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de vitrerie et de fenestration
du Québec

KNOWLEDGE GUIDE

PVC Revisited—Doors and Windows

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Introduction

In 2010, one of the world's most used and best known thermoplastic polymers, PVC, continues to be the subject of questions that receive ample media coverage. Few synthetic materials have been the focus of so much in-depth research. The manner in which PVC affect health and the environment has been examined at every phase of production, use and final disposal. As one of the world's most self-regulated industries, the PVC sector continues to grow internationally in terms of quantities produced and new applications discovered. The industry is continuing to pursue its efforts to improve the performance of its product in terms of manufacturing conditions and applications. PVC has become the second leading basic plastic today.

PVC has been carefully examined over the past few years for ecological reasons. PVC manufacturers have particularly focused on PVC use, in the broad sense of the term, including energy efficiency, waste management techniques and human health.

Despite all of these efforts, PVC critics continue to insist that it has toxic effects. This debate sometimes goes to extremes, using allegations that have no basis in truth or science. Greenpeace, for example, called PVC a "poison plastic" and "chlorine" the "devil's element" in 2000. According to Patrick Moore,¹ a Greenpeace founder who later left the organization: "such claims take the form of a religious rite or war of political interests, not based on any scientific evidence."

Like other chemical industry compounds, PVC is subject to the regulation of and constant study by national and international authorities. This sector is highly sensitive to environmental concerns and promotes technical progress geared to the constant improvement of processes and products.

This manual was designed to provide information, based on the latest scientific and technological knowledge, of existing legislation, economic conditions of consumption habits. It does not pretend to be complete, but is written in straightforward language to meet needs for information and clarification of consumers and PVC window and door industry specialists and employees.

Did you know?

PVC was first made in 1835. PVC is more than 57% chlorine.

¹ Patrick Moore, with a Doctors Degree in Ecology from the University of British Columbia, is a co-founder of Greenpeace and has been a "green activist" for 15 years. He has now created his own blog, www.greenspirit.com and opposes the demonization of PVC.

PVC: Information Sheet

PRODUCTION

Chlorine reacts with ethylene to produce the liquefied gas dichloroethylene (DCE). This monomer is then polymerized to create polyvinyl chloride (PVC). At this stage, PVC is a resin, in the form of a white and inert powder. Additives can be used to produce different kinds of PVC products:

- Stabilizers: to keep PVC from deteriorating on exposure to heat and sunlight.
- Plasticizers: to make it soft and flexible.
- Colourings.
- Fillers: to give it the desired mechanical properties.
- Lubricants: to facilitate its use.
- Fire retardants: to make it more fire resistant.

The resulting product is known as a "compound."

Items are then manufactured by heating* the compound:

- As it passes through an extruder to create profiles, conduits, etc.
- As it is squeezed between the wheels of a calender to obtain flat substances, such as rigid or flexible films and membranes.
- By blow moulding for hollow objects.

**The list of extrusion processes is only partial.*

COMPOSITION

- 57% chloride (the same as in salt).
- 43% ethylene.

More than 50% of PVC's composition is mineral.

MAIN APPLICATIONS

- Construction: pipes, profiles (doors and windows), wires and cables, floor coverings, roof coatings, pipelines.
- Packaging: food, pharmaceutical and cosmetic products.
- Consumable goods: shoes, credit cards, clothing, toys.
- Automotive sector: each car contains some 10 to 16 kg of PVC (coatings for parts, dashboards, door panels).
- Medical sector: blood bags, catheters, small pipes and tubes, surgical gloves, inhalation masks, sterile packaging.

INTERNATIONAL PVC MARKET

Plastic Europe Market Research Group

- World's second leading plastic.
- 3.5% annual growth.
- International demand for PVC resin was 30 million metric tonnes in 2006.

Main Applications:

- Pipes: 27%.
 - Profiles (doors and windows): 25%.
 - Films and sheets: 14%.
- (PVC Info Belgium 2006)

- Cables: 6%.
- Floor coverings: 5%.
- Other: 23%.

CANADIAN PVC INDUSTRY

- Production: 12.8% of Canada's synthetic resin production.
- Jobs: 6,300 people employed in the transformation of synthetic resin in 123 establishments.
- Geographic concentration: Ontario, Quebec and Alberta.
(Industry Canada, 2006)

Key organizations:

- Vinyl Council of Canada www.plastics.ca/vinyl
- Vinyl Institute www.vinylinfo.org
- CSST www.csst.qc.ca
- US Green Building Council www.usgbc.org

Institutional Accreditations

PVC has received many approvals from different governments and institutional agencies. The following partial list provides specific examples of authorized uses demonstrating that the product is safe for the health.

- The **US Food and Drug Administration** (FDA) has approved the use of PVC for the manufacture of blood product bags and intravenous bags.²
- The **National Sanitary Foundation** (NSF), has approved the use of PVC in the manufacture of drinking water pipes.³
- The **US Consumer Product Safety Commission** (CPSC), the principal US government agency in charge of monitoring the safety of convenience goods, evaluated the safety of PVC in toys in 2003. An in-depth analysis disclosed that PVC toys pose no risk to the health. However, in response to pressure by lobbyists, the use of 6 phthalates has been limited to 0.1% in products for children under 12 years of age since February 10, 2009. A scientific committee continues to study this issue and the use of phthalates may once again be approved.
- The **National Fire Protection Association** (NFPA) oversees issues pertaining to buildings, fires and electricity. PVC is perfectly consistent with its standards for the insulation of electrical and data transmission cables.
- The **Public Health Agency of Canada** has neither condemned nor prohibited the use of PVC in **doors and windows**. It perceives a real danger in other applications involving flexible PVC such as toys for children under three years of age and curtains containing DEHP, a plasticizer. Health Canada is focusing its attention on additives by limiting concentrations of plasticizers⁴ and stabilizers such as phthalates (DEHP) and stabilizers (cadmium and lead) that are known to be dangerous. Generally, all additives are the subject of permanent research and follow-ups and are regulated by the FDA (Food and Drug Administration) and the EPA (Environmental Protection Agency).

² www.fda.gov/default.htm

³ www.corrosion-products.com/PipingProducts/PVCCPVC.htm

⁴ Health Canada: www.hc-sc.gc.ca/cps-spc/alt_formats/hecs-sesc/pdf/advisories-avis/info-ind/phthalate_consultation_070716.pdf

The **Commission de la santé et de la sécurité du travail** (CSST) has created standards and regulations to minimize risks for workers. It regularly inspects businesses and produces updates that respond to new hazards. All instructions in the **Regulation respecting occupational health and safety**⁵ concerning standards (compliance with air quality, personal protection gear for breathing, vapour and flammable gases and combustible dust, etc.) depend on the type of factory and substances handled. No specific information pertaining to PVC is mentioned in it. Rather, it provides general directives to protect workers in production plants.

⁵ www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=%2F%2FS_2_1%2FS2_1R19_01.htm

The PVC Window and Door Industry Value Chain

The following chart identifies different production phases in the PVC door and window industry. It can be used to identify the point at which any issues or problems may arise in this sector's value chain.

STEP A	STEP B	STEP C	STEP D	STEP E	STEP F	STEP G
Resin production	Conversion Incorporation of additives	Extrusion	Production and assembly of doors and windows	Distribution of doors and windows	(Installation and use)	Recycling and/or disposal

A. Resin Production

The PVC resin production industry is part of the petrochemical industry sector. These industries are among the most self-regulated in the world. The following information on toxicity of compounds, the environment and sustainable development will be useful to industry specialists and employees.

Resin Performance

Polyvinyl chloride is a thermoplastic polymer, roughly similar in structure to polyethylene, except that each molecule contains one atom of chlorine. Although the chlorine atom makes the resin vulnerable to certain solvents, it makes it stronger in many other respects. Chlorine gives PVC excellent resistance to oils (except essential oils) and very low permeability to most gases. Although some other polymers are stronger than PVC, they are much more expensive and difficult to produce.

Polyvinyl chloride resin is a white powder. It is amorphous or slightly crystalline in structure. When the resin is mixed with plasticizers, the PVC becomes soft and flexible. It is used to make an excellent quality of tubing, that is found in all well-equipped laboratories.

Vinyl Chloride Composition and Toxicity

Vinyl chloride monomer (VC) is an industrial chemical compound that takes the form of an explosive, flammable gas that liquefies at $-14\text{ }^{\circ}\text{C}$ and has an ether-like odour. It is produced through the chlorination of ethylene or by treating ethyl chloride with calcium hydroxide. The primary use for vinyl chloride is in making PVC through the polymerization process. Vinyl chloride comes in the form of a hazardous monomer gas that has been proven to be potentially carcinogenic in humans. However, it is rendered inert when it is polymerized in PVC, thereby eliminating virtually all fumes and risk to humans. Furthermore, to minimize the possible impact of the monomer on worker health, drastic measures were taken in 1970. The maximum limit for the monomer in factory air is 5 ppm. This threshold is 1 ppm in PVC objects and materials that come into contact with food products. The substance is listed in Appendix 1 of the 1999 *Canadian Environmental Protection Act*.

Criticism of Chlorine in Non-PVC Uses

Chlorine is used in a wide variety of applications including impermeable clothing (“wetsuits”), bleach and antibacterial soaps. The use of chlorine has been criticized in other industries, particularly that of water treatment. However, if chlorine were not used to disinfect drinking water and maintenance products, millions of people would die each year from infections. An experiment conducted in Peru in the 1990s led to a halt in drinking water chlorination. The consequences were disastrous. Statistics showed that more than 500,000 people were contaminated by cholera and more than 5,000 died as a result. Chlorine happens to be one of the planet’s most abundant elements. The problem with chlorine primarily pertains to its storage. One benefit of PVC is that it reuses chlorine that has been discarded in the manufacture of such products as soap and detergent. This has now become one of the solutions to avoid creating large and hazardous stockpiles and to reuse residues from the production of other products.

Monomer Source

Vinyl chloride is the monomer used to produce PVC. As described above, the monomer is an industrial chemical compound that assumes the form of an explosive, flammable gas with an ether-like odour. Vinyl chloride was first produced in 1835 by Justus Von Liebig and his assistant, Henri Victor Regnault. They obtained it by treating 1,2-dichloro-ethane with a solution of potassium hydroxide in ethanol. In 1912, Fritz Klatte, a German chemist employed by Griesheim-Elektron, patented a process for producing vinyl chloride from acetylene and hydrochloric acid by using mercury chloride as a catalyst. This technique was commonly used in the 1930s and 1940s. It has subsequently been replaced by less expensive techniques. Vinyl is now industrially produced from ethylene and chlorine.⁶ Canada does not manufacture this monomer.

⁶ *Wikipedia, Vinyl chloride (November 2009)*

Monomer-Related Hazards

Vinyl chloride is a monomer that presents different kinds of hazards depending on the situation. The international Chemical Safety⁷ fact sheet describes vinyl chloride as being highly flammable in its monomer form. It emits fumes and irritating or toxic gases in the event of a fire (however, this irritating gas helps warn people of an approaching blaze). Vinyl chloride becomes explosive when mixed with air. Inhaling the gas results in dizziness, drowsiness and headaches and can result in a loss of consciousness. If the eyes come into contact with the gas they become red and painful. In its liquid form, this monomer can cause frostbite on contact with the skin. A visit to the doctor is recommended even in the event of brief exposure.

Safety Measures with Monomers

Three important rules apply: avoid the risk of combustion, contain the risk of explosion and prevent all physical contact. To avoid the risk of combustion, keep the substance away from an exposed flame, do not create sparks and do not smoke. The risk of explosion is virtually nil if the system is self-contained, the compartment ventilated and the electrical equipment and lighting are protected against explosions. Explosion-proof tools should be used. All physical contact should be avoided. The compartment must be ventilated, with local exhaust ventilation and respiratory protection. Wear protective gloves against the cold, wear protective clothing and sealed goggles or protective eyepieces built into protective respiratory gear. Do not eat, drink or smoke during working hours.

Treatment of Toxic Production Waste

Resin production creates two products: the monomer itself and caustic soda. Caustic soda is generated along with chlorine during electrolysis of sodium chloride. Caustic soda is used in a wide variety of applications, such as aluminum production, the pulp and paper industry, chemical products, water treatment and the manufacture of soaps and detergents. All toxins generated during the electrolysis of sodium chloride are monitored. As with American plants, the risk of living within 7 km of a vinyl chloride production facility has been estimated at less than 0.1 cases of cancer for every 5 million residents over a 70 year period⁸ in Canada.

⁷ *International Chemical Safety Fact Sheets (2000)*

⁸ *Quick reference, The Vinyl Institute*

Best Management Practices

Although the monomer resin production industry is, as previously mentioned, one of the world's most self-regulated sectors, best management practices should emphasize continuous improvement of ever more accountable production and manufacturing processes. These best practices not only require business intelligence on best environmental and OHS practices, but proactive application of government regulations and standards. Critical but constructive appraisals should be made of initiatives by other trans-Atlantic industries, such as the REACH program, a new European chemical regulation aimed at collecting data on substances produced to demonstrate that they are monitored, produced and consumed.

Worker Health

Individuals may accidentally come into contact with the vinyl chloride monomer only when the resin is being transformed into PVC. At the present time, only one possible incident of cancer has been demonstrated and it dates back to 1974.⁹ It was a rare type of liver cancer contracted under extreme conditions of exposure. Safety measures defining maximum exposure levels for individuals in different nations were subsequently introduced. Exposure limits apply in Canada, corresponding to exposure intervals. The CSST has established strict standards on the subject. Tests in resin production plants have show that monomer levels are always very low. Furthermore, technological progress serves to minimize the risk to individuals. Bear in mind that the PVC industry is one of the world's most self-regulated sectors.

⁹ www.belgochlor.be/fr/H306.htm#PVC

The Environmental Impact of Vinyl Chloride

Virtually no (< 1 ppm) monomer is emitted from the finished product, but monomers can be released in minute quantities through such activities as burning the polymer. Monomer emission is always below what are classified as “harmful” levels. Generally speaking, all manufacturing processes generate emissions. Studies have sampled vinyl chloride levels in the air near PVC factories. They demonstrated that levels were lower than the worker health protection standards set by the health authorities. If minimal monomer emissions are present in the atmosphere near production sites, the vinyl chloride monomer tends to remain in the air for two days because it breaks down very quickly. Its impact on stratospheric and greenhouse impact is thus negligible. The potential impact of this monomer on tropospheric ozone has not yet been assessed.

Standards and Practices

The PVC resin production industry is regulated by standards defining PVC resin qualities: ASTM 1755—Standard Specification for Poly (Vinyl Chloride) Resins and ISO standard 1264:1980 Plastics—Homopolymer and copolymer resins of vinyl chloride. Both standards pertain to the same topic, but focus on different technical issues.

Energy Consumption

While large quantities of power are required to electrolyse salt in producing the vinyl chloride monomer, they are far less than those needed for steel or aluminum. PVC resin is largely derived from salt (57% chlorine), an abundant and very inexpensive resource.

Resin Recycling

It is very difficult to reverse the polymerization process. PVC resin does not break down. Most resin scrap is recycled for non-critical (safe) applications. Resin can be reused if it can be recovered. That way, nothing is discarded or wasted.

B. Conversion and Incorporation of Additives

The properties of the PVC polymer can be altered in useful ways during the transformation process and through the addition of additives. These changes increase the range of PVC applications. The following section on toxicity of additives and their environmental impact, as well as issues of sustainable development, will be of interest to industry employees and specialists.

Review of Principle Additives and Their Uses

The key additives used in transforming PVC are stabilizers, plasticizers, lubricants, fillers, pigments and fire retardants. They provide the PVC with a variety of characteristics including better strength, additional flexibility and more durability. The additives will not alter the quality of the finished product if used in appropriate quantities and are of the quality required for their application. Market requirements—primarily consumer demand—dictate which additives are used and are based on agreements between clients (retailers and distributors of finished products) and suppliers. Such additives as fillers are solid materials that do not melt (titanium dioxide, calcium carbonate). Volatile fillers are not present in the PVC. The choice of including additives depends on the needs of end users, governmental laws and regulations and standards of multinational corporations.

Tin is Still Used

In March 2008, the Vinyl Council of Canada, Tin Stabilizer Association and Environment Canada signed an environmental performance agreement concerning tin. Tin is a stabilizer used as part of an environmental approach to producing PVC. In its many industrial application, tin assumes a mineral or organic form. Tin-based organic stabilizers are used as substitutes for lead and cadmium. Tin-based compounds have less hazardous profiles than their lead- and cadmium based counterparts.

Sensitive Additives in Canada

PVC window and door manufacturers stopped using lead in their products about a decade ago. Lead pigments were used in the past, but are no longer applied to PVC windows and doors. Cadmium is being phased out too. Lead-stabilized products have been under some pressure for the past few years because of their alleged risk to people and the environment. The industry addressed these pressures by introducing lead-free products. Despite such concerns, no medically serious poisoning resulting from the use of lead stabilizers in PVC has ever been reported.

Phthalic Acids

Phtalates are the main plasticizer additives used to make PVC more malleable. DEHP (or di(2-ethylhexyl) phtalate is the most common phtalate. Phtalates that are used to soften PVC are often accused of being carcinogenic and of having pseudo-estrogen effects. Although phtalates can produce carcinogenic effects in rodents exposed to very high doses, it is now well established that this same risk does not apply to people. The pseudo-estrogen effect (natural or synthetic molecules could interfere with the body's sexual hormones and trigger undesirable effects, particularly in terms of reproduction) has also been studied. In-vitro experiments on isolated cells demonstrate that most phtalates have no such effect. Only dibutyl-phtalate (DBP) and butyl-benzyl-phtalate have a slight estrogen effect under experimental conditions. An interesting phenomenon was however noted in the case of the DEHP used to make blood bags flexible. Phtalates migrate in very low concentrations to red blood cells, which are themselves membranes. This very slight migration serves to preserve blood for a longer period of time.

Industries are seeking ways of replacing DEHPs with other phtalates of high molecule weight. Other plasticizers have been considered for use in PVC. The most important substitution for phtalates concerns the production of toys and children's products, as well as the manufacture of medical equipment. The challenge is to produce substitute products with the same strength and flexibility required for applications, particularly in the medical sector. Studies must demonstrate the safety and effectiveness of these replacement products. The basic question in replacing phtalates is if it would be better to use substitutes with no proven track record based on the assumption that phtalates are harmful.

Durability and Discolouration

Colouring additives, which may consist of dyes or pigments, are added to plastic to improve their appearance. Dyes are generally used to produce a transparent, shiny look in such clear plastics as polystyrene, as well as in acrylic and cellulosic resins. Colourings are occasionally added at the same time as a pigment. Charcoal blacks constitute an important group of pigments that are also used as fillers and are good stabilizers against UV illumination.

Compound Characteristics

Compounds represent the preparatory phase for the final conversion of PVC resins into different applications. They are obtained by compounding PVC resin with other additives (stabilizers, lubricants, fire retardants, etc.) that enable them to adapt to the type of transformation. There are two types of compounds: plastified and rigid. Products can be tailored to specific application requirements, ranging from highly flexible cables to very rigid windows. The compound's final transformation will involve extrusion, injection, pressing, blow extrusion, rotomoulding, moulding, calendaring and electrostatic coating. The compound is extruded beforehand for doors and windows.

Chalking

Chalking refers to the deterioration of PVC, exposing titanium dioxide (TiO₂) particles to the surface. The appearance of a porous or chalky white can removed from most PVC surfaces. This effect results from titanium particles and products of PVC deterioration caused by the sun's action. The term "uPVC" (u = "unplasticized") means that the PVC does not contain plasticizer. uPVC tends to more effectively withstand chalking and oxidation of its components.

Non-compliant Products and Waste

All scrap produced by the close-loop conversion process is collected and re-used in formulations of equal or inferior quality to ensure complete recycling of all materials used in the conversion industry. Non-compliant materials are returned to the manufacturer.

Different Toxicity Levels for Products Manufactured in Other Parts of the World

Special testing is conducted on products made outside Canada. Some countries, for example, do not regulate the use of such stabilizers as lead. This verification is particularly important since Canada has not always regulated the use of these products.

Existing Standards and Legislation

The CSST has implemented standards¹⁰ and regularly conducts tests to provide maximum protection to workers and reduce risks. Except in its vinyl chloride monomer form that occurs during manufacture of the resin, PVC is not classified as a hazardous product and is not included in CSST worker protection initiatives. The regulations require pouring basins and spill compartments in conversion plants to ensure that no materials are accidentally spilled on floors used by employees or in the natural environment. The CSST used to take four blood samples per year on employees from the compound's plant. However, since lead is no longer being used, the tests have been suspended. Excellent industrial hygiene is required to minimize dust inhalation. The PVC industry is proactive in these areas. No accidents pertaining to the inhalation of PVC has been reported to date at plants in which this compound is produced. However, the appropriate protective gear must be used, as with all other dust products.

¹⁰ Publication (July 2009), Normes de sécurité et santé au travail, Annexe 1, Partie 1, liste des niveaux acceptables pour tous les produits [acceptable levels for all products]:
www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=%2F%2FS_2_1%2FS2_1R19_01.htm

Recycling the Compound

Everything in the compound's manufacturing chain is recycled.

C. Extrusion Process

Extrusion is a process that mechanically forces hot, pressurized PVC powder through a die that produces the shape of a door or window profile. The following section on the process's toxicity and environmental impact, as well as sustainable development issues, will be of interest to industry experts and employees.

Vapours Released by the Die

Vapours of dioxins are not released under normal production conditions. Only the vapours of stabilizing additives, lubricants and plasticizer may be emitted. Industry ventilation standards merely require dispersal of the vapour to eliminate any risk.

Did you know? The extrusion process involves melting, not burning.

Residue on the Calibrator

Vapour may be emitted from the die during extrusion. This is because certain lubricants are not compatible with the PVC and are ejected from the plastic material, carrying along titanium oxide, calcium carbonate and certain inorganic additives. Vapours from the lubricants, stabilizers and plasticizers condense on the calibrator. This condensate is regularly trapped and collected and cleaned.

Treatment of Cooling Water

Cooling water that comes into contact with the polymer is constantly reused in a closed circuit.

Worker Health

The extruded PVC compound is not regulated.¹¹ No standards apply, because it is not harmful to workers. Tests conducted in PVC extrusion plants have shown that monomer levels are virtually nil and well below the 1 ppm level.

¹¹ WHMIS: Workplace Hazardous Materials Information System.

PVC Powder

Powdered products are not more toxic than pellets because of their volatility.

Flexible PVC Continue to Emit Gas and Odours

Flexible PVC emits odours at room temperatures. Remember the scent of plasticizer, stabilizer or rubber additives the last time you removed a new shower curtain of poor quality from its package? Or the smell of a new car's interior? Technologies exist to make phthalates odour-free or to simply replace them with another substance. Flexible blood bags are manufactured in this manner. But such technologies are not applied universally because of cost. Furthermore, flexible PVC with the stronger odour is typically from imported products.

Danger of Releasing Dioxins into the Environment

Extrusion is not a combustion process. Consequently, there is no emission of dioxins from the processing of chlorinated compounds. No dioxins are released into the environment.

Energy Consumption

Extrusion is powered by hydroelectricity, which is a clean form of energy. Extrusion also requires the use of much water, which is recirculated in a closed loop. The water is used to cool the polymer.

Environmental Impact of Extrusion in the Product's Life Cycle

The industry is currently in the process of reviewing its impact on the product's overall life cycle. Some companies have begun in-depth analyses. The major portion of the work, however, remains to be done.

Recycled Products

There are two types of recycled PVC products: "post-extrusion/fabricator" wastes and "post-consumer" wastes. Post-extrusion/fabricator wastes in pellet form are called "regrinds." Recycled PVC in either form has shown that it maintains the same features as its virgin polyvinyl chloride polymer. Cleanliness is the key to success in using recycled PVC. Any materials that could deteriorate under heat during the transformation process should be removed and scrapped. Such substances are however reused for non-critical applications. Nothing is lost.

D. Manufacturing Doors and Windows

The following information will provide industry employees and experts with information on the toxicity of the window and door manufacturing process, the environmental impact of this process and issues of sustainable development.

Gas and Dust Emitted During Welding

Welding vapours primarily consist of lubricants, stabilizers and hydrochloric acid. Plasticizer vapours are generated in the welding of flexible PVC. Given the lower emission levels of chemical compounds appearing on safety standards for plant workers, any risk to worker health is virtually nonexistent.

Comparative Energy Consumption

The amount of energy needed to make PVC windows is lower than that of other plastics. It is much less than that needed for aluminum and slightly more than that required for wood. The following comparative data¹² include the energy needed to extract natural resources, transportation to the plant and transformation.

- Energy Consumption to manufacture a PVC window frame is 7.19 kWh kg⁻¹. The CO₂ emission factor is 2.04t CO₂ t⁻¹ PVC.
- Energy Consumption to manufacture an aluminum window frame is 45.56 kWh kg⁻¹.
- Energy Consumption to manufacture a wood window frame is 0.58 kWh kg⁻¹ (these data assume that the materials will be shipped 250 Km and the energy source will consist 92% of diesel and 8% of electricity).

Much energy consumption is needed to produce aluminum windows (more than 52% of their total value) compared with 14% for PVC windows and 4% for wooden windows.

¹² *Estimate of energy consumption and CO₂ emission associated with the production, use and final disposal of PVC, aluminum and wooden windows, Barcelona, 2005.*

Did you know? The same amount of energy (4.48 kWh/window from an electric source) is needed to assemble windows, whether they are made of PVC, wood or aluminum.

Safety of PVC Compared to Other Raw Materials

PVC is harmless to the health and particularly appropriate for asthmatic or allergic individuals. PVC used for window profiles are totally harmless, highly stable and inert. They release no toxic ingredients through their contact with the environment or in the course of their maintenance. Furthermore, PVC windows are fire resistant. They do not propagate fire, they are self-extinguishing, they do not discharge drops of flame and they do not release chlorine or phosgene (see the PVC and Fire section on page 31). Window and door PVC profiles generate negligible emissions, which make them highly appropriate for sensitive applications.

Environmental Impact of Painting

In contrast with aluminum windows and doors, using PVC does not mean changing the paint or stain colour. Many pigments exist. Some traditional ones for plastic substances contain chrome and lead. Other colourings are entirely organic. Toxic pigments (those containing heavy metals) particularly concern a special form of chrome (hexavalent chrome) with concentration levels well below any danger threshold. Its use is highly regulated by national and international legislation. The longest lasting and most environmentally friendly paints are water-based and formulated for PVC.

Important: colouring additives are not released by PVC under normal use or under the impact of atmospheric conditions.

Did you know ? Surgical steel and cutlery contain about 15% chrome. The ceramic pigments used in the agri-food business are used to colour many PVC products. Lead pigments have been replaced by inorganic pigments, such as titanium dioxide as a substitute for white lead pigment.

The Energy Star Program

The Energy Star Program is an internationally known symbol of energy efficiency. ENERGY STAR certified doors and windows have demonstrated better energy performance and economy, while helping to protect the environment. To obtain this quality rating, a product must meet specific levels of energy efficiency for four Canadian climate zones. Canada is divided into four zones, ranging from the mildest (A) to the coldest (D). The four climatic zones are based on heating degree days (an annual average temperature level). Different levels of efficiency are used to assess door and window performance as insulation against cold and in using the sun's heat to supplement that of the building. The more zones for which a product is suited, the better its energy performance. Look for Energy Star products to make the best selection of PVC windows and doors. This label also indicates appropriate zone(s) of use.

Did you know? The ENERGY STAR label was created in the United States in 1992 with the massive growth in computer use. Canada quickly signed on as well. Since April 2004, ENERGY STAR accreditation criteria have been developed to label windows and glazed doors designed for our latitudes. Main entrance doors have also been eligible for this rating since 2005. The ENERGY STAR seal is well-deserved label of choice.

Sources of Loss of Insulating Ability

Glass represents the weakest link in a window's insulating ability and its prime source of heat loss.

E. Distribution

This information is valuable for industry consumers and specialists concerned with environmental issues.

Transportation Benefits

It is easier to obtain Energy Star certification for PVC windows than for their wooden or aluminum counterparts. PVC window and door shipping costs are often lower than wood because they weigh less. This means fewer greenhouse gases are generated by their transport. No special conditions are required for storing PVC, compared with wood, which requires humidity monitoring.

F. Consumption (Installation & Use)

Window and door customers are very sensitive to health and environmental issues. This information pertains to the concerns of specialists and consumers concerning PVC use in doors and windows.

Health Hazard of Resin

It is possible to detect traces of vinyl chloride monomer in the resin that did not react within the PVC. This residual monomer is present in virtually insignificant quantities that can be counted in parts per million—or a concentration of only 1/1,000 the safe maximum exposure level to the monomer. This level of concentration poses no more of an issue in terms of consumption than it does with respect to the manufacture and use of PVC products. The most critical fields are food and medical applications that require certain safety initiatives. Standards obviously serve as preventive measures.

Important fact: a finished PVC product cannot pose any risk of cancer because the monomer is virtually absent.

Phthalic Acids in Doors and Windows and the Hazard They Pose

Windows and doors consist primarily of rigid PVC and only 1% to 2% of flexible PVC. Flexible PVC includes plasticizers, such as phthalates, that often give it its malleability. In their daily use of PVC Doors and Windows, consumers have virtually no contact with flexible PVC. The risk of plasticizers migrating from one environment to another is also virtually non-existent. In such a scenario, concentrations would be so low that the risk of impact on personal health would be almost nonexistent. Existing studies on phthalate toxicity have demonstrated that they present risks to animals, but only at a dose equivalent to an exposure of 300 gr per day for a human. However, humans are only in contact with an average of 2 gr per year.

Painted Profile Risk

Colouring or lacquering of PVC windows should be performed in the shop with finishes and according to a procedure defined by the process development engineer. Through the present, it has been particularly recommended not to apply colour to white windows, even with a special PVC paint, because it is generally difficult to anticipate their resulting performance and such treatment could alter the PVC's ability to withstand shock. Currently, a market shift is underway with the use of water-based paints.

Impact of a Heat Source

There is no danger of harmful gas being released if a window is exposed to a source of heat.

Transformation over Time

Profiles changes over time through oxidation and may stretch depending on their exposure to heat and UV rays in particular.

Comparative Performance

With other materials

PVC windows and doors are durable products with service lives of more than 30 years in North America and 50 years in Europe. They are not only very safe, but are excellent insulators (PVC does not absorb moisture), highly contemporary in appearance and energy efficient. PVC does not rot and is never cold to the touch. Like wood, PVC is an excellent insulator. PVC Doors and Windows do not disintegrate to let cold air currents enter. Rigid PVC also does not require antimicrobial treatment with toxic materials or even plastic (acrylic) coatings in paints that require higher levels of maintenance. PVC doors and windows receive less condensation than their aluminum counterparts.

With competitive products

The Swiss consulting firm PROGNOSE-AG conducted a study¹³ comparing the performance of various PVC products with competitive materials. PVC window frames offer short- and medium-term environmental, economic and social benefits over these competitors. Only the use of additives containing heavy metals is considered a negative point over the long term. This impact is in the process of being eliminated by the PVC's sector commitment to stop using such additives.

¹³ PVC sustainability study, Prognos, 1999

Comparative Energy Consumption for Different Types of Windows

According to a study¹⁴ conducted by Prof. Baldasano from the University of Barcelona in Spain comparing CO₂ emissions and energy consumption for frames of different materials throughout the product's service life (from production of raw materials to the end of the product's service life), PVC affords substantial energy savings compared to wood or aluminum windows. The window's "usage" period was clearly identified as the interval in which the CO₂ gain/loss impact is greatest. That is why a well-designed window with better insulating characteristics is so important.

Table 1: Comparative study of energy consumption and CO₂ emissions between PVC, aluminum, steel and wood.¹⁵

Window	Electrical Consumption (kWh)	CO ₂ (kg)	Recycled Material (kg)					
			Glass	PVC	Steel	Aluminum	Total Recycled Materials	% of Total Material
30% recycled in PVC, double glazed	1.740	730	21.4	21.1	6.7		49.2	93.4%
0% in recycled PVC	1.780	742	21.4	21.1	6.7		49.2	93.4%
In wood, double glazed	2.045	886	21.4				21.4	61.5%
In wood, single glazed	2.633	1.155	10.7				21.4	45%
30% recycled in aluminum	3.244	1.418	21.4			40.8	62.2	94.1%
0% recycled in aluminum, double glazed	3.819	1.672	21.4			40.8	62.2	94.1%

Did you know? The production of raw materials for the plastics industry only consumes 4% of total petroleum production. Energy production for manufacturing a similar volume of steel is 2 times greater and for aluminum 7 times greater than for PVC.

www.pvcinfo.be/bestanden/Baldasano%20study_windows.pdf

¹⁴ Baldasano J. et al., (2005). "Estimate of energy consumption and CO₂ emission associated with the production, use and final disposal of PVC, aluminum and wooden windows," Environmental Modelling Laboratory, Barcelona, April. www.pvcinfo.be/bestanden/Baldasano%20study_windows.pdf

¹⁵ Source: Baldasano, 2005, p. 31.

PVC Doors and Windows

In the window and door sector, all polyvinyl chloride (PVC) profiles are actually uPVC. The “u” means “unplasticized.” Manufacturers prefer to use the more familiar term PVC.

Support for the Environmental Quality Standard

LEED (Leading Engineering Environmental Design) certification is an international standard implemented by the US Green Building Council in 1998. It certifies architectural structures in terms of their environmental and energy efficiency and use, selected materials, etc. It is difficult to claim that the United States Green Building Council (USGBC) supports PVC use, but in late 2004, it published a provisional report describing PVC as “a product like any other.” The USGBC’s “Assessment of technical basis for a PVC related materials credit in LEED®” compares life cycle studies and risk studies of PVC products and products in competitive materials. Impact criteria taken from the US EPA (Environmental Protection Agency) were also considered. The study focused on the question of: is there any material evidence to classify a particular material as “harmful” to humans or to their environment? The first finding was that “based on life cycle information and potential risks for different kinds of construction products, we cannot conclude that PVC is always the least desirable. In other words, there is no material evidence to show that PVC is less effective than other materials in terms of life cycle analysis or danger to the environment or human health.”

PVC windows performance rates the top grade of 3 points on the LEED scale.

PVC and Fire

One reason that PVC is recommended as a construction material and is preferred by fire departments is because of its excellent fire resistance. It is very difficult to ignite PVC, which cannot continue to burn in the absence of a powerful outside flame. Furthermore, the chlorine present in the PVC is a fire retardant that helps protect the material from fire. But the big benefit of PVC is that it gives the alert. When PVC burns, it emits hydrochloric gas, carbon monoxide and very little heat. Carbon monoxide is a highly toxic colourless and odourless gas and victims near a fire will breathe it without being aware they are doing so. Because very small quantities of released hydrochloric gas irritate the nasal mucosa, men and women are alerted at an early stage to the presence of a fire. After a fire, PVC will be blackened, marred and warped in places. PVC windows only burn with great difficulty, do not spread flame, are self-extinguishing and do not generate drops of flame. Furthermore, PVC never releases chlorine in its free state, or phosgene (a combat gas).

Dioxins are a chemical family of substances produced in many types of combustion including cigarette smoke, automotive exhaust and even family barbecues. Accidental fires are another source. Many studies have shown that the quantities of dioxins produced are not potentially hazardous. Any fire also generates polyaromatic hydrocarbons (PAHs) from a wide range of combustible organic materials. PAHs do however pose a much more serious level of risk than dioxins, which are often overlooked in the discussion on accidental fires.

Did you know? The combustion temperature of PVC is 150°C more than that of wood. No death has ever been attributed to the combustion PVC. The greatest sources of dioxin emissions are forest fires and volcanoes.

Green Alternatives

The Polytechnic University of Catalonia has published a study comparing PVC, wood and aluminum windows in terms of their respective energy consumption and CO₂ (greenhouse) emissions, based on their production, use and disposal in the Barcelona region. The researchers found a method for calculating energy consumption and CO₂ emissions for a standard (1.34 m x 1.34 m) window at different stages of its lifecycle: extraction of raw and production materials, assembly, transportation, use for 50 years and recycling. The study demonstrated that the window that consumed the least energy overall and that was responsible for less CO₂ emission is the double-glazed window with a PVC frame containing 30% recycled PVC.

Did you know? PVC's low cost is one of the reasons it has become so popular. PVC was originally developed on an industrial scale during the Second World War, during shortages of raw materials and sudden price hikes at times of high demand for production volume. This substance can also be used in place of glass and wood in many applications.

G. Recycling and Disposal

The recycling and disposal of PVC doors and windows is a key concern in terms of environmental and sustainable development issues. This following information will be of particular interest to specialists and consumers.

Recycling PVC

There is no inherent difficulty in recycling PVC. The study by Prof. Baldasano demonstrated that 97% of a PVC window can be recycled.¹⁶ Furthermore, 100% of the production chain can be recycled, according to the European Commission.¹⁷ During window production, surplus PVC profiles have been recycled for many years as part of good management practices. The recycling of older window products poses a challenge because multiple products (PVC, glass, doors and metal in windows) are combined in the final application and because clean and homogenous recycled PVC is necessary. Progress over the past decade has revealed recycling techniques that are far more efficient and effective than in the past. Optical sorting devices can now sort materials according to their chemical composition in record time, with virtually no error. Many successful recycling programs have been developed in Sweden and the Netherlands. Profile and floor covering recycling programs in Germany and Austria are models of success in this area.

¹⁶ Baldasano (2005).

¹⁷ European Commission, "Life Cycle Assessment of PVC and of principal competing materials," July 2004.

The reuse of rigid PVC is only limited by its quality, which diminishes each time it is recycled. After several complete recyclings, the PVC may become destabilized. However, the substance can be reused indefinitely through the introduction of new PVC.

Recycling with Other Plastics

Success depends on the purpose of the recycling. If the goal is to produce a high-quality material, mixtures with other substances will be a problem. The same issue applies to every kind of plastic. All polymers have the same requirements in obtaining very pure recycled material.

Biodegradability

Biodegradability is not desirable. First of all, most plant- or paper-based degradable materials take a great deal of time to break down. Even more important, the introduction of biodegradable materials should not avert consumer concern from waste or even encourage such practices. Furthermore, such degradable products require the creation of special composting centres and for this reason cannot be included in existing recycling programs. Recycling and incineration are techniques that add more value to the product at the end of its service life than does biodegradability.

Best International Practices

For products at the ends of their service lives, PVC no longer poses any problems in a modern and properly managed incineration facilities or in a dump.¹⁸ The caloric content of PVC can be recovered as energy during its controlled incineration. Various policies exist to reduce the amount of PVC discarded in dumps. The most advanced region in this field is Europe with the policies of the European Council Vinyl Manufacturers” (ECVM) aimed at reducing quantities discarded in dumps. Economically and technologically viable recycling operations depend on the characteristics of the finished product and available quantities of it. European recycling programs pertain specifically to door and window frames. The European PVC Window Profile and Related Building Association (EPPA)¹⁹ was created in 2000 to obtain a voluntary commitment from the European PVC industry to create and implement recycling policies and initiatives for PVC door and window profiles that would apply throughout Europe. According to EPPA Director Volker Hoffman in 2006, 37,000 tonnes of waste profiles were recycled in the United Kingdom, Austria, Belgium, Denmark, France, Ireland, Italy and the Netherlands. Incineration posed problems when lead was used. It continues to pose problems with heavy metals. Acid-removal methods are fairly complicated, but acid purifiers have long been in use and have demonstrated their effectiveness in acid rain elimination operations with the nickel smelting process in Sudbury, for example.

¹⁸ PVC-Info, www.pvcinfo.be

¹⁹ EPPA (European PVC window Profile and related building Association): eppa-profiles.org/index.php

Percentage Recycled in Quebec and in Canada

All materials in the PVC window and door industry value chain are recycled through to the extrusion phase. Even compounds are reused. Recycling after production, however, is not cost effective enough to produce the same recycling rate.

Efforts Deployed by the Private Sector

The private sector is currently considering different options for recycling doors and windows at the ends of their life cycles. These efforts will not prove fruitful without government involvement.

Efforts Deployed by the Government

As of January 2010, the government still had not launched incentive programs for recycling PVC windows at the ends of their service lives.

Recycling Depot

No PVC door and window site exists at the present time in Quebec or elsewhere in Canada.

Comparative Recycling Performance

Up to 97% recycling is possible if certain recycling equipment is on hand. PVC is generally recycled mechanically. After it is disassembled and sorted, the PVC is crushed and turned into pellets. It is then used to make new profiles, windows, etc. It should be possible to repeat this operation up to four times, which would give the basic materials a service life in excess of 200 years.

Cost and Cost Effectiveness of Recycling

The recycling of PVC doors and windows requires a network of PVC waste collectors and recyclers, so that these materials can be processed and reused. Although the regenerated material can be reused in many applications and as flexible or rigid PVC, this level of organization and processing currently make the recycling of doors and windows economically nonviable.

H. Conclusions and Recommendations

Conclusion

PVC stands out as an ideal material for doors and windows that it is difficult for substitutes such as wood or aluminum to surpass in terms of energy efficiency and savings. Despite research and tests conducted for more than a quarter of a century, no official organization has been able to scientifically demonstrate the PVC is harmful to humans or to the environment. Furthermore, stricter regulations and standards apply to worker health and safety. No cancer has been recorded since the standards were established in 1974. In addition to benefit from a price-quality ratio much better than what is offered by most of the competition, consumers are sure to like a solid and reliable product, as long as it is used in accordance with recommendations. In contrast with conventional wisdom, PVC profiles help preserve the environment throughout their life cycles.²⁰ During manufacture of the raw material (PVC Powder) energy consumption and carbon emissions are kept to a minimum. During extrusion, cooling water is recycled and reused internally to avoid the pollution or waste of freshwater. Production wastes are reintroduced into the production chain. Similarly, door and window manufacturing scrap is recovered and reused in the extrusion process. Once installed, these doors and windows contribute to thermal and acoustic insulation, thereby contributing to significant savings in heating costs. The long lives of these materials prevents their frequent replacement, which is a source of waste. Despite a state-of-the-art self-regulated industry, one point could be improved: recycling of doors and windows at the ends of their service lives.

Recommendations

Clearly certain regions are ahead of others with respect to the end of a product's service life. As part of the voluntary commitment of Vinyl 2010, the European industry is committed to going further in improving healthcare, safety, environmental protection and the socio-economic value of its products. This voluntary policy has been established to address future needs while complying with the Responsible Care Program's²¹ sustainable development policy that was launched by the entire chemical industry. Vinyl 2010 represents a change of approach and thinking at all levels, particularly in terms of economic prosperity, environmental protection and social welfare. Recycling programs have accordingly been instituted and have proven fairly effective. For example, the recycling of recoverable PVC materials from windows has climbed overall from 25% in 2003 to 50% in 2005.

Our primary recommendation pertains to the enhancement of recycling efforts in Quebec to include the recycling process at all phases of the PVC door and window service life cycle.

Another important effort will be to lobby to establish a waste reclamation and management program to extend product service lives and to make this program cost effective through the appropriate government decisions.

It would also be appropriate to communicate good practices of the Canadian PVC sector to the public.

²⁰ "PVC profiles help preserve the environment throughout their service lives," Volker Haufmann, President of the EPPA, European PVC Window Profile and Related Building Association, November 2007.

²¹ www.responsiblecare.org/page.asp?p=6406&l=1

Appendix

Table 2: *Web Sites Pertaining to PVC Recycling*

Organization	Web Site
Vinyl Material Council (VMC) of the American Architectural Manufacturers Association (AAMA)	www.aamanet.org/
National Vinyl Recyclers Directory	www.vinylinfo.org/Recycling/VinylRecyclingDirectory.aspx
The Vinyl Institute	www.vinylinfo.org
Vinyl Institute Recycling Page	www.vinylinfo.org/Recycling.aspx
Recycled Vinyl Products Manufacturers	www.vinylinfo.org/Recycling/VinylManufacturersDirectory.aspx
1999 Principia Partners Report of Post-Industrial and Post-Consumer Vinyl Reclaim	www.vinylinfo.org/Recycling/VinylRecyclingReport.aspx
Vinyl In Design Targeted Toward Product Specifiers, Architects and Construction Professionals	www.vinylbydesign.com/site/new_index.asp
U.S. Green Building Council's LEED Green Building Rating System	www.usgbc.org/DisplayPage.aspx?CategoryID=19
Green Building Initiative (GBI) Green Globes Rating	www.thegbi.org/home.asp
National Association of Home Builders National Green Building Program	www.nahbgreen.org
Recovinyl PVC Recycling Program, Initiative of Vinyl	www.recovinyl.com
Vinyl 2010—The European PVC Industry Commitment to Sustainability	www.vinyl2010.org
Vinyl News Service (VNS)	www.vinylnewsservice.com

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PVC-INFO was originally a work group within the Fechiplast (Belgian association of plastic materials transformers). Since 2002, it has been an independent nonprofit.

The PVC-INFO NPO promotes the use of PVC products and the PVC brand. PVC-INFO is a sounding board and provides information to the authorities, to consumers, to the industry, to the media, to educational institutions and to interest groups.

PVC-INFO is part of an international structure and a member of the European Council of Vinyl Manufacturers (ECVM), an organization that represents PVC producers in Western Europe. The ECVM is itself a member of Plastics Europe. Through this European network, PVC-Info provides objective and timely information to interested parties.

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