Is PVC a problematic plastic?

From production to use to waste management: everything you need to know about PVC.

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THE PRODUCTION OF PVC

Is chlorine unique to PVC?

Chlorine is not unique to PVC. Around 30% of the chlorine produced is used specifically in the manufacture of PVC. The remaining 70% supports a wide range of other applications, including the manufacture of other plastics such as polyurethane (PUR) and polycarbonate (PC), as well as epoxy used in wind turbine blades. Chlorine is also essential for products such as batteries for electric cars, solar panels, and for disinfecting drinking water and treating wastewater. In addition, chlorine is involved in the manufacture of almost 90% of all medicines.

PVC is composed of 57% of chlorine. As such, it is linked to the broader Chlor-alkali value chain: a strategic value chain for Europe which produces caustic soda, chlorine and hydrogen. Caustic soda is widely used in industries such as aluminum manufacturing, medicine, food, paper, cosmetics and detergents. Hydrogen is considered to be a potential future replacement for fossil fuels in sectors where electrification is difficult, such as shipping and aviation.

The high chlorine content in PVC means that it requires less primary energy than other materials[1]. The chlorine also creates strong polymer chains, making PVC a highly stable and long- lasting material that can be mechanically recycled again and again without losing functional properties.

Are mercury and asbestos still used in chlorine production for PVC?

In Europe, mercury and asbestos have been banned since 2017. No European PVC producer is running a Mercury cell room, therefore there is no mercury emissions in the European PVC production.

The remaining use of asbestos-based diaphragm technology must be phased out by 2025, and PVC production does not rely on such technology[2]. In the US, there has been a long-standing shift away from asbestos diaphragms to membrane technology, and in March 2024, the US Environmental Protection Agency (EPA) banned the use of asbestos. This means that the remaining eight facilities using this technology will have to phase it out within a few years[3].

In 2022, membrane technology accounts for almost 86.2% of the European capacity[4]. Membranes and asbestos-free diaphragms are recognised as Best Available Techniques (BAT), as described in BREF documents published by the EU in 2014. Membrane technology also offers significant energy savings compared to the processes it replaced[5].

Are PFAS used in PVC production?

In PVC production, per- and polyfluoroalkyl substances (PFAS) are not directly used as raw materials in the manufacturing processes themselves. However, polymeric PFAS are present in equipment and materials used in production due to their unique properties such as durability in extreme conditions.

For example, polymeric PFAS are used in membranes and asbestos-free diaphragms for electrolysis, gaskets and lined pipes or vessels, all of which are critical components in the production process for chlor-alkali and further for PVC. Perfluorinated membranes and membrane technologies used in chlor-alkali production have no known alternatives at the moment and are therefore essential at present.

The production and disposal of production equipment take place under strict environmental protection measures. The industry continues to improve these processes and develop opportunities for reuse and recycling.

The chlor-vinyl industry is actively engaged in following regulatory developments around PFAS and continues to re-evaluate all PFAS-containing materials and equipment and investigate available alternatives. This is to reduce the use of these substances where possible while maintaining the safety and reliability of industry operations.

It should be noted that PFAS are widely used throughout society, in sectors such as aviation, transport, medical devices, energy, electronics, architecture and construction, textiles, food and medicine[6]. For many of these sectors, PFAS' ability to perform under extreme conditions makes them difficult to replace, although it brings environmental and health challenges, which the wider industry is actively working to address.

Is PVC production safe for people and the environment?

PVC is made by combining ethylene and hydrogen chloride or chlorine, to produce ethylene dichloride (EDC). EDC is then converted into vinyl chloride monomer (VCM) at high temperature and pressure. VCM is polymerised into PVC[7]. Both EDC and VCM are hazardous substances that require proper handling. The process of converting EDC and VCM into PVC takes place in a closed system, with no exposure to humans and the environment. In Europe, strict regulation exists to protect workers and the environment. Additionally, safe handling of EDC and VCM is part of the voluntary charter that European PVC raw material producers members of ECVM (the European Council of Vinyl Manufacturers), have signed up to[8] and plants undergo regular third-party audits to verify compliance with legislative requirements. Emissions limit values are set based on Best Available Techniques of the Industrial Emissions Directive.

For these reasons, ECHA (the European Chemicals Agency) has concluded in its Investigation Report on PVC and PVC additives that "the operational conditions and risk management measures implemented in the VCM/PVC industry are adequate and effective to control the risk for workers from EDC and VCM", and that "the levels of residual ECD/VCM in PVC articles seem to be appropriately controlled in Europe"[9].

Beyond EDC and VCM, the PVC industry also controls the emission of other chemicals: there are no relevant emissions of chloroform, hexachlorobutadiene, or PCBs from the European VCM plants. VCM plants do not use or emit any CCl4. The emissions of dioxins and furans are regulated by the Industrial Emissions Directive, and dioxin/furans emission data are collected yearly by ECVM and show a constant downward trend.

Is there a risk of PVC accidents?

In 2023, a train derailment in the US lead to the spillage of VCM. However, it should be noted that transport conditions for VCM are quite different in Europe. As with other flammable and volatile materials, when Vinyl Chloride is transported, the tankers used are designed and constructed to the highest standards to resist impact and corrosion. Risk assessments are conducted to make sure that the least risky transport option is always selected. The European industry has taken on additional logistics costs to minimize risks as much as possible and is committed to continue supporting rigorous regulatory compliance.

For many years, there has been an ongoing trend in the European PVC industry towards integrated plants where both Vinyl Chloride and PVC are manufactured on the same site or on sites connected by dedicated pipelines. However, Vinyl Chloride transport is still needed for some smaller PVC plants that do not require sufficient quantities of Vinyl Chloride to make on-site production feasible. In 2017, about 1 million tons of Vinyl Chloride (20% of the volume produced that year in Europe) has been shipped between EU countries, and half of this volume has been transported by rail.

Since 2003, ECVM has developed Guidelines for the Distribution of VCM by rail, including comprehensive checklists with verifications on the rail cars before, during and after vinyl chloride filling.

Moreover, the distribution of VCM is subject to strict regulations within all countries in Europe. With EU Member States, the distribution of VCM by rail is subjected to national provisions or regulations of the respective rail company in case of national shipments. In case of shipments within EU members, the Regulation concerning the International Carriage of Dangerous Goods by Rail (RID) applies.

Is importing PVC from non-EU countries problematic?

Due to high energy prices and increasingly difficult framework conditions for plastic production in Europe, PVC is being imported from other parts of the world, primarily the US, and to a lesser extent Mexico, Egypt, South Korea and Taiwan. The same trend applies to plastics in general. In 20 years, Europe's share of global plastic production has halved from 28% to 14%[10].

While the EU is at the forefront of health and environmental regulation, other regions' requirements for industrial production are becoming increasingly stringent. For example, South Korea has long been recognised for its climate work[11]. This trend also applies to PVC production. For example, VCM emissions in the US have decreased by 86% since 1987. In the same period, PVC production increased by 91%.

VinylPlus®, the European PVC industry's commitment to sustainable development, works to ensure that the high European requirements for PVC production become global, partly through the UN Global Plastics Treaty and partly through cooperation with PVC industries outside Europe to transfer knowledge and technology.

THE USE PHASE OF PVC

Do PVC pipes release harmful chemicals into drinking water?

PVC acts as an effective barrier that stops small molecules from leaching into drinking water. Testing has shown that the amount of substances migrating from PVC is well below what even the most advanced analytical methods can detect.

The safety of PVC pipe systems for the transportation of drinking water in Europe is tightly regulated, partly by the EU REACH regulation on chemical substances, partly by the European Drinking Water Directive and its related standards and national legislation. PVC pipe manufacturers are subject to third-party certification by accredited laboratories and institutes, who subsequently also carry out regular audits to ensure continued compliance.

Starting substances for materials to be used in drinking water products are regulated under the EU's recast Drinking Water Directive[12]. Within this framework, a positive list specifies which starting substances can be used and their allowed migration limits[13]. VCM and the other substances needed to manufacture PVC resin, compounds and pipes are included in the list. It is important to understand that VCM is a precursor, and that all PVC resin grades manufactured by the ECVM members and the other European PVC manufacturers have less than 1 ppm VCM content, which means PVC pipes are safe for drinking water applications.

Actual field studies confirm the safety of PVC pipes, for instance from Denmark. According to the Danish Environmental Protection Agency "no measurable release of pollutants, including degradation products from antioxidants, organotin or volatile organic compounds has been found in migration tests on PVC pipes."[14]

Lastly, the EU has also established a methodology to measure microplastics in water intended for human consumption, where considered in the identification of microplastics[15].

Does PVC emit harmful chemicals in people's homes?

Firstly, there is strict regulation at the EU level for products for the home, including wall coverings, flooring, and toys. The EU's Toys Directive bans the use of specific phthalates in toys and childcare articles, while the Construction Products Regulation sets strict requirements for emissions of toxic gases, volatile organic compounds (VOCs) and hazardous particles[16]. These regulations ensure that products meet strict safety standards, thus minimising the risk of harmful chemical off-gassing.

Secondly, the migration of plasticisers during normal use is minimal due to the fact that they are tightly bound in the PVC matrix via non-covalent bonds.

Thirdly, the release of VOCs from PVC/vinyl is often lower than from other materials. For example, vinyl flooring can achieve M1 classification, which is only given to products that guarantee a good indoor climate. Off-gassing from vinyl flooring below 10 µg/m3 after 28 days, and many vinyl floors are even below the detection limit. In comparison, emissions from lacquered floors and linoleum are 25 µg/m3 and 100 µg/m3 respectively[17]. It is also well known that formaldehyde can off-gas from the glue in laminate flooring, just as it is naturally occurring in wood[18].

Does PVC require more additives than other materials?

In November 2023, ECHA determined that around 470 additives are used in PVC. Of these, the agency has identified 63 for further investigation for possible restrictions, based on potential hazard and volume. It should be noted that the list includes substances that are already regulated, such as low molecular weight phthalates.

VinylPlus collaborated with ECHA throughout the investigation process. After the publication of the report, VinylPlus analysed and responded to ECHA's work in detail[19].

Additives are used in all plastics and are instrumental in ensuring that plastics can meet the functional requirements needed for key applications (flexibility, heat-resistance, etc.). The PlastChem project, launched by Norway and Switzerland in the context of the UN Global Plastics Treaty, finds that around 16,000 chemicals are used to manufacture ten of the most common plastics. According to PlastChem, at least 4,200 of these substances fulfil the criteria for toxicity, persistence, bioaccumulation or mobility[20]. PlastChem thus upgrades data from Wiesinger et al (2021), who found that 10,000 substances are used, of which 2,400 substances fulfil the aforementioned criteria[21].

What is important is that additives used in PVC are safe: Additives which were identified as harmful in the past have been phased out, and industry has a track record of acting ahead of regulation to substitute dangerous additives (for example, lead). Today, all additives used in PVC have been assessed under EU chemicals legislation and, at present, have been found to be safe. Of course, new data is constantly produced, and regulatory work is ongoing for many of the additives used in PVC.

Are plasticisers used in PVC safe?

Additives in PVC and all other plastics are regulated by the EU REACH regulation. Under REACH, the responsibility lies with the industry to prove the safety of substances - the principle is no data, no market.

Some plasticisers which were previously used in PVC have been identified as harmful and regulated under REACH: these are the "low molecular weight" phthalates. The European plasticiser industry has invested over 6 billion Euros over 25 years in developing safe alternatives to low molecular weight phthalates such as DEHP. These alternatives, such as DINCH, DEHT, BTHC, ATBC, DEHA, DEHCH and TOTM, have been subject to extensive testing under REACH. All toxicological data for these substances are available in the REACH dossiers. The alternatives are neither identified as Substances of Very High Concern (SVHC) under REACH nor classified in the Classification, Labelling and Packaging Regulation (CLP).

The four alternatives DINCH, DEHT, BTHC and TOTM are also approved for medical devices and have therefore undergone a special test regime[22]. ATBC, DEHA, DINCH, DEHT, ESBO, DEHCH and TOTM are approved for food contact materials[23].

It is worth noting that several of the alternatives have been used for over 20 years in many critical applications without adverse effects being observed. Furthermore, REACH obliges registrants to update the dossiers if new evidence of environmental and health effects becomes available. ECHA can also review any dossier at any time to check if the information is correct.

Why is DEHP still allowed to be used in medical devices?

The transition period for DEHP in medical devices has been extended due to the postponement of the Medical Device Regulation due to Covid19 and lack of notified bodies.

The phasing out of DEHP with safe alternatives is already a reality in most applications. One challenge is blood bags, where PVC plasticised with DEHP has been the only solution since the 1950s to ensure a blood shelf life of up to 49 days. This long shelf life is vital, especially for patients with rare blood types, which are often found among minority groups[24].

The industry is collaborating with European blood banks in the complicated process of developing DEHP- free blood bags that do not compromise blood availability and thus patient safety[25].

Are organotin stabilisers problematic?

Today, calcium-based stabilisers are the standard solution for the vast majority of PVC products, with a market share of over 80%. Organotin compounds account for only 6%, but still play an important role in certain applications as they ensure transparency, colour fastness and work even under harsh processing conditions.

As mentioned above, the use of additives in PVC and other plastics is regulated by REACH, which means that manufacturers must prove that the substances are safe before they are placed on the market. This also applies to stabilisers, which are always used to process the PVC plastic and to achieve the desired properties of the product. Stabilisers make up a very small amount of the product's weight and are tightly bound in the polymer matrix, so migration is minimal.

Some organotin compounds are restricted, while others may continue to be used in critical applications such as food contact materials, medicine blister packs and medical devices.

There is still significant use of organotin stabilisers outside the EU, including in North America, where the use of such products is based on risk assessments demonstrating safe use and regulatory approvals, such as the National Sanitation Foundation (NSF).

Are lead and cadmium still used outside Europe?

When it comes to lead, Europe and North America have been leading the phase-out, but the rest of the world is well on its way. The conversion rate from lead to calcium-based stabilisers has moved from around 40% to 80% since 2017. This is partly due to bans on their use in drinking water pipes in India and China, as well as increased global exchange of knowledge and technology in the PVC field[26].

Cadmium is only used in very limited quantities in PVC worldwide, making it difficult to obtain accurate tonnage data. Today, one of the main uses of cadmium is in solar cells, and the United Nations Environment Programme (UNEP) predicts that the growing demand for renewable energy will lead to an increase in cadmium production[27].

How can we ensure that consumers do not encounter products from third countries with unwanted additives?

Normally, REACH ensures that it is not possible to place on the European market products which have been restricted in Europe. However, market surveillance can be imperfect, resulting in consumers buying PVC products imported from non-EU countries that contain unwanted additives that are illegal to use in Europe. This issue is real, but far from unique to PVC. The solution is enforcement by authorities, consumer education and the transfer of knowledge and technology to the countries where the substances are still used. As mentioned above, VinylPlus is working to globalise European standards for PVC as part of the UN Global Plastics Treaty and by working with PVC industries outside Europe.

WASTE MANAGEMENT OF PVC

RECYCLING AND REUSE

How is PVC recycled in Europe?

Whether rigid or flexible, PVC can be recycled, and industry efforts over the past 20+ years have led to a significant increase in its recycling rate. Today, it is estimated that about 35% of PVC waste is recycled: this includes both pre-consumer and post-consumer waste. Since the inception of VinylPlus in 2000, 8.8 million tonnes of PVC have been recycled, resulting in 17.6 million tonnes of CO_2 saved[28].

The steady increase of PVC recycling since 2000 results from the industry's targeted investment in collection and recycling over several decades. The majority of PVC waste comes from the construction industry, which is logical, as 70% of PVC is used in the construction sector.

There are two main options for recycling PVC waste:

- Mechanical recycling is an established, well-functioning model that covers processes that preserve the polymer chains. This is the most important recycling technology for PVC waste and is energy efficient. Processes allowing a separation of PVC from other materials in composite articles (flooring, architectural membranes, etc…) before recycling are under development.
- To complement mechanical recycling and close the gap for PVC waste that cannot be mechanically recycled, advanced recycling technologies are being developed. These include chemical recycling and selective extraction of harmful additives. Because, similar to mechanical recycling, the PVC polymer chains are preserved by selective extraction, the yield is high and processes are energy efficient. Europe is a global leader in the development of these technologies for PVC, thanks to significant investments from the industry. Technological developments are happening at a rapid pace: it is expected that industrial plants will be available by 2030 for extracting additives by selective dissolution, for example.

Can PVC contaminate other plastic fractions during recycling?

It is often heard that PVC waste can "contaminate" other plastic fractions through incorrect sorting so that they cannot be recycled. Correct sorting is a prerequisite for successful recycling of all plastics. This is because polymers differ in melting point and other properties. In modern sorting plants, the different types of plastics - including PVC - are sorted into the right fractions for further processing and use in new products.

What are legacy additives, are they unique to PVC, and do they impact recycling?

Legacy additives are additives which are no longer use in PVC produced today, but can still be found in old PVC products being recycled. Legacy additives are a common challenge for many materials, including PVC and other plastics[29]. The presence of unwanted substances and the fact that many historical products are composed of different materials can create challenges.

However, these challenges are not unsurmountable:

- One effective way to ensure that PVC containing legacy additives can be recycled whilst safeguarding human health and the environment is to set maximum concentration values for legacy additives in PVC products containing recycled PVC. For example, the

EU REACH restriction on lead in PVC sets a 10-year derogation for PVC articles containing recycled PVC, provided the lead concentration is lower than 1,5 % by weight of the recycled rigid PVC.

- Other solutions are being developed: There are major research programmes by the industry on recycling technologies enabling the extraction of legacy additives. These programmes are still at pilot stage. Innovation takes a decade to be fully mature, which is why legislation needs to allow time for these innovations to be ready. As an example, Vinylplus has contributed to REMADYL, a project funded by the European Union's Horizon 2020 research and innovation programme. This project aimed, among other goals, at removing hazardous legacy phthalates and lead from end-of-life PVC compounds and recycling the latter into high-purity PVC through innovative continuous one-step processes. These processes are based on an extractive extrusion technologies which is combined with new scavengers or solvents and melt filtration.

Due to the long shelf life of PVC products of up to 100 years or more, waste will be generated in the coming decades containing substances that were previously considered safe to use but are now unwanted. The PVC industry is working with the authorities in Europe to ensure that the resources in PVC already produced are utilised without compromising a high level of protection for health and the environment.

INCINERATION

Are harmful substances emitted when PVC is incinerated in waste incinerators?

Emissions during the combustion of PVC is an area where key progress has taken place, and whilst formation of by-products can be further improved upon, PVC is far from being a significant cause of by-product formation in modern incinerators.

PVC is mostly made of chlorine. Burning of any chlorine-containing waste, including municipal household waste, and wood from the seashore can lead to the formation and emissions of dioxins, heavy metals, etc.

Incineration at high temperatures avoids the formation of these by-products. However, if chlorine-containing waste is incinerated incorrectly, hydrochloric acid, dioxins and furans can be released.

For many years, European incinerators have been required to clean the smoke of these substances, as well as dust particles, NOx, SO2, cadmium, mercury and several other metals. Together with other waste, PVC contributes to flue gas cleaning products or flue gas waste, which typically make up around 5% of the weight of the waste. According to the Danish Environmental Protection Agency, PVC's share of flue gas waste is less than 5%[30].

Flue gas waste is classified as hazardous waste and is therefore managed for recovery in special landfills. Typically, it is utilized to neutralise various acidic wastes or serves as a substitute for gravel, filling former salt mines. New technology, partly developed with EU LIFE funding, can now recover residues, avoiding landfill as hazardous waste. The technology has been proposed as BAT by the Nordic Council of Ministers[31].

According to ECHA, European incinerators can receive waste with up to 2% PVC without problems with smoke cleaning or corrosion, which can also occur if the chlorine content is too high or the incinerators are made of low-quality steel[32].

Is PVC causing the release of dioxins and furans from waste incinerators?

The incineration of chlorinated waste used to be the largest source of dioxin and furan pollution, but the introduction of better incineration and flue gas cleaning requirements under the Industrial Emissions Directive has led to a 94% reduction in emissions since the early 1990s. In the same period, the amount of waste incinerated has doubled[33].

While PVC incineration was previously considered a source of dioxins and furans, according to ECHA, it is highly questionable whether PVC waste has any role to play today. According to ECHA, the formation of dioxins, furans and other unwanted emissions depends on the type of furnace, operating conditions and flue cleaning systems. There is also no proportional relationship between the amount of chlorine in the waste and the amount of dioxins and furans formed[34]. The same conclusion has been reached in previous studies, including by the Swedish Environmental Protection Agency[35].

In other words, the small amounts of chlorine found in salty food waste, for example, are sufficient for dioxins and furans to be formed through inappropriate incineration. Adding the amounts of PVC found in waste has little or no effect. Nor can a reduction in dioxins and furans be achieved by removing PVC from waste.

Is PVC particularly problematic in uncontrolled combustion?

PVC, like all other materials, must be handled correctly in the waste phase. Uncontrolled incineration of waste is harmful. In many countries, the practice is already illegal, and strict enforcement is needed to ensure it does not take place.

However, the main reason for uncontrolled incineration is that around two billion people in the Global South live with a lack of waste management. This can only be solved by massive investments in setting up systems for collection and proper management according to the waste hierarchy.

TO CONCLUDE

Reassessing PVC: Progress made and societal value

PVC products contribute to society in key areas such as building products, medical devices, electronics, food, energy, transport, sports and leisure.

Ramboll's report "Circular visions for soft PVC" emphasises that PVC is often indispensable due to its unique properties. For example, blood bags, inflatables and lorry tarpaulins are products where PVC's special properties cannot be replaced[36].

Phasing out PVC ignores the essential function of the material in many applications where alternatives either do not exist or would lead to compromises in terms of functionality, safety or cost- effectiveness. Furthermore, unless alternatives are assessed throughout their lifecycle, as PVC has been, there is a real risk of regrettable substitution.

The European PVC industry is aware of the differences that exist globally in the production, use and waste management of PVC and sees international agreements such as the UN Global Plastics Treaty as a step towards a more responsible and sustainable handling of PVC worldwide. In parallel, the European PVC industry continues to be committed to improving circularity and sustainability of PVC products throughout their lifecycle.

VinylPlus believes that a balanced approach which recognises the many benefits of PVC while identifying and effectively addressing and resolving any challenges, is needed.

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