

SUMMARY OF FINDINGS

from *Environmental Impacts of Polyvinyl Chloride (PVC) Building Material*
a briefing paper for the Healthy Building Network, by Joe Thornton, Ph.D.
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In the last 40 years, polyvinyl chloride plastic (PVC) has become a major building material. Global vinyl production now totals over 30 million tons per year, the majority of which is directed to building applications, furnishings, and electronics.

The manufacture, use, and disposal of PVC poses substantial and unique environmental and human health hazards. Across the world, governments, companies, and scientific organizations have recognized the hazards of PVC. In virtually all European nations, certain uses of PVC have been eliminated for environmental reasons, and several countries have ambitious programs to reduce PVC use overall. Scores of communities have PVC avoidance policies, and dozens of green buildings have been built with little or no PVC. Firms in a variety of industries have announced measures to reduce PVC consumption and are using or producing alternative materials in a variety of product sectors, including building materials. This paper discusses the hazards of the PVC lifecycle that have led to this large scale movement away from PVC products.

The major hazards of the PVC lifecycle discussed in this report are summarized below.

PVC production is the largest use of chlorine gas in the world. PVC consumes about 40 percent of total chlorine production, or approximately 16 million tons of chlorine per year worldwide. PVC is the largest production-volume organochlorine, a large class of chemicals that have come under scientific and regulatory scrutiny in the last decade because of their global distribution and the unusually severe hazards they tend to pose. PVC (vinyl) is the only major building material that is an organochlorine; alternative materials, including most other plastics, do not contain chlorine and do not pose the hazards discussed in this report.

Hazardous by-products are formed throughout the PVC lifecycle. At numerous points in the vinyl lifecycle, very large quantities of hazardous organochlorine by-products are formed accidentally and released into the environment.

Production: Formation of hazardous organochlorine by-products begins with the production of chlorine gas. Extremely large quantities - on the order of one million tons per year -- of chlorine-rich hazardous wastes are generated in the synthesis of ethylene dichloride and vinyl chloride monomer (EDC and VCM, the feedstocks for PVC).

Combustion: Still more by-products are created and released to the environment during the incineration of hazardous wastes from EDC and VCM production, the incineration of vinyl products in the waste stream, the recycling of vinyl-containing metal products by combustion, and the accidental burning of PVC in fires in buildings, warehouses, or landfills.

By-products of PVC production are highly persistent, bioaccumulative, and toxic. The chemical mixtures produced in the synthesis of EDC and VCM include such extremely hazardous and long-lived pollutants as the chlorinated dioxins (polychlorinated dibenzo-p-dioxins), chlorinated furans (polychlorinated dibenzofurans), PCBs (polychlorinated biphenyls), hexachlorobenzene (HCB), and octachlorostyrene (OCS). In addition, a very large portion of these mixtures consists of chemicals that have not yet been identified or tested. Many of the by-products of the vinyl lifecycle are of great concern, because of their persistent bioaccumulative toxicity:

Persistence means that a substance resists natural degradation, builds up over time in the environment, and can be distributed globally on currents of wind and water. Many of the by-products of the PVC lifecycle are now ubiquitous global pollutants, which can be found not only in industrialized regions

but in the planet's most remote ecosystems. Absolutely every person on earth is now exposed to these substances.

Bioaccumulation means that a substance is fat-soluble and therefore builds up in the tissues of living things. Most bioaccumulative substances, including many formed during the PVC lifecycle, magnify as they move up the food chain, reaching concentrations in species high on the food chain that are millions of times greater than their levels in the ambient environment. These substances also cross the placenta easily and concentrate in the breast milk of human and other mammals.

Toxicity. The feedstocks, additives, and by-products produced and released during the lifecycle of PVC have been shown to cause a range of health hazards, in some cases at extremely low doses, including:

- **Cancer**
- **Disruption of the endocrine system**
- **Reproductive impairment**
- **Impaired child development and birth defects**
- **Neurotoxicity** (damage to the brain or its function), and
- **Immune system suppression.**

Dioxins. Among the most important by-products of the PVC lifecycle are dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin) and a large group of structurally and toxicologically related compounds, collectively called dioxins or dioxin-like compounds. Dioxins are never manufactured intentionally but are formed accidentally whenever chlorine gas is used or chlorine-based organic chemicals are burned or processed under reactive conditions.

Dioxins are formed during numerous stages of the vinyl lifecycle Formation of dioxins has been documented in production of chlorine, synthesis of the feedstocks EDC and VCM, burning of vinyl products in accidental fires, and incineration of vinyl products and the hazardous wastes from PVC production.

Vinyl is a major dioxin source. Vinyl is the predominant chlorine donor and therefore a major and preventable cause of dioxin formation in most of the leading dioxin sources that have been identified. When its entire lifecycle is considered, vinyl appears to be associated with more dioxin formation than any other single product.

Dioxins are global pollutants. Dioxins are now found in the tissues of whales in the deep oceans, polar bears in the high Arctic, and virtually every human being on earth. Human infants receive particularly high doses (orders of magnitude greater than those of the average adult), because dioxins cross the placenta easily and concentrate in breast milk.

There is no known safe dose of dioxin. Dioxin causes damage to development, reproduction, and the immune and endocrine systems at infinitesimally low doses (in the low parts per trillion). Toxicological studies have not been able to establish a "threshold" dose below which dioxin does not cause biological impacts.

Dioxin is a potent carcinogen. Dioxin is the most potent synthetic carcinogen ever tested in laboratory animals and is a known human carcinogen.

Dioxin poses health risks to the general public that are already too high. The dioxin "body burden" of the general human population of the United States is already in the range at which adverse health impacts occur in laboratory animals. The dioxin exposure of the average American already poses a calculated cancer risk of one in 1,000 to one in 100 - thousands of times greater than the usual standard for an "acceptable risk."

Phthalate plasticizers. In its pure form, PVC is rigid and brittle. To make flexible vinyl products, such as roofing materials, floor tiles and wall coverings, plasticizers must be added to PVC in large quantities - up to 60 percent of the final product by weight. The dominant group of plasticizers used in vinyl are a class of compounds called phthalates, which pose considerable health and environmental hazards. Vinyl is the only major building product in which phthalates are used extensively, and it accounts for about 90 percent of total phthalate consumption. Over 5 million tons of phthalates are used in vinyl every year.

Phthalates have become global pollutants. Phthalates are moderately bioaccumulative and moderately persistent under some conditions. They can now be found in the water of the deep oceans, air in remote regions, and the tissues and fluids of the general human population. Infants and toddlers are subject to exposures several times higher than those of the average adult.

Massive quantities of phthalates are released into the environment each year. Millions of pounds of phthalates are released annually into the environment during the formulation and molding of vinyl products. Phthalates are also released when vinyl is disposed of in landfills or incinerators or when PVC products burn accidentally. More than 80 million tons of phthalates are estimated to be contained in the stock of PVC products now in use in buildings and other applications.

Phthalates leach out of vinyl products. Phthalates are not chemically bonded to the plastic but are merely mixed with the polymer during formulation. They therefore leach out of the plastic over time into air, water, or other substances with which vinyl comes in contact.

Phthalates damage reproduction and development. Phthalates have been found to damage the reproductive system, causing infertility, testicular damage, reduced sperm count, suppressed ovulation, and abnormal development and function of the testes and male reproductive tract in laboratory animals. They are known carcinogens in laboratory animals.

DEHP exposure is already too high. An expert committee of the National Toxicology Program recently reviewed the hazards of diethylhexyl phthalate (DEHP, the most common vinyl plasticizer) and expressed “concern that exposure [of infants and toddlers in the general U.S. population] may adversely affect male reproductive tract development” and “concern that ambient oral DEHP exposures to pregnant or lactating women may adversely affect the development of their offspring.” The average American’s dose of the plasticizer DEHP is now approximately equal to EPA’s reference dose - the maximum “acceptable” exposure based on studies of health impacts in laboratory animals.

Lead and other heavy metal stabilizers. Because PVC catalyzes its own decomposition, metal stabilizers are added to vinyl for construction and other extended-life applications. Common PVC additives that are particularly hazardous are lead, cadmium, and organotin, with global consumption of each by vinyl estimated in the thousands of tons per year. .

Metals do not degrade in the environment. All three of the major PVC stabilizers resist environmental breakdown and have become global pollutants.

Metal stabilizers are highly toxic. Lead is an exquisitely potent developmental toxicant, damaging brain development and reducing the cognitive ability and IQ of children in infinitesimal doses. Cadmium is a potent neurotoxin and carcinogen, and organotin can suppress immunity and disrupt the endocrine system.

Metal stabilizers are released through out the vinyl product lifecycle. Metal stabilizers are released from vinyl products when they are formulated, used, and disposed. Releases of lead stabilizers from interior vinyl building products have been documented. Metals cannot be destroyed by incineration but

are released entirely into the environment, via air emissions or ash residues. Trash incinerators are a dominant source of lead and cadmium pollution, and PVC contributes a significant amount of these metals - an estimated 45,000 tons of lead each year -- to incinerators.

Accidental fires in buildings and landfills are also potentially important sources of lead, cadmium, and organotins. In a fire, metals in PVC will be released to the environment; an astounding 3.2 million tons of lead are present in the current stock of PVC in use. Potential lead releases from this stored PVC must be viewed as a major potential health hazard.

Flexible PVC harms indoor air quality. Flexible vinyl products appear to contribute to the health hazards of poor indoor air by releasing phthalates and facilitating the growth of hazardous molds.

PVC products release phthalates into the building environment. Phthalate levels in indoor air in buildings with PVC are typically many times higher than in outdoor air. Phthalate accumulation in suspended and sedimented indoor dusts are particularly high, with concentrations in dust as high as 1,000 parts per million.

PVC phthalate exposure may be linked to asthma. In laboratory animals, metabolites of phthalates used in vinyl cause asthma-like symptoms through a well-described inflammatory mechanism. Three separate epidemiological studies have found that human exposure to PVC in building interiors causes significantly elevated risks of asthma and other pulmonary conditions, including bronchial obstruction, wheezing, pneumonia, prolonged cough, and irritation of the nasal passages and eyes.

PVC products can release heavy metals into the building environment. Metal stabilizers, particularly lead, cadmium, and organotins, can be released from vinyl products. Significant quantities of lead have been found to be released from vinyl window blinds into air and from PVC pipes into water. Toxicological effects of these substances include neurological, development, and reproductive damage.

Vinyl wall covering encourages toxic mold growth. Because vinyl wall coverings form a barrier impermeable to moisture, they encourage the growth of molds on wall surfaces beneath the vinyl, particularly in buildings where air conditioning or heating systems produce significant temperature and humidity differentials between rooms and wall cavities. Some molds that grow beneath vinyl produce toxic substances that are released into indoor air and are suspected causes of severe human health problems. Numerous liability suits are active on the link between vinyl-produced molds and respiratory and neurological symptoms among exposed persons. Vinyl has been cited as the interior building material most likely to facilitate the growth of these molds.

Workers and communities are exposed to toxic substances due to PVC production. In the production of PVC, many thousands of tons per year of the feedstocks ethylene dichloride (EDC) and vinyl chloride monomer (VCM) are released into the workplace and into local environments.

PVC feedstocks cause cancer and other health impacts. Both EDC and VCM cause cancer in laboratory animals; VCM is classified as a known human carcinogen and EDC is a probable human carcinogen. Increased risks of liver cancer and brain cancer have been documented among workers exposed to VCM. They are toxic to the nervous system and cause a variety of other impacts on human health. There is preliminary evidence that workers involved in the manufacture of PVC products may have elevated risks of testicular cancer.

There is no safe VCM exposure level. Although workplace exposures in U.S. chemical and plastics facilities have been significantly reduced from the levels of the 1960s, there is no threshold below which VCM does not increase the risk of cancer, so current exposures in the U.S. continue to pose cancer

hazards to workers. Further, occupational exposure to VCM remains extremely high in some facilities in Eastern Europe and Asia.

VCM production facilities are major polluters. Severe contamination of communities and waterways in the vicinity of VCM production facilities has been documented. In Louisiana, significantly elevated levels of dioxins have been found in the blood of people living near a VCM facility, several communities have been evacuated due to VCM contamination of groundwater, and extremely high levels of highly persistent, bioaccumulative by-products attributable to VCM production have been found in local waterways. In Europe, VCM production facilities have caused severe regional contamination with dioxins and other by-products.

Chlorine production consumes enormous amounts of energy. Chlorine production is one of the world's most energy-intensive industrial processes, consuming about 1 percent of the world's total electricity output. Chlorine production for PVC consumes an estimated 47 billion kilowatt hours per year - equivalent to the annual total output of eight medium-sized nuclear power plants.

Chlorine production causes mercury pollution. The mercury-based process for producing chlorine accounts for about a third of world chlorine production. In this process, very large quantities of mercury are released into the environment. Mercury is now a global pollutant that causes severe reproductive, developmental, and neurological impacts at low doses. The vinyl lifecycle is associated with the continuing release of many tons of mercury into the environment each year.

PVC is extremely difficult to recycle. Very little PVC is recycled, and this situation is unlikely to change in the foreseeable future. Because each PVC product contains a unique mix of additives, post-consumer recycling of mixed PVC products is difficult and cannot yield vinyl products with equivalent qualities to the original. Even in Europe, where PVC recycling is more advanced than in the United States, less than 3 percent of post-consumer PVC is recycled, and most of this is merely "downcycled" into other products, which means there is no net reduction in the production of virgin PVC. By 2020, only 9 percent of all post-consumer PVC waste in Europe is expected to be recycled, with a maximum potential of no more than 18 percent.

PVC is one of the most environmentally hazardous consumer materials ever produced. The PVC lifecycle presents one opportunity after another for the formation and environmental discharge of organochlorines and other hazardous substances. When its entire lifecycle is considered, it becomes apparent that this seemingly innocuous plastic is one of the most environmentally hazardous consumer materials produced, creating large quantities of persistent, toxic organochlorines and releasing them into the indoor and outdoor environments. PVC has contributed a significant portion of the world's burden of persistent organic pollutants and endocrine-disrupting chemicals-including dioxins and phthalates-that are now present universally in the environment and the bodies of the human population. Beyond doubt, vinyl has caused considerable occupational disease and contamination of local environments as well.

In summary, the feedstocks, additives, and by-products of the PVC lifecycle are already present in global, local, and workplace environments at unacceptably high levels. Efforts to reduce the production and release of these substances should be environmental and public health priorities.

It is time to phase out PVC building materials. The hazards posed by dioxins, phthalates, metals, vinyl chloride, and ethylene dichloride are largely unique to PVC, which is the only major building material and the only major plastic that contains chlorine or requires plasticizers or stabilizers. PVC building materials therefore represent a significant and unnecessary environmental health risk, and their phase-out in favor of safer alternatives should be a high priority.

PVC is the antithesis of a green building material. Efforts to speed adoption of safer, viable substitute building materials can have significant, tangible benefits for human health and the environment.