Of this, about 7,500 t goes into incineration, which is a relatively insignificant quantity.

PVC breaks down in the temperature range of 200°C - 300°C. However, hydrogen chloride (HCl) is already split-off from 150°C on, and reacts in the atmosphere very quickly to form acid. In 1986, in the TA-Air, the emission limit for HCl was reduced from 100mg to 50mg/m³ exhaust air; although this can only be complied with by using the most modern fume purification technology. However, through the TA-Air

1986, a renovation concept came into force for all the old plants, which require a licence in accordance with the Federal Law on Protection from the Effects of Emissions. According to this, municipal solid waste incineration plants must be improved within 3 years, that is by 1 March 1989 at the latest, corresponding to the advanced level of the technology to maintain atmospheric purity. Thus, today, of the 48 municipal solid waste incineration plants in the Federal Republic of Germany, 47 have modern fume purification, which always complies with the stipulated HCl limit of 50mg/m³ exhaust air, and usually even undercuts it by a long way. Only one plant does not yet fulfill this standard. It is currently out of operation.

Taking the average of the analyses of domestic waste in the Federal Republic of Germany, it was established that roughly 21% of the lead and 50% of the cadmium were brought into the waste with plastic refuse. The percentage of PVC within this plastic refuse was not given. The Federal Office of the Environment stated in 1986 that approx. 5% - 10% of cadmium emissions in the Federal Republic of Germany arise from municipal solid waste incineration plants, and that 85% of them are brought in through plastics (of that, close to half is through PVC). With modern fume purification plants these days, cadmium emissions are greatly reduced at the same time - by around 90%.

As mentioned often already, cadmium stailizers are only used for PVC products demanded for applications outdoors, such as window profiles. Almost exclusively, these do not end up in municipal solid waste incineration plants, so that PVC building products have practically no part in the cadmium emissions from solid waste power stations.

Chlorinated dioxins originate during incomplete incineration processes, if materials containing chlorine and organic materials are present. It is possible that the decisive portion of dioxin and furan pollution in our environment is caused through the production and application of chlorinated organic materials. However, whether the chlorine percentage in PVC leads to an increased formation of dioxins and furans in municipal solid waste incineration plants has not been proven.

6. Summary

- In the Federal Republic of Germany around 6.0 million t plastic, including about 1.2 million t PVC, are manufactured annually. Of that, about 0.6 million t is used in the building sector.

- Pollution to employees, primarily through the intermediary product vinylchloride, which has a carcinogenic effect, is kept so low, through legal regulations, that health hazards do not arise during the manufacture and processing of PVC.

- PVC products in the building and construction industry do not cause any impairment to health during their use, provided that the conditions and regulations for fabrication, which are normal in the Federal Republic of Germany, are complied with.

- A maximum of 0.15 million t PVC building products are waste managed annually in the Federal Republic of Germany. That is 25% of the current production and 1%, of the total quantity of building rubble arising. Essentially, PVC building refuse is got rid of separately from domestic waste.

- Currently, the much larger portion of PVC building waste ends up on landfills. There, the great durability of PVC is a disadvantage. Owing to the limited availability of disposal space in the Federal Republic of Germany, a reduction in the quantity of all building rubble, including the PVC portion, is advisable. Further disadvantageous effects through the disposal of PVC on landfills are not known.

- Only a small portion of PVC building products end up in municipal solid waste incineration plants. This possibility of waste management is not significant for PVC building refuse.

- Recycling PVC building products represents the best and most economic waste management for the future. The PVC producing and processing industry is already making increased use of the reservoir of raw materials arising through this. The prerequisites for this

possibility of waste management do exist in the Federal Republic of Germany. They are constantly being developed at all levels, so that about one-third of the PVC building refuse can go into the recycling process in the medium-term.

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Sachverständigengremium
"Gesundes Bauen und Wohnen"
beim Bundesminister für Raumordnung,
Bauwesen und Städtebau

PVC-Produkte im Bauwesen

Antworten zu Gesundheits- und Umweltfragen