The Vinyl Institute

A Division of The Society of The Plastics Industry, Inc.

POLYVINYL CHLORIDE:

An Overview Of The Role Chlorine Plays In This Plastic Material

Chlorine, a common element typically found in sodium chloride, or table salt, has a number of uses in industry and agriculture. Perhaps the best known use is in water purification, where chlorine has been used since the turn of the century to eliminate the threat of waterborne diseases such as typhoid fever, cholera, viruses and parasites. Literally hundreds of millions of individuals benefit from chlorine everyday when they drink municipally treated water, and chlorine is credited with saving countless lives every year.

Chlorine also is used as a basic building block for the production of vinyl plastics -- PVC, or polyvinyl chloride. Vinyl plastics are used to make hundreds of industrial and consumer products, many of which evolved as a replacement for other materials that did not perform as well in a given application, cost more to produce or put a greater strain on the environment and natural resources. Examples of such applications include water piping, insulation and sheathing for electrical wiring, house siding, packaging, components for appliances and electronics, and medical goods and devices.

This document is designed to address some of the questions associated with the manufacture of this chlorine-based material and the use of vinyl products like these.

Major U.S. Markets for PVC -- 1990
(Source: Modern Plastics, January 1991)

Rigid PVC			**Flexible PVC**	
Pipe and fittings		32%	Wire and cable	7%
Profile extrusion		26	Film and sheet	9
Siding	13		Flooring	4
Other	13		Other	8
Packaging		2	**Total Flexible**	**28%**
Records		>1	Export	10%
Total Rigid		**62%**		

(Includes imports, estimated at 290 million pounds in 1990.)

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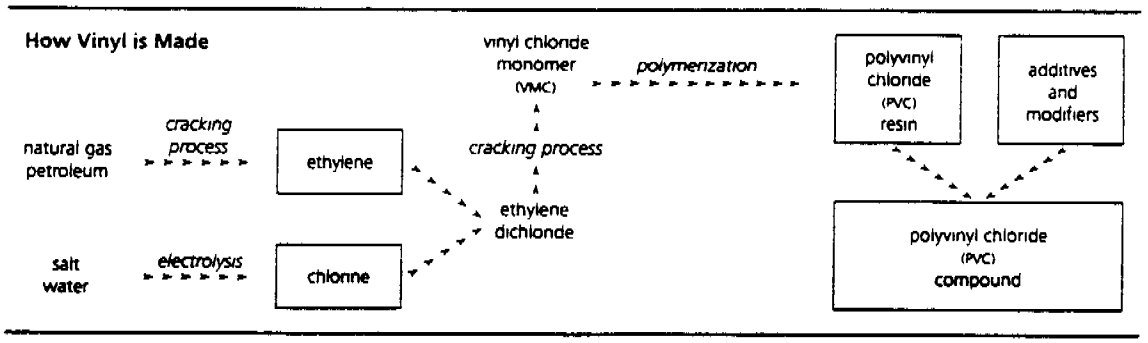
HOW CHLORINE BECOMES POLYVINYL CHLORIDE

Precautions and Safeguards Observed in the Process

Chlorine is produced by processing salt and water, or brine, with electricity. To make PVC, chlorine is combined with ethylene to produce ethylene dichloride, which is then converted into vinyl chloride monomer, or VCM. Using water and catalysts, VCM is in turn converted into polyvinyl chloride resin. The PVC resin is customized for the intended end use by first mixing it with various additional ingredients -- referred to as additives and modifiers -- in a sequence called compounding. These ingredients impart various performance properties such as impact resistance, weatherability or flexibility to the finished product, enabling PVC or "vinyl" to be used in applications as diverse as flexible packaging film and rigid drain pipe.



Essentially, the entire vinyl production process through the production of PVC resin is a closed one. That is, most activities take place within closed vessels. There are two reasons for this. First, it helps maximize production efficiencies. Second, it reduces environmental emissions and minimizes worker exposure to potential processing hazards -- primarily, the potential hazard posed by the use of vinyl chloride monomer.

In the 1970s, a link was made between extremely high, prolonged exposure levels to VCM among PVC production workers and a rare form of liver cancer, angiosarcoma. Approximately 100 such cases have been recorded worldwide since this discovery was made. Since then, the vinyl production process has been substantially modified to eliminate the high level of VCM exposure believed responsible for these cases. In addition, the vinyl industry has introduced an ongoing program of worker monitoring to track any health problems that might be associated with working with VCM or PVC. There are several important points to remember about the potential health risks associated with vinyl chloride monomer:

1) ***Risks to workers have been virtually eliminated.*** All vinyl production facilities are closely regulated by the Occupational Health and Safety Administration in order to eliminate potential health risks to workers. Not one case of angiosarcoma has been

definitely linked to a vinyl production worker whose work history began after the introduction of revised processing technology in the late 1970s.

2) *All VCM emissions are regulated; the nationwide totals are declining.* All vinyl production facilities also are closely regulated by the Environmental Protection Agency, which monitors VCM emissions to the environment. The EPA sets limits for the quantity of VCM that any vinyl production plant may release into the atmosphere, and all VCM emissions must be reported to the EPA. Since 1987, EPA has required such reporting under SARA Title III, the Emergency Planning and Community Right-to-Know Act of the Superfund Amendments and Reauthorization Act. Other monitoring requirements were in place prior to that date, and the vinyl industry can trace a 95% reduction in VCM emissions nationwide since monitoring began in the 1970s.[1]

3) *Community health risks are negligible.* The largest potential health hazard associated with VCM is exposure to air emissions. However, like any other gaseous material released into the atmosphere, VCM disperses. That is, the concentration of the material -- or the parts per million concentration (ppm) -- becomes less as it leaves the site of the release due to dilution in air. This means that the most significant health risk is at the site of the release and diminishes rapidly as the VCM disperses. Consequently, the potential health risk to residents who live near VCM production sites has been found to be virtually nonexistent. Over the years, a number of monitoring programs have substantiated the low exposure levels that typically exist in communities where VCM/PVC plants are located, and there is no documentation of any chronic health effects in residents of such communities that can be traced to VCM exposure.[2]

THE SAFETY OF PVC END-PRODUCTS

Regulations Set Standards for Performance

When vinyl chloride monomer is converted into vinyl, virtually all of the VCM is chemically transformed into the new polymeric material, thereby becoming inert and presenting no health hazard. In some cases, a small amount of vinyl chloride monomer ("residual VCM") may be present in the vinyl resin before it is converted into a finished product. However, the heat used in the compounding sequence as well as in the subsequent processing into a finished product eliminates even this small amount of residual VCM.

As an extra precaution, vinyl resin used to make items that convey or contain products designed for human consumption (food packaging, beverage bottles, potable water pipe, medication packaging, etc.) must meet federal regulations and national standards for residual VCM levels. Both the U.S. Food & Drug Administration and the National Sanitation Foundation (NSF) set standards in these areas. Certain vinyl materials are

cleared by the FDA and may be used as specified by the agency for a range of food applications, pharmaceutical and medical products, and nonalcoholic beverages. NSF certifies the use of PVC and CPVC (chlorinated PVC) pipe; both materials are used throughout the country to deliver drinking water.

PVC'S FIRE PERFORMANCE
Chlorine Enhances Vinyl's Fire Safety

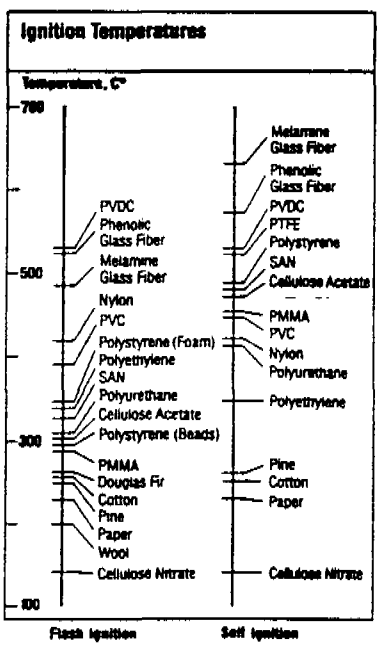
Chlorine is one of four halogenated elements known for their ability to impart flame-retardance. Because chlorine constitutes a significant portion of PVC resin (57 percent), it gives vinyl a range of outstanding fire performance characteristics that include ignition resistance and low flame spread.[3] As a result of these properties, vinyl has been called the material that stops fires from starting and from spreading. In some cases, small amounts of vinyl are added to other polymers to enhance their fire performance as well.

Like all other products used in critical fire performance applications (such as electrical applications and certain building products), vinyl compounds must meet the standards set by such groups as the National Fire Protection Association's National Electrical Code, Underwriters' Laboratories and the American Society for Testing and Materials. All three U.S. model building codes often set additional requirements that vinyl products must meet.

Surface flammability of some materials

Material	Thickness (mm)	Flame spread index
Chlorinated PVC	3	4
Polyether sulphone	3	5
PVC	4	10
Polyester	3	30-56
FR polystyrene	3	59
FR polycarbonate	6	73
Polycarbonate	3	88
Red oak	19	99
Phenolic resin	2	114
Plywood (fir)	6	143
Hardboard	6	185
GRP polyester (21%)	2	239
FR acrylic	3	316
Polystyrene	2	355
Acrylic	6	416
Polyurethane foam (flexible)		1490
Polyurethane foam (rigid)		2220

Note: The fire performance for this test improves as the flame spread ratings become lower.



In two key areas, vinyl's fire performance ranks well compared to other commonly used materials, underscoring its appropriate use for demanding construction and electrical applications.

PVC COMBUSTION BY-PRODUCTS:
HCl Not An Unusual Fire Hazard

When vinyl does burn (as in the case of a large-scale, fully involved fire), it produces carbon dioxide, carbon monoxide and hydrogen chloride (HCl). Of these, the most significant fire hazard comes from carbon monoxide, a known toxic substance produced by virtually any combustible substance, whether it is a "natural" material or synthetic.

Hydrogen chloride will act as an irritant. In those cases where a vinyl product is involved in the early stages of a fire, its distinctive acrid odor can serve as an alert mechanism. Recent technology developed by Bell Communications Research, Inc. takes this one step further: that organization's new device is designed specifically to sense the hydrogen chloride produced by burning vinyl.[4] In certain types of fires involving high concentrations of electrical and electronic equipment (such as telephone switching stations), the presence of vinyl may help Bellcore's new product supersede traditional smoke alarms, thereby arresting the development of these fires at an even earlier stage than is now possible.

Extensive research, conducted on behalf of the Federal Aviation Administration by Southwest Research Institute, has demonstrated that the hydrogen chloride produced by burning vinyl presents no unusual fire hazard to fire fighters or others exposed to fire gases.[5] These tests revealed that baboons -- who have respiratory systems similar to humans -- could survive HCl exposure levels up to 10,000 parts per million for 15 minutes. In a typical fire, hydrogen chloride levels rarely exceed 300 parts per million.

PVC RECYCLING
Chlorine Gives Vinyl An Edge In The Separation Phase

New developments in the area of vinyl recycling indicate that the presence of chlorine in vinyl facilitates the separation and, therefore, the reuse of vinyl products found in the solid waste stream.

Recent separation technology developed by the Center for Plastics Recycling Research at Rutgers University, and at National Recovery Technologies, Inc, of Nashville, Tennessee, are based on the fact that vinyl packaging contains chlorine. In vinyl packaging, the chlorine acts as an invisible "marker," or product identifier. The Rutgers and NRT systems detect this marker and then automatically separate vinyl packaging from a mixed stream of post-consumer plastic packaging waste.

The use of such technology may help eliminate the need for consumers to individually separate vinyl packaging for curbside recycling, and the need for hand identification/sorting of vinyl packaging at municipal solid waste handling facilities.

A recent study conducted by the University of Toledo has identified nearly 100 potential uses for recycled vinyl packaging.[6] In addition, the study indicates that demand for this material -- estimated at nearly 500 million pounds annually -- could be more than double the roughly 200 million pounds of vinyl available from rigid containers. An equal amount potentially is available by recovering rigid vinyl film used in "blister" packaging. Industry estimates calculate that all of the rigid vinyl currently being landfilled could be absorbed if only 10 percent of the vinyl siding market and 25 percent of selected pipe markets began using recycled vinyl.

These potential uses for recycled vinyl illustrate another unique characteristic of the material: unlike other packaging materials, second-generation uses for recycled vinyl packaging can be long-term applications -- some well in excess of 20 years. This means that even after reuse, vinyl packaging can be kept out of landfills for an extended period of time.

PVC IN LANDFILLS
Inert and Stable

Currently, vinyl products in general make up about 0.5 percent by weight of all materials found in municipal solid waste and vinyl packaging only about 0.2 - 0.3 percent.[7] Because of its inert chemical resistance, vinyl remains a stable, inert material when landfilled, and for this reason, it is often used to manufacture landfill liners and leachate collection systems. Vinyl disposed of in landfills does not revert to vinyl chloride monomer and vinyl plastics do not leach VCM or other harmful chemicals into groundwater.[8]

Components of Municipal Solid Waste
(By Volume)

Nondurables		34.0%
All Packaging		29.0
Paper	14.1	
Plastics	8.1	
Metal	3.9	
Glass	1.8	
Other	1.4	
Durables		22.2
Other Wastes		14.3

Source: U.S. Environmental Protection Agency, Characterization of Municipal Solid Waste in the United States, 1990 Update.

PVC IN INCINERATORS
Recent Study Finds No Impact on Emissions

In 1987, the New York Energy Research and Development Authority conducted extensive tests to determine what effect, if any, the presence of vinyl plastics had on municipal solid waste incinerator emissions. Those tests revealed that the presence or absence of vinyl had no effect on incinerator dioxin formation.[9] Rather, it was found that incinerator operating conditions (primarily, temperature) were the key to controlling dioxin formation. At temperatures upwards of 1500 to 1800° F, generation of dioxins is minimal.

Research has also found that incinerator scrubbing systems can remove about 99 percent of the hydrogen chloride generated by incinerating vinyl plastics.[10] New requirements from the U.S. Environmental Protection Agency will make scrubbers mandatory equipment on all incinerators. One of the leading manufacturers of incinerator systems, Ogden Martin Systems, has advised the Environmental Protection Agency that its equipment "can tolerate reasonable increases in acid-producing waste components without adverse effect," and does not "perceive the anticipated increases in PVC food packaging to be problematic."[11]

Power plants burning fossil fuels, which produce sulfur dioxide and nitrogen oxide, are considered to be the primary cause of acid rain, and in Europe and Japan, studies show that only about 0.3 percent of all atmospheric acidity can be traced to incineration of vinyl.[12] Other studies have indicated that about 50 percent of the HCl generated in incinerators comes from sources other than vinyl such as table salt and yard wastes.[13] European studies have demonstrated that HCl produced in incinerators can be treated with sodium hydroxide and converted (recycled) into industrially usable salt.[14]

PVC AND OZONE DEPLETION
No Known Connection

Once chlorine is processed into polyvinyl chloride, free chlorine gas cannot be liberated from the product. This means that vinyl products -- either incinerated or landfilled -- do not release chlorine gas to the atmosphere.[15] There is no connection between vinyl products and chlorofluorcarbons, and chlorine gas is not considered by scientists to play a role in the depletion of the ozone layer.

SOME PRODUCT LIFE CYCLE CONSIDERATIONS
The Case for Vinyl

The most comprehensive evaluation of a product's impact on the environment takes a "cradle to grave" approach to assessing its overall performance. Under such a system, not only is a product's recyclability considered, but also a number of other factors including: raw material usage; energy used in processing; distribution and transportation costs (energy usage); durability (time until the product must be disposed of/replaced); and unique or important performance properties provided during use. For these reasons, there is new interest in vinyl as a "green" material.[16] These considerations include:

- Over 50 percent of the base polymer product consists of chlorine -- a readily available, inexpensive commodity that makes vinyl a cost-effective alternative to many other materials. Vinyl is also far less dependent on hydrocarbon feedstocks that other polymeric materials.

- Vinyl can be produced more efficiently using less energy than many materials it replaces, such as aluminum, steel or glass.

- Likewise, the energy used to process vinyl scrap for reuse is less than that for many other materials.

- Because of their relative light weight, the cost to transport and handle products like vinyl pipe and packaging is far less than for comparable items made out of "traditional" materials.

- In a number of applications, including blood bags, tubing for dialysis machines and flexible food wrap, vinyl is the only viable material choice. In many others, vinyl provides superior performance properties such as better weatherability, better fire properties, longer durability or better corrosion resistance. In these applications, vinyl products last longer and require less maintenance.

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For more information about the issues discussed in this document, contact The Vinyl Institute, 155 Route 46 West, Wayne Interchange Plaza II, Wayne, NJ 07470. Or contact the Vinyl Environmental Resource Center at 1-800-969-VINYL (1-800-969-8469). The Vinyl Institute is a division of The Society of the Plastics Industry, Inc. For additional copies of this document, ask for the Chlorine White Paper.

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The Vinyl Institute

National Vinyl Environmental Resource Center

1-800-969-VINYL
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The Center's hotline is staffed M-F, 9 a.m.- 5 p.m. EST; please leave your message at other times.

For information on:

- Where/how to recycle vinyl
- Other options for managing post-consumer vinyl waste
- Markets for recycled vinyl
- The impact of vinyl products on the environment
- Vinyl's health and safety effects
- Vinyl's fire performance properties

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