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Healthy Environments:
What's New (and What's Not) With PVC

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Healthy Building Network
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What's New (and What's Not) With PVC

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As a research-driven architecture firm, Perkins+Will has created a practice where design, technology, and research converge to create places that improve how we live and work. To help keep us at the forefront of innovative design, we believe that it is essential to make focused investments in thought leadership in order to solve our clients' increasingly complex challenges and advance our profession. Toward that end, the Perkins+Will Science Fellow program was initiated in 2014. In 2015, in lieu of awarding an individual researcher the fellowship, the Healthy Building Network was engaged to aid our efforts to better understand the impacts our buildings have on human and environmental health.

The Healthy Building Network is a research-based not-for-profit organization focused on identifying chemical ingredients in the products that make up our built environment. The Pharos Project (a web-based building material evaluation system) and the Healthy Building News (since 2002) are just two means by which they have achieved deep respect within the design and construction industry. Perkins+Will and the Healthy Building Network possess many complementary synergies between our organizations, including core values around the Precautionary Principle, transparency, and optimism around the power of design to make positive change. The Science Fellowship program provided our organizations the perfect opportunity to see where those synergies could lead.

SPECIAL THANKS TO OUR PEER REVIEWERS

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Foreword

The health and environmental concerns associated with polyvinyl chloride plastic (PVC; commonly known as vinyl) have been the subject of many publications over the past twenty years, including several extensive reviews by the Healthy Building Network (an abbreviated list of publications is provided in Appendix A: Additional Resources for Further Reading as a resource for readers seeking further information). Given the weight of this evidence, Perkins+Will has included PVC on its Precautionary List[a] since 2008.

This does not mean that Perkins+Will has eliminated the specification of all PVC-based products. Instead, in keeping with the precautionary principle,[b] when evidence indicates a relevant adverse finding as it relates to human health or negative environmental impact, Perkins+Will seeks to, where possible and appropriate, present alternatives to building owners for their consideration. The goal is to empower design teams to make informed decisions, recognizing that this is an issue where scientific certainty is elusive.

Perkins+Will includes PVC on the Precautionary List because it presents hazards to people and the environment, beginning with its synthesis and continuing through its manufacture into products, use, and additional significant hazards during its disposal or recycling. In a review of 55 polymers[c] used in global production, researchers found that while other plastics vary in their use of hazardous substances, any of the highest production volume polymers reviewed were preferable to PVC from an environmental health perspective. This same study noted that, "of the polymers ranked most hazardous, PVC is by far the most used one."[1]

a The Precautionary List is a list of 25 substances identified by Perkins+Will as chemicals of concern. The intent of the List is to focus on those hazards likely to be found in building products; the substances were compiled from various authoritative lists. Available http://transparency.perkinswill.com/

b "The precautionary principle states that, in cases of serious or irreversible threats to the health of humans or ecosystems, acknowledged scientific uncertainty should not be used as a reason to postpone preventive measures. The principle originated as a tool to bridge uncertain scientific information and a political responsibility to act to prevent damage to human health and to ecosystems." [Excerpted from *The precautionary principle: protecting public health, the environment and the future of our children*, World Health Organization, http://www.euro.who.int/__data/assets/pdf_file/0003/91173/E83079.pdf.]

c In 2011, a team of Swedish scientists examined the environmental hazards and risks associated with 55 thermoplastic and thermosetting polymers, including the monomers released during the production, use and disposal of these products. Only polyurethane and polyacrylonitrile polymer types fared worse than PVC in their hazard rankings. [See Delilah Lithner, Ake Larsson and Goran Dave, "Environmental and Health Hazard Ranking and Assessment of Plastic Polymers Based on Chemical Composition," Science of the Total Environment 409, no. 18 (August 2011), http://www.sciencedirect.com/science/article/pii/S0048969711004268]

Chlorine is one of five elements on the periodic table known as halogens, including chlorine, fluorine, and bromine (iodine and astatine are also halogens[2], but uncommon in building products). Halogen-based compounds have been the source of many of the most difficult chemical contamination problems society has dealt with since World War II: for example, the herbicide "Agent Orange,"[3] and DDT,[4] dioxin,[5] PCBs,[6] and CFCs.[7]

PVC is not singled out within the Precautionary List. As a halogen-based chemistry, it joins numerous other halogen-based compounds on the List, including bromine-based flame-retardants and fluorine-based coatings that repel liquids.[8] The Consumer Product Safety Commission has even been petitioned to categorically ban halogenated chemistry, in an effort to avoid significant human and environmental hazards.[d]

d In 2015 a petition was submitted to the Consumer Product Safety Commission urging the agency to prohibit categorically the inclusion of flame retardants based on halogenated chemistry from certain products (including furniture). Petitioning organizations include the American Academy of Pediatrics, International Association of Fire Fighters, and the Green Science Policy Institute. The petition is available from regulations.gov at http://www.regulations.gov/#!documentDetail;D=CPSC-2015-0022-0002

Purpose Statement

This paper was prepared by Perkins+Will, in partnership with Healthy Building Network (HBN), as part of a larger effort to promote health in the built environment. Indoor environments commonly have higher levels of pollutants, and architects and designers may frequently have the opportunity to help reduce or mitigate exposures.[9]

The health and environmental concerns associated with PVC have been the subject of many publications over the past twenty years. The purpose of this report is to present information on the environmental and health hazards of PVC, with an emphasis on information found in government sources. This report is not intended to be a comprehensive analysis of all aspects of the PVC lifecycle, or a comprehensive comparative analysis of polymer lifecycles. Rather, in light of recent claims that PVC formulas have been improved by reducing certain toxic additives, this paper reviews contemporary research and data to determine if hazards are still associated with the lifecycle of PVC. This research has been surveyed from a perspective consistent with the precautionary principle, which, as applied, means that where there is some evidence of environmental or human health impact of PVC that reasonable alternatives should be used where possible. Furthermore, and more generally, this paper is intended to build greater awareness of this common building material.

Executive Summary

PVC is a popular, highly versatile, low-cost, durable material used in a wide variety of building product applications. However, PVC is unique within the broad spectrum of plastics because it is a chlorinated plastic. Its chlorinated chemistry is responsible for a range of environmental and human health hazards: from the beginning of its lifecycle where the vinyl chloride monomer is a known human carcinogen;[10] to the release of dioxin, another human carcinogen,[11] when PVC is manufactured;[12] and when PVC burns in accidental building and landfill fires,[e] in jobsite burn barrels, as well as in incinerators.[13] PVC-related wastes constitute four of the first 12 substances targeted for international action by the 2001 Stockholm Convention on Persistent Organic Pollutants (POPs).[14]

An extensive range of additives is needed to improve vinyl's versatility and offset the limitations of the plastic. These include lead-based stabilizers and toxic plasticizers, called phthalates,[f] to make it suitable for flexible applications such as flooring, wall covering, and membrane roofing. Additives are not chemically bound to the plastic, and have been documented to migrate out of vinyl products and into household dust, exposing occupants.[15,16]

In recent years, as data on potential health hazards have emerged and the market has moved to alternative products, PVC product manufacturers have been replacing many of the toxic additives.[17] The reformulated products are the subject of a new rebranding campaign in the vinyl industry; "clean-vinyl" and "bio-vinyl" are two examples of the trade names at the forefront of this campaign to position vinyl as a breakthrough and advanced green product.[18,19] While improved by excluding problematic additives, these reformulations have not—and cannot—address the lifecycle hazards tied to PVC's intrinsic chlorinated chemistry.

Further, recycling rates for PVC are very low, but when it does get recycled, workers and the communities surrounding recycling facilities can be exposed to its additives.[20] Once incorporated into the manufacture of new vinyl products, the use of recycled PVC becomes a pathway for the introduction of serious legacy contaminants from prior vinyl formulations into these new vinyl products—including many of the very additives the new formulations have been designed to avoid.

Influential materials rating systems, including the Living Building Challenge building certification and Cradle to Cradle product certifications recommend avoiding PVC. Influential building owners such as Kaiser Permanente and Google have adopted PVC avoidance policies. Perkins+Will, an international architecture practice with about 1,000 architects, included PVC in its Precautionary List as a substance for which to seek alternatives.

Consideration of the current state of PVC manufacturing practices and use of recycled content supports the position that PVC continues to pose hazards to human health. Avoiding PVC in building material choices is nearly always preferable from an overall human health and environmental perspective, recognizing that there may (or may not) be tradeoffs with other environmental attributes depending upon which material is selected.[21] For example, wood flooring or siding may have deforestation impacts that PVC would not.

e The vinyl industry concedes that uncontrolled burning from accidental building fires and burn barrels are a significant source of dioxins in the environment. [The Vinyl Institute, "Dioxin Levels in the United States", vinylindesign.com, accessed October 13, 2015, http://www.vinylindesign.com/mainmenu/Learn/VinyltheEnvironment/DioxinSources.html]

f See Table 3 for a full explanation of health hazards posed by these additives.

Introduction

The Vinyl Institute, a U.S. trade association representing manufacturers of PVC and products made from it, proclaims that it is "one material with infinite uses."[22] The amount of PVC used in building and construction appears to be on the decline. While PVC resin production in the US and Canada has been flat (*see Figure 2*), the share of the resin used in building and construction is falling. The American Chemistry Council's annual reports of resin production in the US and Canada show the building and construction sector consuming 64% of PVC resin made in 2004, and just 47% in 2014.[23] **Table 1** provides an overview of some common examples.

Table 1. Uses of Vinyl in Buildings[g]

Product Type	Rigid	Flexible
Roofing membrane		X
Siding	X	
Pipes and plumbing	X	
Window frames	X	
Resilient flooring (sheet and tile)	X	X
Carpet backings		X
Wallcoverings	X	X
Wall protection		X
Electrical wiring	X	X
Mini-blinds	X	X
Roller shades		X
Molding & trim	X	X
Fencing	X	X

g Sources for the information presented in this table include the Pharos Project's Building Product Library, Healthy Building Network's research experience, and data provided by the Vinyl Institute [The Vinyl Institute, "Uses of Vinyl," Vinyl Info, last updated 2015, http://vinylinfo.org/uses-of-vinyl/.]

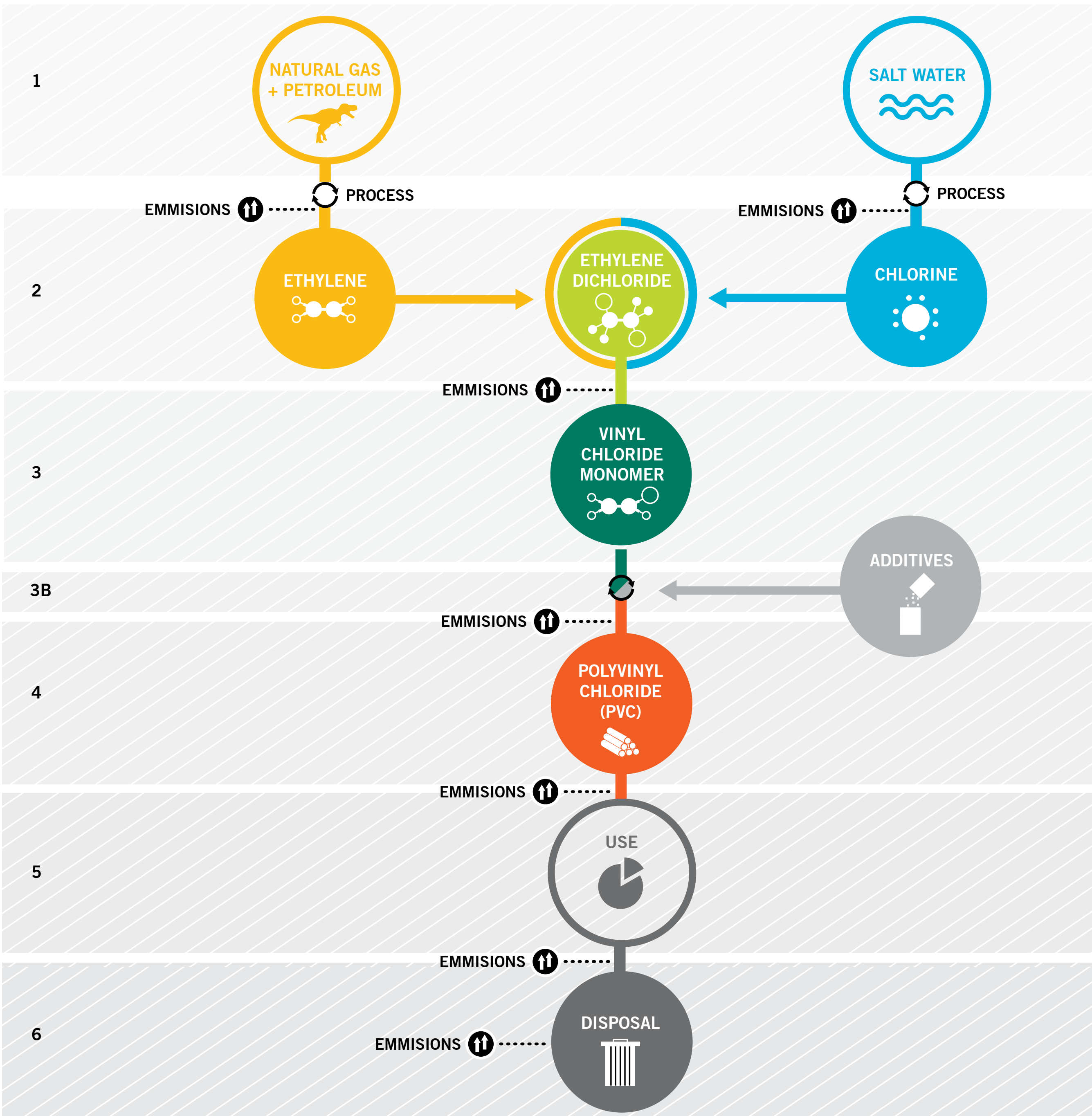
Vinyl is made of 57% chlorine.[24] This inclusion of chlorine in PVC necessitates a process for synthesis that is unique among other plastics. **Figure 1** on the next page outlines the steps of this synthesis, which begins by reacting ethylene (derived from fossil fuels) and chlorine gas (derived from salt water) to create ethylene dichloride (EDC).[25] EDC is converted to vinyl chloride monomer (VCM), and the VCM is polymerized into polyvinyl chloride (PVC) resin. Depending on the performance attributes desired in the PVC products being made from the resin, various additives are incorporated into it to form a final PVC compound.[26] For example, one type of additive commonly used in PVC is plasticizer, used to make products flexible that would otherwise be rigid.

The primary critiques of PVC to date have been, 1) the manufacture of PVC emits various chemicals that pose a hazard to workers, surrounding communities, and the planet at large; 2) once PVC products are incorporated into buildings, their additives pose a health hazard to occupants; and 3) there are no good options for disposing of PVC at the end of its life because it is not readily recycled, and creates hazardous pollutants if incinerated. (*See Table 3 for a listing of the health concerns associated with PVC.*)

In its defense, the vinyl industry has argued that emissions during synthesis are slight, that PVC is in fact recyclable, and that pollution during incineration is largely a problem of the past.[27] In addition, many PVC products have been reformulated to avoid the problematic additives commonly cited as hazardous to occupants.[28]

This paper reviews current information on the lifecycle of PVC, changes to its formulation, and the status of recycling and end of life options to determine what is new, and what is not, in PVC.

Figure 1. Lifecycle of PVC[h]



h Image courtesy of Perkins+Will

What Are The Health Hazards Associated With PVC?

The specific human and environmental health issues linked to the production, use, and end of life of PVC are explored in some detail below, and a list of additional resources is provided in **Appendix A**.

A. HAZARDS DURING SYNTHESIS

As noted in **Figure 1**, PVC synthesis begins with the production of chlorine gas from salt water.[29] One method for accomplishing this is the use of an antiquated process using mercury cells. The United Nations estimates that 100 chemical plants across 44 countries are still using mercury cells,[30] even as this technology is being phased out in other countries due to its heavy mercury emission to the environment.[31] Mercury does not break down, but instead persists and accumulates in living organisms, including people.[32] Mercury is recognized as a reproductive[33] and developmental toxicant,[34] and has been associated with a host of other health hazards, including disruption of the body's hormone systems.[35] China is one country still using mercury cells,[36] and is also the source for many PVC building products on the market today, such as vinyl flooring.[37]

The next step in PVC synthesis is to combine the chlorine gas with ethylene to make ethylene dichloride.[38] Ethylene dichloride is then converted to vinyl chloride monomer,[39] a recognized human carcinogen[40] with a documented history of poisoning workers exposed to it.[41] Furthermore, the processes for making ethylene dichloride and vinyl chloride monomer create dioxins[42]—potent carcinogens—that enter the environment and become global pollutants.[43] VCM is polymerized into polyvinyl chloride resin,[44] which then needs to be compounded with various additives to make it suitable for its intended use.[45]

These processes and the hazards they pose to workers, surrounding communities (and in the case of dioxins, the planet) have been the basis of the critique of PVC during synthesis.

Trade Secrets & Worker Safety[46]

The manufacture of PVC and its feedstock chemistries have a disturbing history with regard to worker health and safety.

In the 2001 PBS Documentary, *Trade Secrets*, the respected journalist Bill Moyers presented his investigation of what appears to be a decades-long effort by companies making and using vinyl chloride monomer to obfuscate the very real possibility of chronic disease following occupational exposures to the chemical.

The leading chemical companies of the time—Dow, Shell, and B.F. Goodrich, to name a few—signed agreements to keep newly emerging studies showing causation between even low levels of exposure to VCM and cancer and other ailments confidential from workers and the medical community alike. Workers at the time claim that, in fact, these companies assured them that VCM was harmless.

In the decades since the practices uncovered in this documentary, the Occupational Safety and Health Administration (OSHA) has established thresholds for occupational exposure to VCM, but the risk to workers in these plants is not gone.

In 2012 the Delaware Department of Natural Resources and Environmental Control cited a PVC manufacturing site owned by Formosa for releases of VCM well beyond allowable limits. The citation included nine infractions in total, including neglecting to submit a required report to the State's Division of Air Quality. Inspectors found the concentration of VCM in processing waters was well above established limits, and 55 pounds of VCM was released from the plant to the air after equipment failure.

While it is true that the production processes of many types of plastic involves the use of hazardous chemicals, only PVC is manufactured with this particular human carcinogen: vinyl chloride monomer.

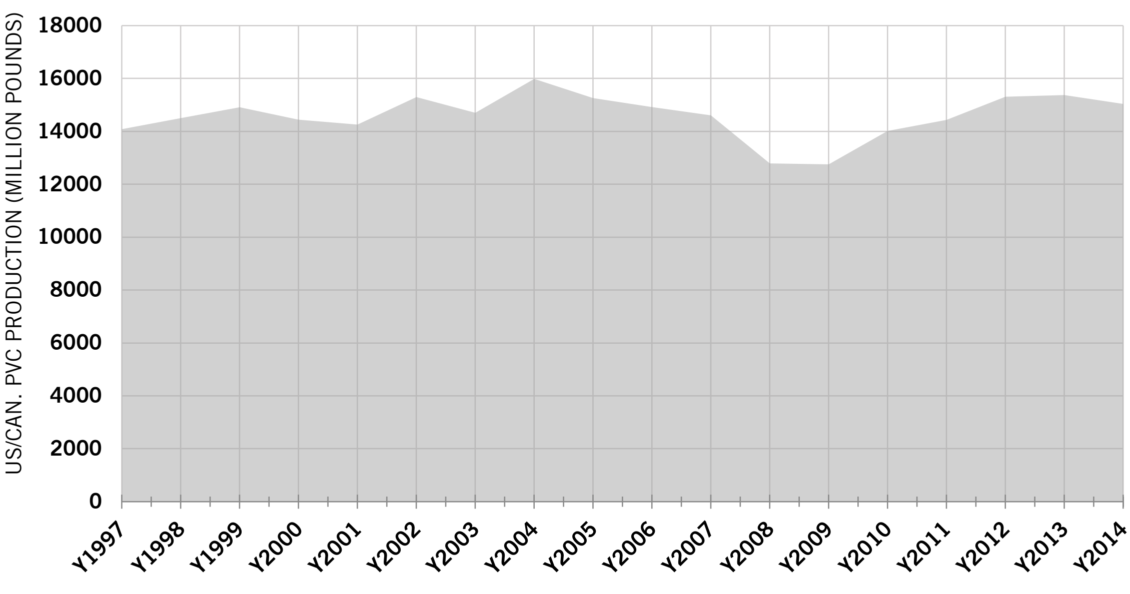
Note: PBS has made the full 90- minute Trade Secrets program available on its website for viewing: http://billmoyers.com/content/trade-secrets/

WHAT ARE THE HEALTH HAZARDS ASSOCIATED WITH PVC?

A. HAZARDS DURING SYNTHESIS

In rebuttal, the Vinyl Institute, a PVC industry trade association, has asserted repeatedly that as they relate to PVC production, dioxin emissions are miniscule, and that VCM emissions are largely a problem of the past.[48,49,50] A recent article from the Institute states that the industry has achieved, "an 82% reduction in dioxin emissions since 2000.... To add context to these numbers, the U.S. vinyl industry emits about 6 to 7 grams of dioxin per year, equivalent in weight to about 100 grains of salt."[51]

Figure 2. North American PVC Production 1997 – 2014[52]

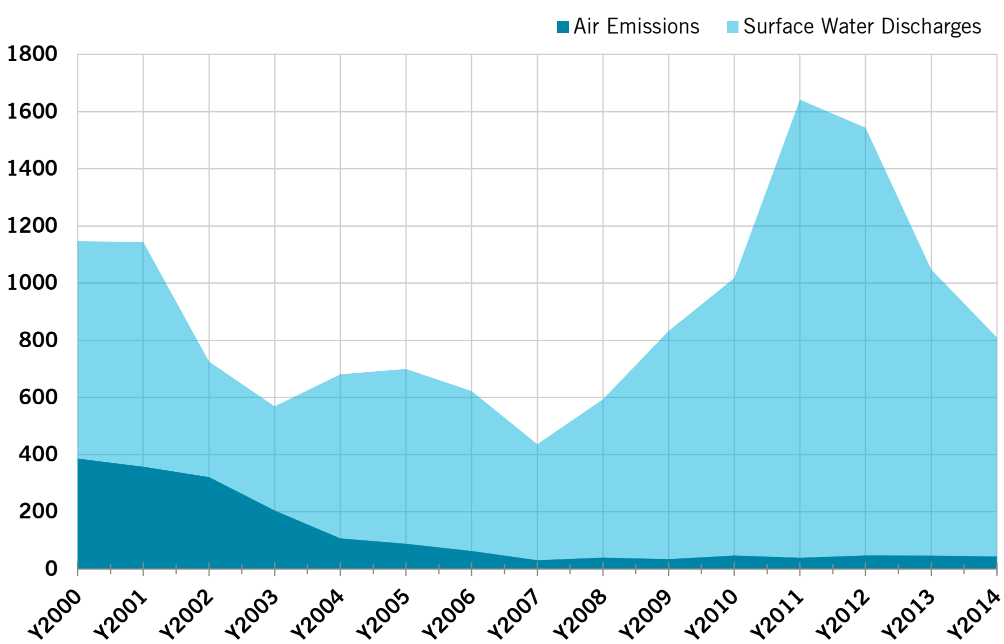


However, an examination of the data reported to the EPA by the PVC industry and its supply chain reveals a different story.[i] EPA first required the PVC industry to report any dioxin emissions over 0.1 grams per year beginning in 2000.[53] In the time since, production of PVC in Canada and the United States has been virtually flat (*See Figure 2*). Despite this, releases of dioxins and dioxin-like compounds

i Facilities included in Appendix C and D of this report produce chlorine used in the synthesis of vinyl chloride monomer (VCM), produce vinyl chloride monomer, and/or produce PVC resin. Most facilities were identified in industry submissions to the US EPA in response to the agency's development of National Emission Standards for Hazardous Air Pollutants for Polyvinyl Chloride and Copolymers Production and in EPA reviews of water effluent discharges from facilities that manufacture chlorine, VCM and PVC. [See Environmental Protection Agency, "Chlorine and Chlorinated Hydrocarbon Data Collection and Analysis Summary," February 2012, accessed October 2015, http://water.epa.gov/scitech/wastetech/guide/cch/upload/cchreport.pdf] Healthy Building Network excluded chlorine plants that primarily supply the pulp and paper industry, rather than PVC.Reported dioxin releases at these facilities were collected for each year beginning in 2000, the first year that EPA required dioxin reporting by these facilities. (Appendix E details vinyl chloride monomer releases, dating back to 1987, the first year of any reporting to the Toxic Release Inventory, or TRI).

from manufacturers of vinyl chloride and PVC, and the chlorine plants that supply the industry, have not declined overall. In the past five years (2010-14), these factories released on average, 1,212 grams of dioxin and dioxin-like compounds annually into the air and water—more than the 1,146 grams released in 2000 (*See Figure 3, Appendix C*). This is far higher than the "6 to 7 grams of dioxin per year" asserted by the Vinyl Institute.[j]

Figure 3. Total Dioxin Releases to Air & Water by PVC Manufacturers and Supply Chain (grams/yr)



In addition to air and water, the PVC industry disposes of dioxin wastes in underground wells and off-site landfills. These disposal methods have increased considerably since 2000. In the last five years, on average, the PVC production chain disposed of 33,152 grams (or 33 kilograms) of dioxin and dioxin-like wastes through these methods, more than twice the amounts reported in 2000 (12,040 grams).[k]

j The Vinyl Institute does not provide an explanation of how it calculated 6-7 grams of dioxin released each year, beyond that it was derived from TRI data. The Vinyl Institute declined to provide HBN with a list of facilities they researched within the TRI. (Personal communication, Richard Krock, Technical Director, Vinyl Institute, October 6, 2015)

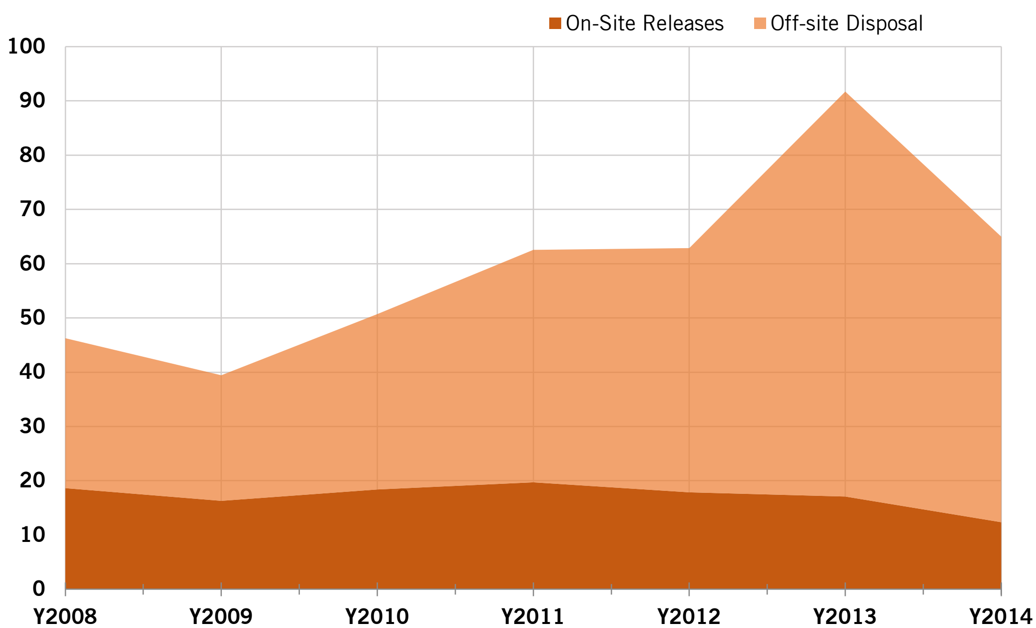
k See Appendix C for data.

WHAT ARE THE HEALTH HAZARDS ASSOCIATED WITH PVC?

A. HAZARDS DURING SYNTHESIS

To ensure that this discrepancy was not biased by the potency of different dioxins, a comparison was also made of the PVC trade association's claims against data reported to the EPA by actual PVC factories using grams TEQ, a measure that factors in potency.[l] While a 2013 paper authored by the Vinyl Institute states that the industry released between 6.8 and 7.9 grams TEQ of dioxin to air and water, between 2007 and 2011,[54] an examination of US EPA Toxic Release Inventory (TRI) data submitted by facilities producing PVC and its feedstocks again reveals much higher figures (*See Figure 4*). In on-site releases to air and water, alone, the industry has been releasing between 12 and 19 grams TEQ of dioxin annually. In addition, the industry has been disposing of increasing amounts of dioxin offsite ranging between 21 and 75 grams TEQ of dioxin per year. In 2013, total on- and off-site releases spiked at 91.7 grams TEQ—or more than 1,000% higher than the Vinyl Institute claims.

Figure 4. Dioxin Emissions in TEQ at PVC and Feedstock Facilities[m]



l TEQ - Toxic Equivalency - All dioxins and furans (dioxin-like compounds) are toxic in very small quantities, but the different types have widely ranging toxicity factors varying by several orders of magnitude. The 2,3,7,8-TCDD molecule is the most potent of all the dioxins measured to date and is used as the baseline for comparison. Measurements of the varying mixtures of dioxin-like compounds released by different facilities are made comparable by use of a factor called Toxic Equivalency which compensates for the differences in relative potency.

m Total dioxin releases, in TEQ grams, per year. See Appendix D for data.

Until 2015, the US EPA had not restricted the PVC industry's dioxin or dioxin emissions. In 2003, Earthjustice, a nonprofit environmental law organization representing the Sierra Club and Mossville Environmental Action Now, filed a suit demanding that the EPA limit PVC industry emissions. They charged that the US EPA "has failed to require any reduction in current toxic emissions from PVC facilities" and sued the agency for "failing to protect communities and the public from toxic air pollution."[56]

According to Earthjustice,

"The Clean Air Act requires the Environmental Protection Agency to set emission standards for each hazardous air pollutant PVC plants emit. But in 2002, the Bush EPA decided to set standards for just one: vinyl chloride. This left plants' emissions of dioxins, chromium, lead, chlorine, and hydrogen chloride—substances associated with a wide variety of serious adverse health effects including cancer—entirely unchecked."[57]

After over a decade of rulemaking,[58] EPA issued a new rule on PVC industry emissions on February 4, 2015.[59] The final rule establishes new air emission limits for dioxins, furans, vinyl chloride, and hydrogen chloride. It also established limits on vinyl chloride monomers in PVC resins.[60] The rule may result in some reductions in emissions, and will not eliminate the problems of dioxin and vinyl chloride releases from this industry. For example, the new limits on dioxin emissions have been set at the rate at which most facilities currently emit dioxin. The agency noted, "We estimate that ten out of 13 sources for which we have data are able to meet the emission limits without additional control."[61]

Furthermore, this new rule does not extend to water releases from PVC resin manufacturers, or to VCM or EDC manufacturing operations, which are often co-located with these facilities.[62] As shown in Figure 3 above, the water releases of dioxin are already a much larger contributor to environmental burdens than the air emissions.[63,64]

Hazardous Emissions from PVC

As discussed above, the manufacture of PVC results in the emission of vinyl chloride monomer (VCM) and dioxins.

A review of Toxics Release Inventory reports provided to the US EPA by facilities making PVC or its feedstocks (*see Appendix D for more detail*) found the following:

In 2013 alone, total on- and off-site releases of dioxin equivalent (TEQ) spiked at 91.7 grams—more than 1,000% higher than the amount of dioxins the Vinyl Institute claims the industry is responsible for.

Dioxins are highly potent carcinogens that persist in the environment for many years.[65] To put these releases in context, EPA advises that children should not have more than one nanogram of the dioxin 2,3,7,8-TCDD per liter of water (ng/L) (parts per trillion) in one day, or more than 0.01 ng/L per day for long-term exposure.[66] A nanogram is equal to one billionth of a gram. Therefore the 91.7 grams of TEQ released in 2013 is enough to pollute 25 billion liters of water daily beyond the EPA established safety limits for long-term exposure.

Dioxins are one of a small set of the most persistent and bioaccumulative toxicants known to humanity that are subject to global treaty: the Stockholm Convention commits all signatory countries, of which the U.S. is one, to reduce activities which produce significant quantities of these dangerous substances.[n]

In 2014 alone, vinyl chloride monomer and PVC manufacturers released 531,203 pounds of VCM into the air.

As discussed previously, vinyl chloride monomer is a human carcinogen, capable of impacting human health even in very small amounts. The Occupational Safety and Health Administration established that workers should not be exposed to VCM at levels exceeding 1 part per million when averaged over an 8 hour work day.[67] By this metric, the 531,203 pounds of VCM released in 2014 could be dispersed in a space more than 30,000 times the volume of the Dallas Cowboys AT&T Stadium, and VCM concentrations in the air would still exceed this OSHA limit.[o]

Beyond production emissions, the precursors of PVC are often shipped to and from various industrial sites. In 2012 a freight train carrying four tankers of VCM derailed in Paulsboro, New Jersey. The walls of one of the tankers were ruptured in the incident, "sending thousands of gallons of the carcinogenic vapor into the atmosphere." Twenty-seven blocks around the tanker had to be evacuated in an effort to protect residents from VCM exposure. One week after the leaking tanker had been cleaned up, residents closest to the accident site were still unable to return to their homes.

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n The Stockholm Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from the most harmful of PBT chemicals. It was adopted by the Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden and entered into force on 17 May 2004. The United States is one of the 152 signatory countries, but Congress has not yet ratified (all but 6 other countries have). See http://chm.pops.int/

o Calculated as follows, where 1 m3 = 35 ft3 and 1 lb = 453592 mg:
531,203 lbs VCM = ~241 billion mg)
AT&T stadium volume = 104 million ft3 (~ 2.9 million m3)
OSHA limit = 1ppm (2.6 mg/m3)
Concentration of VCM when released into 1 stadium: 241 billion mg/3 million m3 = ~80,000 mg/m3
Number of stadium spaces required to achieve OSHA limit: 80,000mg/m3 / 2.6 mg/m3 = 30,769
[AT&T specs available at http://stadium.dallascowboys.com/assets/pdf/mediaArchitectureFactSheet.pdf]

B. HAZARDS FROM PERFORMANCE ADDITIVES

The primary hazards associated with the use phase of PVC products (risks posed to occupants, installers, or users) come from the additives incorporated into the resin to give it specific performance properties. PVC is thermally unstable and will self-degrade in ultraviolet light[70] (a component of sun light) so both flexible and rigid PVC products must be stabilized with chemical additives at high concentrations (typically 4% by weight).[71] Traditionally these heat stabilizers have been based on known hazardous ingredients[72] (lead or cadmium).[73]

Because it is inherently brittle, PVC also requires plasticizers to make it flexible—a necessary attribute for sheet resilient flooring, window roller shades, or roofing membrane, for example.[74] Until recently, virtually all PVC-based flexible building products used plasticizers selected from a family of chemicals called phthalates.[75] As a family, phthalates have also been identified on the Perkins+Will Precautionary List,[76] and individual phthalates may be asthmagens[77] (meaning, they can cause the onset of asthma as opposed to simply triggering an asthmatic response in those who already have the disease). The amount of phthalate added to a PVC formulation varies depending on end use,[78] but can be as high as 50% of the final compounded product.[79] There is a growing trend among PVC product manufacturers to replace phthalates with a number of other plasticizers.[80] A recent Healthy Building Network report has examined these alternatives and determined that all are superior to phthalates from a human health perspective and many from an environmental standpoint as well. However, the level and results of toxicity testing vary among the six non-phthalate formulas found now in use.[81] Significantly, plasticizers can be avoided entirely by using many of the non-PVC materials instead.

Certain uses of PVC product applications also require the addition of chemical flame retardants.[98] In the 1970s toxic[99] polychlorinated biphenyls (PCBs) were added to PVC for flame retardancy,[100] but have since been replaced with antimony trioxide or bis(2-ethylhexyl) tetrabromophthalate (TBPH).[101]

Antimicrobials can also be present in PVC building product formulations, either intentionally[102] or through the use of recycled PVC content.[103] **Appendix B** provides a list of biocides that may be found in recycled PVC feedstocks.

What are Phthalates?

A "phthalate" (pronounced "thall-ate") is a chemical compound formed by reacting a phthalic acid with an alcohol.[82] Many chemicals fit this description, but generally the term "phthalate" is used to refer to orthophthalates, a subset of chemicals commonly used as plasticizers.[83] Phthalates are generally referred to by shortened abbreviations, and, challengingly, can be known by more than one name and sometimes share the same CAS number[p] or have multiple CAS numbers.[84]

DEHP (di-2-ethylhexyl phthalate) was the first commonly used phthalate that raised concerns about human health effects.[85] It is listed as a probable human carcinogen by the US EPA, and is associated with reproductive and developmental hazards by multiple agencies and authoritative bodies.[86] It is also marked for restriction under the European Union's REACH chemical regulation system.[87] Many manufacturers replaced DEHP with a similar compound, DINP (di-isononyl phthalate)—the primary plasticizer used in PVC—but DINP is also listed under California's Proposition 65 as a carcinogen,[88] and evidence is emerging that DINP may impact endocrine systems.[89,90]

In 2009 the President's Cancer Panel reported that,

"Phthalates inhibit normal binding to estrogen receptors and suppress male androgens. In girls, phthalates may cause early puberty and higher breast cancer risk later in life.... Male fetuses in the first trimester of pregnancy appear to be particularly vulnerable to damage by phthalates, which may cause undescended testicles, hypospadias, and possibly higher testicular cancer risk. In humans, phthalates have been linked to problems with sperm count and sperm quality, and...are a suspected breast carcinogen." [91]

As discussed in this paper, many manufacturers are moving to replace phthalate plasticizers in PVC formulations with alternative additives. In 2014 Healthy Building Network reviewed six such alternatives used in vinyl building products at the time and concluded that non-phthalate plasticizers presented fewer human health hazards than phthalates.[92] While all plasticizers—phthalate or not—will migrate from PVC products into living spaces,[93] some phthalate-free plasticizers raise fewer concerns than others. Two non-phthalate plasticizers came out on top in the analysis: Acetylated monoglycerides of fully hydrogenated castor oil (abbreviated COMGHA) and isosorbide diesters were deemed to be well studied, and the least toxic of the six substances reviewed.[94]

One of the plasticizers reviewed in this 2014 report was a terephthalate rather than an orthophthalate: DEHT (di-(2-ethylhexyl) terephthalate), promoted as an alternative plasticizer for PVC.[95] While data are sparse as to whether terephthalates as a class are an improvement over orthophthalates, a review of this particular substance under the GreenScreen[96] system for chemical assessment rates it as significantly better than orthophthalates reviewed with the same criteria.[97]

p A CAS number is an identifying number assigned to many chemicals and materials used in commerce by the Chemical Abstract Service. See the Chemical Abstract Service's FAQs at https://www.cas.org/content/chemical-substances/faqs for more information.

Beginning with the derivation of chlorine gas from salt, up until the finished PVC resin is compounded with its particular additives, the processes and direct ingredients required for PVC chemistry present hazards to workers in plants and to nearby residents, especially in the event of a spill or similar release.[104] These "fenceline communities" are often communities of color or low-income[105,106] and are already facing hurdles to health-sustaining conditions.[q]

MOSSVILLE, LOUISIANA: A FENCELINE COMMUNITY PROFILE

Mossville is an historic African American community in southwestern Louisiana surrounded by 14 industrial facilities.[107] The US Agency for Toxic Substances and Disease Registry (ATSDR) has been investigating residents' exposures to dioxins since 1998.[108] In a 2006 follow-up study, it found that most of the older participants in the follow-up exposure investigation had "higher-than-expected blood dioxin concentrations" compared to the general U.S. population. During environmental sampling, the agency also found that many fish samples "exceeded the Food and Drug Administration's action level" for dioxin.[109]

The area is in "extreme proximity" to "the largest concentration of vinyl production facilities in the U.S.," notes a 2007 report prepared by Mossville Environmental Action Now, The Subra Company, and Advocates for Environmental Human Rights.[110] The authors noted in particular the similarity between the types of dioxin emissions reported by Georgia Gulf, which produces vinyl chloride monomer, and the types of dioxins found in residents' blood. "Mossville residents have average dioxin levels in their blood that is three times higher than the national comparison group, which ATSDR deems is representative of the U.S. population," according to the authors. "In addition, the dioxin compounds detected in Mossville residents' blood are a unique group that is different from that of the national comparison group."[111]

Since 2007, Georgia Gulf (now part of Axiall Corp.) has released, on average, 0.44 grams of dioxin per year into the air, only slightly less than the 0.48 grams the company reported releasing, annually, into the air, from 2000 to 2006.[112]

Another source of dioxin and other pollution in the Mossville area[113] is the South African chemical company Sasol. Last year the company offered to purchase the entire town as a buffer zone for a new $21 billion industrial complex.[114]

In 2014, a panel discussion at Greenbuild (the world's largest conference and expo dedicated to green building, according to the US Green Building Council) featured residents of the Mossville community. When asked what the audience of architects and designers could do to address the situation, residents simply suggested that they not buy vinyl products.[115]

q A 1994 Executive Order signed by President Clinton committed federal agencies to the development of a strategy to address Environmental Justice, which it defined as "disproportionately high and adverse human health or environmental effects on minority populations and low-income populations."

C. HAZARDS FROM RECYCLED CONTENT

While conventional wisdom suggests that it would be beneficial to replace virgin PVC with recycled content (and some PVC product manufacturers have made considerable investments to do so), in an ironic twist, it is the recycled PVC—the reuse of old vinyl floors, siding, and wiring in new products—that is a major pathway for hazardous materials to be incorporated into new products.[116] When post-consumer recycled PVC products were originally compounded with traditional additives (such as lead or cadmium stabilizers, phthalate plasticizers, or PCB flame retardants), those additives now found in the recycled feedstock become a toxic legacy that continues into new vinyl products.[117] PVC products made with post-consumer recycled content may have much higher levels of hazardous ingredients in them—including many ingredients that wouldn't necessarily be in a virgin product today—due to the contaminants found in the recycled feedstock.[118]

To underscore this issue, in 2014/2015, the non-profit Ecology Center, Ann Arbor, Michigan, conducted x-ray fluorescence (XRF) tests on 74 vinyl floors made by eight different manufacturers and purchased from six different retail chains. The tests revealed that while the surface layer of the floors contained virgin PVC, with an expected composition of ingredients for a resilient floor, the core of the floors was made with recycled PVC and displayed a very different composition. The Ecology Center found a mix of heavy metals in the recycled PVC that suggested wire and cable scrap had been used to fill the cores. The test also revealed lead levels consistently much higher than those found in the surface layer (virgin material). One sample core[r] lead level was more than 220 times higher than the amount of lead found in the virgin PVC layer.[119]

Appendix B provides a full list of contaminants that may be found in post-consumer PVC. The role of recycling in perpetuating exposures to PVC additives is further discussed in the next section of this paper.

Additives also pose a problem during the use phase of vinyl products. Plasticizers, for example, are not tightly bound to the PVC resin,[120] so over time work their way out of the plastic and collect in household dust that can be ingested,[121] or may be directly absorbed by bare hands and feet. As discussed above, the class of plasticizers typically used in PVC, phthalates, affect the body's hormonal systems and have been associated with infertility,[123] obesity,[124] and birth defects.[125] In August 2015 the publication Consumer Reports recommended that parents err on the side of caution with regard to phthalate exposure, and "wet-mop the floor often and wash children's hands after the little ones have been crawling on a vinyl floor."[126]

r No research on potential heavy metal exposures from the degradation of PVC floors containing recycled content in the inner layer specifically has been identified, however a logical concern is that when floors are damaged, the contents of the inner layer become exposed. The inner layer flooring may reach the surfaces upon which children crawl, and in dust that travels through the air. This is particularly of concern in low-income housing where less expensive flooring (with less wear layer thickness) is likely more common.

In 2015 the Ecology Center conducted an extensive follow-up XRF analysis on the surface layers of resilient flooring. The group analyzed the composition of the surface layers of 65 vinyl floor tiles representing 11 different brands and purchased from five different retailers across seven states.[127] The Ecology Center summarized their findings in a press release, stating:

"Most vinyl tile flooring samples tested contained one or more hazardous chemicals. Fifty-eight percent of vinyl flooring tiles tested contain phthalate plasticizers, which are hazardous and are subject to a pending ban in the European Union. Moreover, almost all (89 percent) of vinyl flooring samples tested contained organic tin-based stabilizers. Over half of the samples tested contained multiple plasticizers." [128]

Stabilizer additives are also loosely bound to the PVC and leach out of the plastic.[129] In the late 1990s press releases from the North Carolina Department of Environmental Health[130] and Health Canada[131] sounded the alarm about the potential for lead poisoning in young children following the installation of PVC mini-blinds that included lead compounds. Health Canada warned that the lead exposure from these mini-blinds, "may result in a daily intake of lead by children which is greater than the World Health Organization's tolerable level."[132] Parents were urged to remove the products from their homes to reduce potential exposure.

PVC products also present additional hazards to occupants, emergency first responders, and community residents during a building fire.[133] Although the vinyl industry often touts the fire-resistant properties of the chlorine content in PVC,[134] the resultant smoldering creates a deadly mixture of toxic gasses.[135] When burned, PVC creates carcinogenic dioxins, a mist of corrosive hydrochloric acid, and thick smoke.[136] For this reason, firefighters have provided testimony at policy hearings where agencies or governments are seeking to restrict the use of PVC,[137,138] citing the unique exposure burden carried by first responders.

"Exposure to a single PVC fire can cause permanent respiratory disease… Due to its intrinsic hazards, we support efforts to identify and use alternative building materials that do not pose as much risk as PVC to fire fighters, building occupants or communities."

Richard M Duffy, International Association of Fire Fighters[139]

D. HAZARDS DURING DISPOSAL/RECYCLING

After a vinyl product has reached the end of its useful life and is disposed of, the toxic inputs that presented hazards during the synthesis of PVC again present hazards to workers and fenceline communities.[140]

The Worldwatch Institute has estimated that PVC is the source of 80% of the chlorine that flows into municipal waste incinerators.[141] Because PVC is a chlorinated plastic, when incinerated, the chlorine is released to form dioxins[142]—the same potent carcinogens that were also created when PVC precursors were being synthesized.[143] Even the vinyl industry stipulates that:

"Through complete combustion, PVC can be broken down into water, carbon dioxide and hydrogen chloride. However, complete combustion is rarely feasible in reality, and dioxins can be unintentionally generated as by-products according to incineration conditions." [144]

The disposal alternative to incineration is landfilling. Construction and demolition (C & D) wastes are both the previously installed materials removed from a building following a demolition or renovation, and the scrap materials left over after new products are installed. Exactly what constitutes C & D waste varies by state, but EPA recognizes "vinyl siding, doors, windows, flooring, pipes and packaging" as a typical portion of this waste. These wastes may end up in C & D specific landfills, or in municipal landfills with household trash.[145]

However, landfilling PVC doesn't necessarily protect it from incineration. While statistically uncommon compared to other types of fire, a rather large number of landfill fires still do occur. The US Fire Administration estimates that 8,400 fires occur at dumps and landfills each year (an average of 23 fires per day), and acknowledges that this estimate may be low due to fires that go unreported.[146] Landfill fires in which PVC is burned exposes people living nearby to dioxins and other pollutants.[147]

"Landfill fires threaten the environment through toxic pollutants emitted into the air, water, and soil.... There can be great difficulty in the detection and extinguishment of landfill fires, which is compounded because these fires often smolder for weeks under the surface of the landfill before being discovered."

US Fire Administration, May 2002 [148]

This smoldering behavior of the PVC content in landfills makes these fires some of the most potent producers of dioxins of all sources.[149] The EPA Dioxin Inventory estimates that landfill fires may generate more dioxin than any other source.[150]

Traditionally, PVC has not been considered a recyclable material, and in fact was identified as a contaminant to plastic bottle recycling efforts.[151] The reality of PVC, until quite recently, was that it could not be recycled, only "down-cycled."[152] Rather than the recycling model most familiar to the public where, for example, an aluminum can is melted down and recast as a new aluminum can multiple times,[153] down-cycling refers to a situation where the material in question cannot be recast with its original qualities. Instead, it will become a less valuable item with each iteration. For example, PVC flooring could be downcycled into a traffic cone, but could not be recast into a new flooring product.[154]

The reality today is more nuanced. Only one percent of PVC is recycled,[155] and while its highly variable chemical composition still prevents it from being in a true recycling cycle[156]—such as in the example of the aluminum can—recycled PVC is now making its way into higher quality products in small amounts, and often as filler material rather than as the primary material.[157]

The majority of PVC products that do get recycled are sent to China,[s] where PVC is collected from a variety of sources and previous uses, and commingled into one waste stream. This is a place where untrained, unprotected, and low-wage workers sift through the scrap by hand.[158] Some PVC products are burned in open pits to remove the plastic and collect any valuable metals that may have been inside.[159] These open pits where PVC is burned also create dioxins.[t]

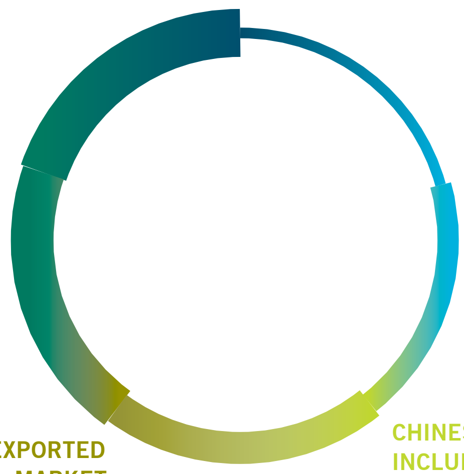
Furthermore, during the recycling process, the toxic stabilizers, phthalates, and other additives compounded into the PVC are released into the ambient air,[160] potentially exposing workers and those living nearby.

s "The leading processor in the world is China, which handles an estimated 82% of the United States' PVC waste scrap exports." See discussion in Jim Vallette et. al. Post-Consumer Polyvinyl Chloride in Building Products, July 2015, http://healthybuilding.net/uploads/files/post-consumer-polyvinyl-chloride-pvc-report.pdf

t This type of open uncontrolled burning is the most potent source of dioxins per ton burned, comparable to a primitive low technology incinerator producing dioxins at many orders of magnitude the rate of a higher technology incinerator with a pollution control system. See also http://toolkit.pops.int/Publish/Main/II_01_Waste.html

Market Advancement

Figure 5. Global Cycle of PVC Recycling[161]



In response to many of these critiques of PVC, the vinyl industry has been working to reformulate many consumer products. European vinyl manufacturers stated in 2013 that more than 80% of lead-based stabilizers had been phased out of their formulations, and that the industry was working toward phasing them out completely "soon."[162] One type of stabilizing compound replacing lead is based on the metal tin.[163] Sometimes referred to as "organotins," this group of substances is noted under the OSPAR convention, the mechanism by which 15 governments and the EU cooperate to protect the marine environment of the North-East Atlantic, as persistent bioaccumulative toxics (PBTs).[164]

Similarly, building product manufacturers have begun to offer phthalate-free PVC product lines. In 2014 Healthy Building Network reviewed many of these products to better understand what phthalate alternatives were being used as plasticizers, and how the health and environmental profiles of those substances compared to diisononyl phthalate (DINP), the primary phthalate used to make PVC flexible.[165] HBN found six phthalate alternatives being used in building products currently on the market, two of which were bio-based (derived wholly or in part from plants).[166] Many of these alternative plasticizers were found to be improvements over DINP and other phthalates, but gaps in available data, according to the study, make definitively assessing them as "safe" impossible.[167]

A. RETAILERS TAKE NOTICE

Reflecting the new reality that vinyl products can be plasticized in apparently preferable ways, building product retailers have begun enacting purchasing policies that restrict the presence of phthalates in vinyl flooring. In April 2015, Home Depot announced a corporate policy to require all suppliers to phase out the use of ortho-phthalate plasticizers by the end of 2015.[168] Lowes also announced a ban on ortho-phthalates in virgin vinyl products in April 2015,[169] followed by Menards in July 2015. Collectively, these three retailers represent the top three home improvement chains in the U.S.[170]

Table 2. Recent Policies to Clean up PVC

Policy Maker	Takes Effect	Restrictions for Virgin PVC	Restrictions for Recycled PVC
RETAILERS			
Home Depot[174]	Dec 31, 2015	Phase out of orthophthalates	None
Lowes[175]	Dec 31, 2015	Phase out of orthophthalates	None
Menards[176]	Dec 31, 2015	Phase out of orthophthalates	None
MANUFACTURERS			
Tarkett[177]	2009 in some product lines; 2014 on all product lines	Phase out of orthophthalates	No post-consumer recyclate used in Europe; only post-consumer VCT accepted in the US
Armstrong[178]	2009	None	Only accepts post-consumer recyclate from PVC previously used in flooring
Interface[179]	2009	None	Only accepts post-consumer recyclate previously used in carpet backing

While none of these retailers directly address phthalates that may be present as legacy contaminants in recycled PVC, manufacturers are apparently concerned about the vulnerability posed by using uncontrolled recycling feedstocks (*see Table 2*).

As an example, some major manufacturers of PVC resilient flooring are proactively reducing phthalates in their products:

Tarkett, with vinyl flooring production plants in the U.S. and elsewhere, has taken an aggressive position on phthalates in their products: a 0.1% threshold. To achieve this, the company has not only phased out the use of the plasticizers in virgin PVC, but also restricted the use of recycled content in those products that may reintroduce the chemicals through contaminated feedstocks. Tarkett's European plants do not use any post-consumer recycled PVC, and restrict the use of post-consumer recycled PVC from its Asian suppliers. In America, Tarkett does use some post-consumer PVC to make its products, but the scrap comes from vinyl composite tiles (VCT) rather than vinyl sheet flooring, and therefore includes much less plasticizer.[171] Tarkett's restriction of post-consumer PVC is an acknowledgement that beyond phthalates, recycled PVC is host to unknown contaminants that the company does not want included in its products.[172]

Resilient flooring manufacturer Armstrong also uses only post-consumer recycled PVC that was previously used for flooring. Similarly, carpet company Interface uses only PVC that was previously carpet backing to make its new carpet backings.[173]

B. PUTTING NEW PVC FORMULATIONS INTO CONTEXT

Significantly, these new advances remedying the problem of historically toxic additives does not address the previously outlined hazards that PVC poses to workers and fenceline communities during the synthesis of its component parts. Nor does it entirely address the hazards traditionally generated at the end of its life previously discussed. PVC waste streams will continue to include toxic additives for some time. As noted, virtually all of the PVC products manufactured today eventually make their way to be landfilled or incinerated, and incinerating vinyl produces carcinogenic dioxins.

The health and environmental impacts tied to the use of PVC are significant and to some degree product-specific. **Table 3** summarizes the major issues raised in this paper, and identifies which hazards have been avoided through the reformulation of vinyl additives and which have not.

Table 3. Hazards Associated With Traditional and New Formulations of PVC[u]

Hazard (Phase of life)	Effect	Impacts	"Old Vinyl"	"Reformulated Vinyl"
Requires chlorine	Very toxic to aquatic systems; listed as developmental toxicant, respiratory sensitizer/asthmagen, mammalian toxicant[180]	Workers, Fencelines communities	X	X
Requires ethylene dichloride (synthesis)	Carcinogen; gene mutation; flammable[181]	Workers, Fenceline communities	X	X
Requires vinyl chloride monomer (synthesis)	Carcinogen; mutagen; reproductive toxicant; mammalian toxicant; organ toxicant[182]	Workers, Fenceline communities	X	X
Releases mercury (synthesis)	PBT; developmental toxicant; reproductive toxicant; potential carcinogen; endocrine disruptor; mammalian toxicant; organ toxicant; skin sensitizer; aquatic and terrestrial toxicant[183]	Workers, Fenceline communities, Planet	X	X
Releases dioxins (synthesis, accidental fire, end of life)	Dioxins as a category are associated with PBTs, reproductive toxicants, mutagens, mammalian toxicants, and aquatic toxicants. Individual dioxins may have other associated hazards, including carcinogenicity[184]	Workers, Fenceline communities, Planet, First responders	X	X

u Data for the "Effects" of each hazard is based on Healthy Building Network's Chemical and Material Library which cross references more than 37,000 chemicals and materials against 66 restriction and other reputable lists commonly used in chemical assessments. Hazards listed in Table 3 earn an orange flag or higher in the Library, and were accurate at the time of this report. For a full explanation of the Chemical and Material Library, see: https://pharosproject.net/uploads/files/library/Pharos_CML_System_Description.pdf.

Table 3. Hazards Associated With Traditional and New Formulations of PVC *(continued)*

Hazard (Phase of life)	Effect	Impacts	"Old Vinyl"	"Reformulated Vinyl"
Creates hydrogen chloride when burned (accidental fires, end of life)	Developmental toxicant; respiratory sensitizer; mammalian toxicant; eye and skin irritation; acute aquatic toxicity[185]	Occupants, First responders, Fenceline communities	X	X
Uses phthalates (during use, end of life)	As a family, phthalates are listed as a reproductive toxicant; DINP is listed as a carcinogen, developmental toxicant, and endocrine disruptor[186]	Workers, Fenceline communities, Occupants	X	
Uses non-phthalate plasticizers (during use, end of life)	No data available for proprietary plasticizers; health effects still unknown for others[187]	Workers, Fenceline communities, Occupants		X
Uses lead stabilizers (during use, end of life)	Lead is a PBT with a well-known impact on development; probable human carcinogen; reproductive toxicant; endocrine disruptor; mutagen; aquatic toxicant[188]	Workers, Fenceline communities, Planet	X	
Uses cadmium stabilizers (during use, end of life)	Cadmium is a PBT; carcinogenic to humans; developmental and reproductive toxicant; mutagen; mammalian toxicant; organ toxicant; aquatic toxicant[189]	Workers, Fencelines communities, Planet	X	
Uses organotin stablizers (during use, end of life)	Organotins categorically are considered PBTs. Individual substances within the category may have additional health considerations[190]	Occupants, Workers, Fenceline communities, Planet		X
Uses flame retardants (during use, end of life)	Health impacts of flame retardants vary significantly by type. Perkins+Will outlines these the hazards of flame retardants extensively in a 2014 report[191]	Workers, Occupants, Planet	X	X
Uses antimicrobials (during use, end of life)	Health impacts vary by compound used. Triclosan is a common additive - listed as a PBT, endocrine disruptor, and aquatic toxicant.[192]	Workers, Occupants	X	X

C. AVOIDING HAZARDS THROUGH MATERIAL SELECTION

Many healthier material options exist for the products that owners, architects, and designers have traditionally looked to PVC to fulfill. **Table 4** outlines common materials that can be used in place of PVC in the most common applications.

Table 4. Substitute Materials for Common PVC Building Components and Interior Finishes[v]

Primary Uses	Alternative Material	Description
Pipes & Plumbing	Cast Iron Concrete Copper HDPE PEX Polyproylene	Depending on the plumbing application, a variety of materials can be used to construct pipes for hot and cold potable water, as well as waste pipe and sanitary drains.
Window Frames	Aluminum Wood	Wooden and aluminum window frames are readily available in a variety of colors.
Resilient Flooring	Cork Linoleum Rubber	Cork and linoleum both source their primary ingredients from plants and natural minerals. Be sure to select a cork floor made without a PVC backing. While rubber flooring is based on styrene-butadiene chemistry and has a number of concerns, a 2009 evaluation of resilient flooring still indicated it as a preferred option over PVC.[193]
Carpet Backing	Polyvinyl Butyral (PVB)	Unlike similarly sounding polyvinyl chloride, polyvinyl butyral is not a chlorinated plastic and therefore avoids many of the lifecycle hazards associated with chlorine. PVB is a polymer primarily used in automotive safety glass, and can be recycled into carpet backings.
Wallcoverings	Textiles Polyethylene	Fabrics offer an alternative to PVC wallcoverings. Xorel, made by Carnegie Fabrics, features a polyethylene fabric made from sugar cane rather than petroleum.
Wall Protection	Aluminum Bio-based Polymers Stainless Steel	Metal sheeting and plates offer a simple alternative to wall protection, while some corn-derived polymers are also entering the market.
Window Blinds and Shades	Textiles Polyethylene	When specifying fabric shades, avoid stain resistant, anti-static, or other surface treatments that may introduce unwanted hazards.

v Alternative materials identified in Table 4 were selected based on Healthy Building Network's review of individual products and materials commonly used in these products, September 2015.

As noted previously, all materials create some form of environmental and human health footprint, based on their raw materials, manufacturing processes, and incorporated ingredients. While this paper focuses on PVC and materials that can be used in its place for various functions in a building project, readers should be aware of unintentional trade-offs that may exist when selecting alternatives. When looking to replace a vinyl window treatment with a fabric one, for example, care should be taken to understand whether the fabric has been treated with any topical chemicals (stain resistant or anti-static treatment, etc.) which might introduce other problematic substances into the built space.

Conclusion

Perkins+Will first put PVC on its Precautionary List in 2008 because the weight of the evidence at that time suggested precaution, and market evidence suggested that in virtually every product category there were materials available that were superior from an environmental and human health perspective.

In light of recent industry shifts away from mercury cell production of chlorine, and heavy metal and phthalate additives, the authors of this paper have reexamined the issues and maintain the previous conclusion that, while improvements in product chemistry are real, the evidence suggests a continued precautionary approach. The fundamental hazards inherent in the chemistry of the material cannot be resolved: PVC remains a plastic based on chlorine chemistry. It will always require vinyl chloride monomer, produce dioxins during synthesis, accidental fires during use and in landfill disposal, and it will continue to present a hazard to building occupants, fire fighters, other first responders, and the local community during fires.

Is PVC necessary? The market suggests that for many applications of PVC, healthier alternative materials exist. In some instances, these alternatives may cost more, may have potential performance differences, and may have other environmental or health impacts, all of which become part of the decision-making that underpins the design.

At the end of the day, architects have a duty to advise their clients at least generally on attributes, effects, life-cycle performance, available alternatives, and costs associated with the use of building materials they specify. As a firm, Perkins+Will believes that the precautionary principle is an important tool that must be used in advising its clients. Therefore, even without scientific certainty, if competent evidence suggests adverse human health or environmental impacts may be associated with a certain substance, and a building material contains that substance or may release that substance during its useful life—the client should be made aware of that fact and other alternative materials may be presented for consideration.

Perkins+Will recognizes that there is much work to be done to both improve scientific understanding and to reduce the toxicity of the material economy that exists today, and applauds the PVC manufacturers who have examined stabilizers and plasticizers and have reformulated to reduce those hazards, and those who are attempting to minimize the recycled feedstock hazards.

A precautionary approach supports PVC remaining on the Precautionary List, and this topic will undoubtedly continue to be revisited as the manufacturing processes shift and other alternatives continue to be developed. This paper serves to inform dialogue and a greater call to action within Perkins+Will, and the design community at large to consider the life cycle human and ecological impacts of our material choices. These are complex issues that invite continued discourse and review that can only benefit from transparent reporting by manufacturers about their products. Perkins+Will remains committed to transparency in understanding and supports informed decision-making alongside the dedicated manufacturers, owners, and consultants who share our commitment to build a healthier environment and world.

Perkins+Will remains committed to open sharing of information, requesting transparency in materials reporting by manufacturers, and supports informed decision-making alongside the dedicated manufacturers, owners, and consultants who share our commitment to build a healthier environment and world.

Endnotes

Endnotes

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Appendix A
Additional Resources for Further Reading

Appendix A
Additional Resources for Further Reading

THE FOLLOWING PUBLICATIONS PROVIDE ADDITIONAL CONTEXT AND DISCUSSION OF PVC:

Post-Consumer Polyvinyl Chloride in Building Products, Healthy Building Network (2015)
http://healthybuilding.net/uploads/files/post-consumer-polyvinyl-chloride-pvc-report.pdf

Phthalate-Free Plasticizers in PVC, Healthy Building Network (2014)
http://www.healthybuilding.net/content/phthalate-report

Resilient Flooring & Chemical Hazards: A Comparative Analysis of Vinyl and Other Alternatives for Health Care, Healthy Building Network (2009)
https://www.healthybuilding.net/uploads/files/resilient-flooring-chemical-hazards-a-comparative-analysis-of-vinyl-and-other-alternatives-for-health-care.pdf

Sorting out the Vinyls - When is Vinyl Not PVC?, Healthy Building Network (2005)
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Appendix B
Substances of Concern in Recycled PVC Feedstock

ACRONYMS

PBT = Persistent Bioaccumulative Toxicant
SVHC = "Substances of Very High Concern" that are banned in the European Union, under REACH, unless authorized.
W&C - Wire & Cable.

APPENDIX B: SUBSTANCES OF CONCERN IN RECYCLED PVC FEEDSTOCK

Chemical (CAS RN)	Hazards	Function	Notes
		BIOCIDES	
10,10' - oxybisphenox-arsine (OBPA) (58-36-6)	PBT; Known human carcinogen; Developmental neurotoxicant	antimicrobial in plasticized PVC	See Hansen, 2014.
Diuron (330-54-1)	Known to cause cancer	biocide in roofing membrane	See Pharos Project, 2012
Triclosan (3380-34-5)	PBT; Endocrine disruptor	antimicrobial in carpet backing	"Should be assumed to migrate (from the product during use) but fairly slow... Judged to stay in the plastic by mechanical recycling" (Hansen, 2014)
		FLAME RETARDANTS	
Antimony trioxide (1309-64-4)	Known to cause cancer and reproductive toxicity	Flame retardant in plasticized PVC	"Plasticized PVC products contain flammable plasticizers and must be flame retarded. They contain a high enough chlorine content so that an additional halogen is usually not necessary, and in these cases 1% to 10% antimony oxide by weight is used" (US Antimony Corporation, 2013)
Bis (2-ethylhexyl) tetrabromophthalate (TBPH) (26040-51-7)	PBT; Developmental toxicant; Endocrine distruptor	Flame retardant; plasticizer	"In addition to its uses as a flame retardant, TBPH is also marketed as a plasticizer for flexible polyvinylchloride and for use in wire and cable insulation, film and sheeting, carpet backing, coated fabrics, wall coverings and adhesives (OEHHA, 2008)
Polychlorinated biphenyls (PCBs) (compound group)	PBT; Cancer; Developmental toxicant; Endocrine disruptor	legacy contaminant; formerly used as flame retardant in PVC wire and cable insulation	Largely phased out by 1978. "There may be a potential risk of exposure to PCBs in recycled-content PVC products that may contain PCBs as contaminants from old PVC coated wires or electrical components used as recycling feedstock. However, this occurrence has not been documented or quantified. This theoretical risk can be essentially eliminated by sampling and testing for PCBs in recycled PVC feed stock. Testing for PCBs in recycling efforts, especially those dealing with electrical wiring, is in some cases routine." (California EPA, 2006)
		PLASTICIZERS	
Benzyl butyl phthalate (BBP) (85-68-7)	SVHC; Clear evidence of adverse developmental toxicant effects; Toxic to reproduction; Endocrine disruptor.	common plasticizers	41% of BBP use is in vinyl flooring. (Hansen, 2014)
Di-2(ethylhexyl) terephthalate) (DEHP (117-81-7)	SVHC; Clear evidence of adverse developmental toxicant effects; Toxic to reproduction; Endocrine disruptor.	common plasticizers	"DEHP has for many years been one of the dominant plasticisers for flexible PVC and used in almost all kind of products made of flexible PVC." (Hansen, 2014)
Dialkyl(C7-11-branched and linear) phthalate (DHNUP) (68515-42-4)	Developmental and Reproductive toxicant	plasticizer in W&C insulation	See Hansen, 2014.
Dibutyl phthalate (84-74-2)	SVHC; Reproductive and developmental toxicant	plasticizer	"DBP has for many years been one of the dominant plasticisers for flexible PVC and used in many products made of flexible PVC." (Hansen, 2014)
Diisononyl phthalate (DINP) (28553-12-0 / 68515-48-0)	Known to cause cancer	plasticizer, often replacing DEHP	"All types of phthalate plasticisers will migrate from the soft PVC as they are not chemically bound and as they are fairly low molecular weight plasticisers.... Will migrate. Release rates by migration are probably in the range of 0.1-1% per year or below (estimate based on [ECB 2008]). Given sufficient time, a significant part of the substance will probably be released by leaching to the surface followed by evaporation or removal by washing. Tear and wear will also take place but be of minor importance. Judged to stay in the plastic by mechanical recycling. By feedstock [chemical] recycling... will be decomposed." (Hansen, 2014)

(CONTINUED ON NEXT)

APPENDIX B: SUBSTANCES OF CONCERN IN RECYCLED PVC FEEDSTOCK (continued)

Chemical (CAS RN)	Hazards	Function	Notes
		STABILIZERS	
Cadmium and cadmium compounds (7440-43-9)	PBT; Carcinogen; Developmental and Reproductive Toxicant	legacy UV stabilizer, widely used in rigid PVC	"Cadmium was the dominating UV-stabilizer in PVC-windows and doors up to the end of the 1980s.... Used mainly for outdoor purposes... After that time it was in Denmark replaced by lead stabilizers (again replaced by other stabilizers about the year 2000). ... Solid bound in plastics. release by wear and tear." Unlikely potential for consumer exposure due to low concentrations in the plastic. Will remain in plastic through mechanical recycling. (Hansen, 2014)
Dibasic lead phthalate (17976-43-1)	PBT; Reproductive and developmental toxicant	heat stabilizer	Present in cable up to 1% by weight. (US EPA, 2008)
Lead and lead compounds, including tribasic lead sulfate (multiple, including 12202-17-4)	SVHC; PBT; Cancer; Developmental neurotoxicant; reproductive toxicant	stabilizers; pigments, in PVC roofing membranes, W&C, pipes, windows & doors.	"Lead stabilisers are dominantly used for (PVC) pipes, gutters, outdoor products inclusive of windows and doors (and) electrical cables and wires... PVC producers in EU expect total substitution in 2015." (Hansen, 2014) Scientists have found that rigid PVC products are much less likely to release stabilizers than their flexible (i.e., plasticized), counterparts.... Metal-based stabilizers are not readily absorbed through the skin so casual dermal contact with building material surfaces is not expected to be a significant route of exposure. Metal-based stabilizers can, however, be absorbed once ingested, primarily by mouth or secondarily through hand-to-mouth contact, or when inhaled as particles. Circumstances where children have been exposed to lead-based stabilizers from contact with aged, higher lead content, imported mini-blinds have been documented." (California EPA, 2006) Present in cable up to 1.8% by weight. (US EPA, 2008)
Nonylphenol phosphite (3:1) (TNPP) (26523-78-4)	PBT, Developmental and Reproductive Toxicant; Endocrine disruptor	stabilizer; secondary antioxidant, in vinyl floorings	Used in PVC shower curtains, floorings and wall coverings. Release potential and consumer exposure are "possible, but likely to be low." Will decompose in chemical recycling process, "assumed to remain" through mechanical recycling. (Hansen, 2014)

ACRONYMS

PBT = Persistent Bioaccumulative Toxicant
SVHC = "Substances of Very High Concern" that are banned in the European Union, under REACH, unless authorized.
W&C - Wire & Cable.

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Table reproduced from Jim Vallette et. al., Post-Consumer Polyvinyl Chloride in Building Products, July 2015,
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Appendix C
TRI Data: PVC Facilities Reporting Dioxin Releases (2000-2014)

SOURCE: Data compiled from EPA Toxics Release Inventory by Healthy Building Network, October 2015

APPENDIX C: TRI DATA: PVC FACILITIES REPORTING DIOXIN RELEASES (2000-2014)

Facility Name	Parent Company	Location	Type of Facility	Dioxin Release Type	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
EAGLE US 2 LLC	Axiall Corp.	Lake Charles LA	Integrated	Air Emissions	0.601	0.777	0.525	0.523	0.532	0.521	0.273	0.55	1.14	1.14	1.33	1.33	1.33	1.33	1.3
Georgia Gulf	Axiall Corp.	Westlake LA	"petrochemical manufacturing"	Air Emissions	0.332	0.289	0.626	0.502	0.285	0.309	0.226	0.52	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Oxy Vinyls La Porte VCM Plant	Occidental Chemical Holding Corp	La Porte TX	Chlorinated HC (VCM)	Air Emissions	0.075	0.076	0.070	0.070	0.67	0.67	0.67	0.81	0.83	0.85	0.87	0.85	0.88	1.76	0.89
Oxy Vinyls LP Deer Park - VCM Plant	Occidental Chemical Holding Corp	Deer Park TX	Chlorinated HC (VCM)	Air Emissions	0.001	0.002	0.005	0.05	0.049	0.057	0.07	0.09	0.11	0.099	0.15	2.682	52.1	51.4	51.9
Occidental Chemical Corp	Occidental Chemical Holding Corp	Convent LA	Chlorine	Air Emissions	0.087	0.000	0.005	0.003	0.008	0.025	0.030	0.008	0.006	0.029	0.036	0.030	0.008	0.003	0.008
Sabic Innovative Plastics		Mt. Vernon IN	Chlorine	Air Emissions	0.261	0.28	0.26	0.35	0.350	0.350	0.371	0.351	0.462	0.441	0.42	0.4	0.41	0.44	0.47
Occidental Chemical	Occidental Petroleum	Niagara Falls NY	Chlorine	Air Emissions	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.012	0.015	0.032
Formosa Baton Rouge	Formosa Plastics Corp	Baton Rouge LA	Integrated	Air Emissions	22.529	22.000	23.733	19.138	18.762	16.759	16.059	15.696	26.637	25.186	16.395	52.000	60.000	58.000	61.000
Westlake Vinyls	Westlake Chemical Corp	Calvert City KY	Integrated	Air Emissions	0.718	0.698	0.679	0.599	0.619	0.546	0.637	0.636	0.62	0.62	0.59	0.591	0.58	0.57	0.5
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Air Emissions	0.032	0.045	0.037	0.059	0.053	0.028	0.040	0.040	0.038	0.055	0.020	0.033	0.048	0.051	0.052
Occidental Chemical	Occidental Petroleum	Ingleside TX	Integrated	Air Emissions	0.447	0.478	0.569	0.565	0.184	0.252	0.232	0.167	0.1	0.1	0.1	0.12	30.1	94.4	99.7
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Air Emissions	1.934	1.862	1.919	1.954	1.851	1.851	1.885	1.940	1.966	2.004	2.057	2.097	2.464	2.635	8.504
Shintech Inc.	C-K TECH INC	Plaquemine LA	Integrated	Air Emissions	0.122	0.050	1.182	0.003	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Air Emissions	2.277	2.313	2.283	2.152	2.100	2	1.913	2.107	1.982	1.958	1.919	1.623	1.660	1.470	1.610
Occidental Chemical Corp	Occidental Petroleum Corp	Wichita KS	Integrated	Air Emissions	NR	NR	NR	NR	NR	NR	NR	NR	NR	14.15	57.01	57.01	61.66	17.268	17.243
Dow Chemical	THE DOW CHEMICAL CO	Freeport TX	Integrated	Air Emissions	6.7	10.100	7.721	5.667	13.970	5.430	11.830	8	26	38.5	23.1	85.39	106.92	124.93	139.6
Axiall Corp.	Axiall Corp	Aberdeen MS	PVC	Air Emissions	0.000	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Air Emissions	0.005	0.005	0.005	0.005	0.005	NR	NR	NR	NR	NR	0.005	0.004	0.005	0.004	0.006
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Air Emissions	7.950	7.969	7.922	7.922	7.922	5.865	5.865	NR	2.874	2.874	2.874	0.259	3.09	3.162	3.162
			TOTAL	Air Emissions	44.070	46.945	47.544	39.563	47.360	34.664	40.102	30.916	63.245	88.487	107.357	204.900	321.747	357.918	386.457
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Underground Injection	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Occidental Chemical Corp	Occidental Petroleum Corp	Wichita KS	Integrated	Underground Injection	NR	NR	NR	NR	NR	NR	NR	NR	20.06	113.22	443.2	442.68	424.561	63.751	283.787
Dow Chemical	THE DOW CHEMICAL CO	Freeport TX	Integrated	Underground Injection	64.72	104.8	104.2	100.478	107.820	94.160	86.710	104	87	84.4	86.2	81	65	83.82	120.6
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Underground Injection	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.040	0.135
			TOTAL	**Underground Injection**	**64.72**	**104.8**	**104.2**	**100.478**	**107.820**	**94.160**	**86.710**	**104**	**107.06**	**197.62**	**529.4**	**523.68**	**489.561**	**147.611**	**404.522**

(CONTINUED ON NEXT)

APPENDIX C: TRI DATA: PVC FACILITIES REPORTING DIOXIN RELEASES (2000-2014) (continued)

Facility Name	Parent Company	Location	Type of Facility	Dioxin Release Type	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
EAGLE US 2 LLC	Axiall Corp.	Lake Charles LA	Integrated	Transfer Off-Site to Disposal	114.733	117.725	96.948	111.854	131.243	114.324	113.480	135.91	128.165	127.594	107.6	98.25	104.5	85.31	134
Georgia Gulf	Axiall Corp.	Westlake LA	"petrochemical manufacturing"	Transfer Off-Site to Disposal	0.101	0.728	0.289	0.627	3.362	0.934	52.084	NR	NR	NR	40.2	44.54	NR	NR	NR
Oxy Vinyls La Porte VCM Plant	Occidental Chemical Holding Corp	La Porte TX	Chlorinated HC (VCM)	Transfer Off-Site to Disposal	32326.056	34548.036	22587.823	21285.997	3221.030	4112.71	4103.42	53623.56	7066.41	2148.28	5534.26	7191.56	6753.65	13570.82	6381
Oxy Vinyls LP Deer Park - VCM Plant	Occidental Chemical Holding Corp	Deer Park TX	Chlorinated HC (VCM)	Transfer Off-Site to Disposal	NR	NR	NR	NR	0.000	0	0.000	23.42	0.14	32.98	0.03	NR	20.1	4.1	22.58
Occidental Chemical Corp	Occidental Chemical Holding Corp	Convent LA	Chlorine	Transfer Off-Site to Disposal	2.210	2.972	1.555	2.633	2.163	2.101	1.943	2.5	2.3	0.293	1.635	1.279	1.284	1.076	1.464
Occidental Chemical Corp	Occidental Chemical Holding Corp	Hahnville LA	Chlorine	Transfer Off-Site to Disposal	1.270	1.059	1.593	1.394	1.404	3.267	3.3	34.02	2.92	3.69	3.51	3.36	3	2.836	3.070
Occidental Chemical Corp	Occidental Petroleum	Mobile AL	Chlorine	Transfer Off-Site to Disposal							17.663	2.466	1.089	1.236	0.856	1.72	4.66	12.661	NR
Occidental Chemical Holding Corp	Occidental Chemical Holding Corp	Muscle Shoals AL	Chlorine	Transfer Off-Site to Disposal	NR	NR	NR	0.83	NR	0.648	24.479	5.3	6.64	3.32	1.9	12.45	1.55	5.331	0
Occidental Chemical	Occidental Petroleum	Niagara Falls NY	Chlorine	Transfer Off-Site to Disposal	0.46	0.36	0.430	0.330	0.330	0.371	0.425	0.576	0.503	0.502	0.43	0.49	0.38	0.044	0.47
Formosa Baton Rouge	Formosa Plastics Corp	Baton Rouge LA	Integrated	Transfer Off-Site to Disposal	18.395	17.78	16.055	12.797	NR	NR	NR	NR	11.7	11.6	22.3	532	600.000	492.001	380.003
Westlake Vinyls	Westlake Chemical Corp	Calvert City KY	Integrated	Transfer Off-Site to Disposal	4348	5924.176	2858.919	2478.791	2702.800	2082.703	2283.101	2324	1363	2068	2262	2326.5	1528.8	186.1	NR
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Transfer Off-Site to Disposal	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	2.322	16.139
Occidental Chemical	Occidental Petroleum	Ingleside TX	Integrated	Transfer Off-Site to Disposal	273.631	378.999	330.741	366.356	242.106	227.179	293.692	287.933	338.3	248.1	381	478.7	378.2	260	347.4
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Transfer Off-Site to Disposal	217.529	247.834	252.390	247.806	257.817	349.770	249.302	265.804	344.385	234.017	275.179	278.201	234.825	429.667	215.750
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Transfer Off-Site to Disposal	NR	123.317	110.559	121.942	102.261	96	94.799	100.566	94.993	112.951	120.930	161.339	126.193	173.292	133.567
Occidental Chemical Corp	Occidental Petroleum Corp	Wichita KS	Integrated	Transfer Off-Site to Disposal	0.016	0.008	NR	NR	NR	NR	NR	NR	104.52	337.82	NR	NR	NR	NR	NR
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Transfer Off-Site to Disposal	0.005	0.005	0.005	0.005	0.005	NR	NR	NR	NR	NR	0.074	0.052	0.055	0.105	0.109
OxyVinyls Deer Park - Caustic	Occidental Chemical Holding Corp	Deer Park TX	PVC & Chlorinated HC	Transfer Off-Site to Disposal	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.092	1.69	1.86	6.05
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Transfer Off-Site to Disposal	251.992	260.758	91.478	100.262	132.706	2.464	64.535	NR	269.29	0.000	0.299	0.150	78.695	214.075	32.426
ASHTA Chemicals	none	Ashtabula OH	Chlorine	Disp Non Metals	NR	NR	NR	1.407	1.19	2.01	1.159	2	2	2	3	1	1	2	NR
Dow Chemical	THE DOW CHEMICAL CO	Freeport TX	Integrated	Other landfills	4088.8	4567	5067.601	6543.430	6399.628	4562.800	2423.450	1808.6	2347.8	1710.2	2096.2	2808.5	2314.3	4144	0
Dow Chemical	THE DOW CHEMICAL CO	Freeport TX	Integrated	RCRA Subtitle C Landfills	135.1	1024	88.29	725.190	121.843	92.840	330.440	543.3	6520.2	8252.6	3779.5	19010.2	8882.1	9209.4	3855.6
Occidental Chemical Corp	Occidental Chemical Holding Corp	Hahnville LA	Chlorine	Releases to Land	0.701	2.61	10.87	0.688	0.688	0.688	0.2	NR	NR	NR	NR	NR	NR	NR	NR
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Releases to Land	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	NR	168.204	119.833
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Releases to Land	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
			TOTAL	Other transfers & releases		47217.367	31515.546	32002.340	13320.576	11650.809	10057.471	59159.955	18604.356	15295.182	14630.903	32950.383	21034.983	28965.202	11649.461

Appendix D
TRI Data: PVC Facilities Reporting TEQ Releases (2008-2014)

SOURCE: Data compiled from EPA Toxics Release Inventory by Healthy Building Network, October 2015

APPENDIX D: TRI DATA: PVC FACILITIES REPORTING TEQ RELEASES (2008-2014)

Facility Name	Parent Company	Location	Type of Facility	Dioxin Release Type	2014	2013	2012	2011	2010	2009	2008
				TOTAL RELEASES	64.984	91.715	62.872	62.547	50.707	39.436	46.266
				5Y AVE TOTAL 2010-2014	66.565						
EAGLE US 2 LLC	Axiall Corp.	Lake Charles LA	Integrated	Total Off-site Disposal or Releases	1.088	1.420	1.044	1.594	1.271	1.719	1.683
ASHTA Chemicals	none	Ashtabula OH	Chlorine	Total Off-site Disposal or Releases	0	0	0	0.095	0.080	0.135	0.079
Axiall Corp.	Axiall Corp	Aberdeen MS	PVC	Total Off-site Disposal or Releases	0	0	0	0	0	0	0
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Total Off-site Disposal or Releases	1.289	1.454	1.486	1.460	1.512	2.043	1.462
Dow Chemical	THE DOW CHEMICAL CO	Freeport TX	Integrated	Total Off-site Disposal or Releases	0	0	0	0	0	0	0
Formosa Baton Rouge	Formosa Plastics Corp	Baton Rouge LA	Integrated	Total Off-site Disposal or Releases	0.176	0.171	0.154	0.122	0	0	0
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Total Off-site Disposal or Releases	0.000	0.000	0.000	0.000	0.000	no data	no data
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Total Off-site Disposal or Releases	0	0.552	0.495	0.546	0.458	0.428	0.425
Georgia Gulf	Axiall Corp.	Westlake LA	"petrochemical manufacturing"	Total Off-site Disposal or Releases	0.002	0.011	0.004	0.010	0.052	0.014	0.830
Occidental Chemical	Occidental Petroleum	Ingleside TX	Integrated	Total Off-site Disposal or Releases	1.669	2.188	1.935	2.386	1.630	1.488	1.342
Occidental Chemical	Occidental Petroleum	Niagara Falls NY	Chlorine	Total Off-site Disposal or Releases	0	0	0	0	0	0	0
Occidental Chemical Corp	Occidental Chemical Holding Corp	Convent LA	Chlorine	Total Off-site Disposal or Releases	0.110	0.149	0.079	0.131	0.108	0.105	0.097
Occidental Chemical Corp	Occidental Chemical Holding Corp	Hahnville LA	Chlorine	Total Off-site Disposal or Releases	0.069	0.059	0.085	0.021	0.024	0.057	0.052
Occidental Chemical Corp	Occidental Petroleum	Mobile AL	Chlorine	Total Off-site Disposal or Releases	no data	no data	no data	no data	no data	no data	1.032
Occidental Chemical Corp	Occidental Petroleum Corp	Wichita KS	Integrated	Total Off-site Disposal or Releases	0.001	0.000	0	0	0	0	0
Occidental Chemical Holding Corp	Occidental Chemical Holding Corp	Muscle Shoals AL	Chlorine	Total Off-site Disposal or Releases	0	0	0	0	0	0.036	1.369
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Total Off-site Disposal or Releases	0	0	0	0	0	0	0
Oxy Vinyls La Porte VCM Plant	Occidental Chemical Holding Corp	La Porte TX	Chlorinated HC (VCM)	Total Off-site Disposal or Releases	28.336	0.424	15.483	0.438	1.824	2.183	0.539
Oxy Vinyls La Porte VCM Plant	Occidental Chemical Holding Corp	La Porte TX	Chlorinated HC (VCM)	Total Off-site Disposal or Releases	0.448	45.481	0.478	14.534	0.792	0.584	2.998
Oxy Vinyls LP Deer Park - VCM Plant	Occidental Chemical Holding Corp	Deer Park TX	Chlorinated HC (VCM)	Total Off-site Disposal or Releases	0	0.000	0.001	0	0.000	0	0
OxyVinyls Deer Park - Caustic	Occidental Chemical Holding Corp	Deer Park TX	PVC & Chlorinated HC	Total Off-site Disposal or Releases	no data, all years						
Sabic Innovative Plastics		Mt. Vernon IN	Chlorine	Total Off-site Disposal or Releases	0	0	0	0	0	0	0
Shintech Inc.	C-K TECH INC	Plaquemine LA	Integrated	Total Off-site Disposal or Releases	0	0	0	0	n/d	n/d	n/d
Westlake Monomers	Westlake Chemical Corp	Calvert City KY	Integrated	Total Off-site Disposal or Releases	n/d all years						
Westlake Vinyls	Westlake Chemical Corp	Calvert City KY	Integrated	Total Off-site Disposal or Releases	8.010	10.914	19.698	17.079	18.622	14.350	15.730
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Total Off-site Disposal or Releases	11.434	11.810	4.070	4.426	5.949	0.004	0
OVERALL (Off-site)		**TOTAL**		Total Off-site Disposal or Releases	52.633	74.632	45.011	42.841	32.324	23.147	27.638

(CONTINUED ON NEXT)

APPENDIX D: TRI DATA: PVC FACILITIES REPORTING TEQ RELEASES (2008-2014) (continued(

Facility Name	Parent Company	Location	Type of Facility	Dioxin Release Type	2014	2013	2012	2011	2010	2009	2008
EAGLE US 2 LLC	Axiall Corp.	Lake Charles LA	Integrated	Total On-Site Disposal or Releases	0.330	0.498	0.324	0.320	0.300	0.308	0.361
ASHTA Chemicals	none	Ashtabula OH	Chlorine	Total On-Site Disposal or Releases	0	0	0	0	0	0	0
Axiall Corp.	Axiall Corp	Aberdeen MS	PVC	Total On-Site Disposal or Releases	0	0.000	0	0	0	0	0
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Total On-Site Disposal or Releases	0.099	0.101	0.098	0.098	0.092	0.090	0.096
Dow Chemical	THE DOW CHEMICAL CO	Freeport TX	Integrated	Total On-Site Disposal or Releases	10.249	14.443	14.277	17.516	16.113	13.598	16.046
Formosa Baton Rouge	Formosa Plastics Corp	Baton Rouge LA	Integrated	Total On-Site Disposal or Releases	0.906	0.902	1.801	0.746	0.732	0.657	0.635
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Total On-Site Disposal or Releases	0.000	0.000	0.000	0.000	0.000	no data	no data
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Total On-Site Disposal or Releases	0.124	0.126	0.125	0.118	0.114	0.539	0.317
Georgia Gulf	Axiall Corp.	Westlake LA	“petrochemical manufacturing”	Total On-Site Disposal or Releases	0.014	0.012	0.022	0.018	0.013	0.013	0.011
Occidental Chemical	Occidental Petroleum	Ingleside TX	Integrated	Total On-Site Disposal or Releases	0.042	0.042	0.043	0.052	0.048	0.054	0.041
Occidental Chemical	Occidental Petroleum	Niagara Falls NY	Chlorine	Total On-Site Disposal or Releases	0.002	0.002	0.001	0.002	0.001	0.002	0
Occidental Chemical Corp	Occidental Chemical Holding Corp	Convent LA	Chlorine	Total On-Site Disposal or Releases	0.009	0.009	0.008	0.006	0.089	0.093	0.096
Occidental Chemical Corp	Occidental Chemical Holding Corp	Hahnville LA	Chlorine	Total On-Site Disposal or Releases	0.193	0.566	0.805	0.486	0.512	0.640	0.743
Occidental Chemical Corp	Occidental Petroleum	Mobile AL	Chlorine	Total On-Site Disposal or Releases	no data	no data	no data	no data	no data	no data	0.002
Occidental Chemical Corp	Occidental Petroleum Corp	Wichita KS	Integrated	Total On-Site Disposal or Releases	0	0	0	0	0	0	0
Occidental Chemical Holding Corp	Occidental Chemical Holding Corp	Muscle Shoals AL	Chlorine	Total On-Site Disposal or Releases	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Total On-Site Disposal or Releases	0.001	0.002	0.002	0.003	0.002	0.001	0.002
Oxy Vinyls La Porte VCM Plant	Occidental Chemical Holding Corp	La Porte TX	Chlorinated HC (VCM)	Total On-Site Disposal or Releases	0.035	0.076	0.021	0.075	0.029	0.031	0.077
Oxy Vinyls La Porte VCM Plant	Occidental Chemical Holding Corp	La Porte TX	Chlorinated HC (VCM)	Total On-Site Disposal or Releases	0.074	0.036	0.077	0.013	0.094	0.085	0.026
Oxy Vinyls LP Deer Park - VCM Plant	Occidental Chemical Holding Corp	Deer Park TX	Chlorinated HC (VCM)	Total On-Site Disposal or Releases	0.000	0.002	0.005	0.002	0.002	0.003	0.003
OxyVinyls Deer Park - Caustic	Occidental Chemical Holding Corp	Deer Park TX	PVC & Chlorinated HC	Total On-Site Disposal or Releases	no data, all years						
Sabic Innovative Plastics		Mt. Vernon IN	Chlorine	Total On-Site Disposal or Releases	0.010	0.010	0.010	0.013	0.013	0.013	0.013
Shintech Inc.	C-K TECH INC	Plaquemine LA	Integrated	Total On-Site Disposal or Releases	0.025	0.010	0	0.001	n/d	n/d	n/d
Westlake Monomers	Westlake Chemical Corp	Calvert City KY	Integrated	Total On-Site Disposal or Releases	n/d all years						
Westlake Vinyls	Westlake Chemical Corp	Calvert City KY	Integrated	Total On-Site Disposal or Releases	0.053	0.057	0.054	0.050	0.043	0.043	0.040
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Total On-Site Disposal or Releases	0.184	0.185	0.183	0.183	0.183	0.117	0.117
OVERALL - On-site		Total		Total On-Site Disposal or Releases	12.352	17.083	17.860	19.705	18.383	16.289	18.628

Appendix E
TRI Data: PVC Facilities Reporting Vinyl Chloride Monomer Releases (2000-2014)

SOURCE: Data compiled from EPA Toxics Release Inventory by Healthy Building Network, October 2015

APPENDIX E: TRI DATA: PVC FACILITIES REPORTING VINYL CHLORIDE MONOMER RELEASES (2000-2014)

Facility Name	Parent Company	Location	Type of Facility	VCM Release Type	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
Axiall Corp.	Axiall Corp	Aberdeen MS	PVC	Air Fug	11560	4929	4915	5156	5178	4942	5055	36609	5863	5078	5264	5292	4873	4807	4927
Georgia Gulf	Axiall Corp.	Westlake LA	"petrochemical manufacturing"	Air Fugitive	2918	1447	5765	5569	7319	4804	4291	4525	18482	5768	8424	3356	2196	968	5290
EAGLE US 2 LLC	Axiall Corp.	Lake Charles LA	Integrated	Air Fug	6000	15000	27000	9100	16000	6300	1700	2700	2600	1100	1505	6200	920	13000	1900
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Air Fug	11283	13795	11666	10615	12000	12000	12000	11000	10846	9670	7584	9596	8578	17000	6400
Colorite Specialty Resins	Colorite Specialty Resins	Burlington NJ	PVC	Air Fug	249	5251	7967	5100	7495	6883	7300	4141	2866	3096	3351	7266	2831	3694	2231
Union Carbide	Dow Chemical	Texas City TX	PVC	Air Fug	NR	NR	NR	NR	NR	795	901	888	4908	10254	4064	4082	4063	8000	11363
Dow Chemical	Dow Chemical	Freeport TX	Integrated	Air Fug	1749	1291	2134	3753	13124	7771	9552	3564	4679	3700	9135	7486	3569	5547	3400
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Air Fug	7590	5170	5697	12525	5984	7320	6079.89	2571.8	147100.68	73070.87	73141.61	62025.76	2858	4206	3304
Formosa Plastics	Formosa Plastics	Illiopolis IL	VCM, PVC	Air Fug											64949	10726	2262	11379	17562
Axiall Corp.	Axiall Corp	Aberdeen MS	PVC	Air Stack	5224	14189	19044	13336	13922	20081	12520	15717	18217	25567	32846	24980	23196	23089	24243
EAGLE US 2 LLC	Axiall Corp.	Lake Charles LA	Integrated	Air Stack	100	160	1200	300	2300	850	700	260	540	180	350	320	350	410	580
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Air Stack	5116	8073	7229	8274	18000	8200	5400	8300	5238	6383	6053	74805	21766	11000	14000
Georgia Gulf	Axiall Corp.	Westlake LA	"petrochemical manufacturing"	Air Stack	27	26	20	70	47	76	49	280	440	917	115	104	107	100	182
Shintech Inc.	C-K TECH INC	Addis LA	PVC	Air Stack	31665	36333	37000	5700	4600	4000	6200	11000	8500	10696	18917	14064	10816	5900	1143
Shintech Inc.	C-K TECH INC	Plaquemine LA	Integrated	Air Stack	45225	44210	46000	19000	12000	9414	7900	NR	NR	NR	NR	NR	NR	NR	NR
Dow Chemical	Dow Chemical	Freeport TX	Integrated	Air Stack	563	665	631	643	643	543	656	8	11	15000	752	1449	382	2342	730
Union Carbide	Dow Chemical	Texas City TX	PVC	Air Stack	NR	NR	NR	NR	NR	3	3	18	7	136	4142	35	804	1837	652
Formosa Plastics	Formosa Plastics	Illiopolis IL	VCM, PVC	Air Stack											7817	24399	28820	30383	45611
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Air Stack	25854	17506	9226	9316	2371	2423	2357.57	4169.4	2577	3330.75	5635.8	4408.22	5921.3	4220	4300
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Air Fug	2253	2070	2520	2644	2795	2640	3120	2660	2104	6322	4669	3248	2674	2750	2680
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Air Stack	47009	45207	56740	54920	53360	41160	46940	34800	36438	65267	64099	59541	100645	94967	111363
Formosa Baton Rouge	Formosa Plastics Corp	Baton Rouge LA	Integrated	Air Fug	10298	11149	12800	10829	12411	12376	10300	16000	14000	5700	6700	14000	10000	8000	4600
Formosa Baton Rouge	Formosa Plastics Corp	Baton Rouge LA	Integrated	Air Stack	5022	4372	5040	4690	4381	3963	2700	2800	3100	1500	2300	290	590	290	1600
Mexichem Specialty Resins	Mexichem Specialty Resins	Henry IL	PVC	Air Fug	2100	2520	1200	6440	1200	1200	1200	10300	1200	1200	1300	2700	1300	1700	3400
Mexichem Specialty Resins	Mexichem Specialty Resins	Henry IL	PVC	Air Stack	18566	19780	21500	18900	20400	15000	20700	24200	25100	26100	25100	19200	32000	30000	34000
Mexichem Specialty Resins	Mexichem Specialty Resins	Pedricktown NJ	PVC	Air Fug	1830	1216	776	1176	975	1707	1729	2316	2904	3571	3222	2578	2579	2959	4906
Mexichem Specialty Resins	Mexichem Specialty Resins	Pedricktown NJ	PVC	Air Stack	14444	13357	13131	16363	11665	7601	8739	10933	11859	15506	15718	12960	13638	14480	18141
Shintech Inc.	No US Parent	Freeport TX	PVC	Air Stack	686	4607	5288	4318.8	9835	10856	10014	13654	17300	18800	18800	17400	16600	22922	24220
Oxy Vinyls LP Deer Park - VCM Plant	Occidental Chemical Holding Corp	Deer Park TX	VCM	Air Fug	4337.52	457.13	3881	4722.86	5541.8	2381.53	2145.59	1487.35	2964	12556	7748	11525	11289	11133	8821
Oxy Vinyls LP Deer Park - VCM Plant	Occidental Chemical Holding Corp	Deer Park TX	VCM	Air Stack	96.29	1552.37	69	1397.58	166.41	106.28	452.9	37.33	45	4	2	0	0	0	0
OxyVinyls	Occidental Chemical Holding Corp	Pedricktown NJ	PVC	Air Fug	1300	941	931	711	734	796	1379	1188	861	1417	1201	1775	943	1353	1914
OxyVinyls	Occidental Chemical Holding Corp	Pedricktown NJ	PVC	Air Stack	1310	1996	825	742	1197	1181	1465	1905	1439	1906	2375	2219	2369	3741	3849
OxyVinyls Deer Park - Caustic	Occidental Chemical Holding Corp	Deer Park TX	PVC & Chlorinated HC	Air Fug	9502	7320	6326	5956	7313	4525	2192	4204	3616	2038	2921	7139	11852	15397	24068
OxyVinyls Deer Park - Caustic	Occidental Chemical Holding Corp	Deer Park TX	PVC & Chlorinated HC	Air Stack	877	288	380	374	466	334	333	507	934	2884	1388	1709	1498	1561	1234

(CONTINUED ON NEXT)

APPENDIX E: TRI DATA: PVC FACILITIES REPORTING VINYL CHLORIDE MONOMER RELEASES (2000-2014) (continued)

Facility Name	Parent Company	Location	Type of Facility	VCM Release Type	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Air Fug	91.3	99.39	121.11	252.25	56.77	126.14	128	119	54	63	14	41	760	80	173
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Air Stack	1434.91	505	794.6	567.01	964.08	107.24	100	270	26	304	225	7212	1294	25	81
Occidental Chemical	Occidental Petroleum	Ingleside TX	Integrated	Air Fug	2394	2117	1505	805	891	3547	1684	2211	2006	845	1091	2576	3069	1825	1655
Occidental Chemical	Occidental Petroleum	Ingleside TX	Integrated	Air Stack	2044	2027	2697	10666	2169	2102	2429	2898	2844	76	27	88	75	250	350
OxyVinyls La Porte VCM Plant	Occidental Petroleum	La Porte TX	Chlorinated HC	Air Fug	4137	4034	4548	6535	7081	1752	4384	6200	9400	14600	9500	6354	8343	9183	8515
OxyVinyls La Porte VCM Plant	Occidental Petroleum	La Porte TX	Chlorinated HC	Air Stack	3163	2786	3049	2975	3158	2434	2923	4100	4000	2890	3582	3236	4816	5775	12228
OxyVinyls	Occidental Petroleum	Louisville KY	PVC	Air Fug							50	259	234	834.87	1105.8	927.3	1189.3	1320	1188
OxyVinyls	Occidental Petroleum	Louisville KY	PVC	Air Stack							76	576	587	491.66	619	383.7	748.7	1011	1241
Occidental Chemical Corp	Occidental Petroleum Corp	Wichita KS	Integrated	Air Stack	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	13	2	20
Polyone Corp.	POLYONE CORP	Louisville KY	PVC	Air Fug	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Polyone Corp.	POLYONE CORP	Louisville KY	PVC	Air Stack	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Certainteed Corp	SAINT-GOBAIN CORP	Westlake LA	PVC	Air Fug	250	600	530	940	1400	640	1500	1000	370	1100	1100	2200	1500	1200	750
Certainteed Corp	SAINT-GOBAIN CORP	Westlake LA	PVC	Air Stack	550	900	1300	1600	1900	1300	2000	1500	720	800	1100	900	1100	1000	750
Shintech Inc.	Shintech	Addis LA	PVC	Air Fug	18828	15252	6900	4900	4900	4900	4900	4900	4900	6833	6852	3592	3592	3592	250
Shintech Inc.	Shintech	Freeport TX	PVC	Air Fug	9794	12491	4449	4542.688	4110	3548	3660	3519	3200	2200	2200	2800	2700	5251	4380
Shintech Inc.	Shintech	Plaquemine LA	Integrated	Air Fug	20055	20080	27000	24000	18000	18354	19000	NR	NR	NR	NR	NR	NR	NR	NR
Westlake PVC Corp	Westlake Chemical Corp	Calvert City KY	PVC	Air Fug	31682	19936	25042	31872	25042	21628	24036	24036	26014	33264	33232	7370	6475	6475	6475
Westlake Vinyls	Westlake Chemical Corp	Calvert City KY	Integrated	Air Fug	91180	15675	15700	28000	16000	15000	15000	15000	15100	20000	16000	15000	16000	15000	NR
Westlake Monomers	Westlake Chemical Corp	Calvert City KY	Integrated	Air Fug															14800
Westlake Monomers	Westlake Chemical Corp	Calvert City KY	Integrated	Air Stack															900
Westlake Vinyls	Westlake Chemical Corp	Calvert City KY	Integrated	Air Stack	750	750	812	740	730	1000	810	800	800	1000	750	690	1000	3800	NR
Westlake PVC Corp	Westlake Chemical Corp	Calvert City KY	PVC	Air Stack	9043	10207	14590	11339	24145	14708	5813	3857	5193	5475	6098	17104	19887	14650	18271
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Air Fug	1200	1900	1300	1567	2038	2227	2626	NR	4700	4700	215	NR	3603	2712	3847
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Air Stack	59000	35000	48000	52247	57928	46935	64826	NR	48455	25805	4653	NR	5678	24612	44683
Colorite Specialty Resins		Burlington NJ	PVC	Air Stack	678	5819	7495	8341	8795	8995	5652	6850	5046	3661	4756	4882	6786	6310	5738
			TOTAL	**Air Fugitive**	**267963.21**	**159782.39**	**173363.71**	**198960.948**	**188283.85**	**155343.38**	**165587**	**84711**	**139638**	**131770.53**	**99803.8**	**86423**	**104348**	**124772**	**155446**
			TOTAL	**Air Stack**	**534616.42**	**317568.78**	**345902.42**	**397179.896**	**375370.7**	**309505.76**	**329709**	**167517**	**277837**	**261635.06**	**197232.6**	**170627**	**206327**	**245803**	**307043**

(CONTINUED ON NEXT)

APPENDIX E: TRI DATA: PVC FACILITIES REPORTING VINYL CHLORIDE MONOMER RELEASES (2000-2014) (continued)

Facility Name	Parent Company	Location	Type of Facility	VCM Release Type	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
EAGLE US 2 LLC	Axiall Corp.	Lake Charles LA	Integrated		NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	16	38	NR	NR
OxyVinyls La Porte VCM Plant	Occidental Petroleum	La Porte TX	Chlorinated HC	Disp Non Metals	NR	NR	NR	NR	NR	NR	38	NR	NR	NR	NR	NR	NR	125	1
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Disp Non Metals	0	0	1	1	1	0	0	0	0	1	0	0	4	6	7
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Disp Non Metals	0.07	3.78	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Occidental Chemical	Occidental Petroleum	Ingleside TX	Integrated	Disp Non Metals	1	3	2	1	0.2	0.15	1	0	0	0	NR	NR	NR	NR	NR
Westlake Vinyls	Westlake Chemical Corp	Calvert City KY	Integrated	Disp Non Metals	NR	NR	NR	NR	1	NR	NR	NR	NR	NR	NR	28	NR	NR	NR
Union Carbide	Dow Chemical	Texas City TX	PVC	Disp Non Metals	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Disp Non Metals	44.46	26.85	16.2	126.6	8.54	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Mexichem Specialty Resins	Mexichem Specialty Resins	Pedricktown NJ	PVC	Disp Non Metals	27	27	27	27	27	27	27	27	27	27	27	26	26	27	17
Shintech Inc.	No US Parent	Freeport TX	PVC	Disp Non Metals	NR	0	0	NR	5	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Polyone Corp.	POLYONE CORP	Louisville KY	PVC	Disp Non Metals	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Certainteed Corp	SAINT-GOBAIN CORP	Westlake LA	PVC	Disp Non Metals	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Westlake PVC Corp	Westlake Chemical Corp	Calvert City KY	PVC	Disp Non Metals	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	4	7	NR	NR	NR
Colorite Specialty Resins		Burlington NJ	PVC	Disp Non Metals	32	54	32	47	10	36	45	13	5	5	105	32	35	29	36
OxyVinyls Deer Park - Caustic	Occidental Chemical Holding Corp	Deer Park TX	PVC & Chlorinated HC	Disp Non Metals	NR	NR	NR	6034	NR	NR	NR	NR	NR	NR	NR	NR	1	2	1
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Disp Non Metals	0	0	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	36	74
Oxy Vinyls LP Deer Park - VCM Plant	Occidental Chemical Holding Corp	Deer Park TX	VCM	Disp Non Metals	NR	NR	NR	NR	NR	NR	NR	NR	NR	7	NR	NR	NR	12	1
Formosa Plastics	Formosa Plastics	Illiopolis IL	VCM, PVC	Disp Non Metals											11.1	5.4	6	272	505
Dow Chemical	Dow Chemical	Freeport TX	Integrated	Incineration		0	0	0	0	8	18	1459	64						
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Landf8795	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Oth Disp	0	0	0	0	0	0	0	0	NR	0.007	0	0	0	0	NR
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Other Disp	0	0	0	0	0	0	0	0	0	NR	0.007	0	0	0	0
Dow Chemical	Dow Chemical	Freeport TX	Integrated	Other landfills	12	1	0												
Dow Chemical	Dow Chemical	Freeport TX	Integrated	RCRAlandfills	15	0	1	0	0	0	1	0				8			
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Surf Imp	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Dow Chemical	Dow Chemical	Freeport TX	Integrated	Surface Water Discharges	2	3	9	7	9	9	6	2	0	0	31	0	2	0	33
Occidental Chemical Corp	Occidental Petroleum Corp	Wichita KS	Integrated	UnInj I	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	426	38	12	19	62
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	UNINJ I	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	1
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	UNINJ8795	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
			TOTAL	**Other Disposal**	**133.53**	**118.63**	**88.2**	**6243.6**	**61.74**	**80.15**	**136**	**1501**	**96**	**40.007**	**604.107**	**144.4**	**86**	**528**	**738**

(CONTINUED ON NEXT)

APPENDIX E: TRI DATA: PVC FACILITIES REPORTING VINYL CHLORIDE MONOMER RELEASES (2000-2014) (continued)

Facility Name	Parent Company	Location	Type of facility	VCM Release Type	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
EAGLE US 2 LLC	Axiall Corp.	Lake Charles LA	Integrated	Water	2	NR	0	2	2	2	4	0	34	18	0	0	0	4	52
OxyVinyls La Porte VCM Plant	Occidental Petroleum	La Porte TX	Chlorinated HC	Water	3	1.73	3	3.2	3.6	3.2	3	3	3	0	1	1	0	0	0
Axiall Corp.	Axiall Corp.	Plaquemine LA	Integrated	Water	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Formosa Plastics	Formosa Plastics	Point Comfort TX	Integrated	Water	NR	1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Formosa Baton Rouge	Formosa Plastics Corp	Baton Rouge LA	Integrated	Water	0	NR	NR	NR	0	0	0	19	0	0	0	0	0	0	0
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Water	NR	0	NR	3.4	0	0	NR	NR	NR	NR	NR	0	0	0	0
Occidental Chemical Holding Corp - Geismar (OxyChem)	Occidental Chemical Holding Corp	Geismar LA	Integrated	Water	NR	0	NR	3.4	0	0	NR	NR	NR	NR	NR	0	0	0	0
Westlake Vinyls	Westlake Chemical Corp	Calvert City KY	Integrated	Water	10	1	0	6	0	0	0	0	3	0	0	7	4	0	NR
Formosa Plastics	Formosa Plastics	Delaware City DE	PVC	Water	NR	4.2	12.43	12.33	5.3	3.58	3	5	12	14	NR	NR	NR	NR	NR
Mexichem Specialty Resins	Mexichem Specialty Resins	Pedricktown NJ	PVC	Water	16	16	16	16	16	16	16	16	16	16	16	15	14	14	14
Shintech Inc.	No US Parent	Freeport TX	PVC	Water	0	0	5	6.1	5	5	NR	NR	NR	0	0	0	0	34	34
Certainteed Corp	SAINT-GOBAIN CORP	Westlake LA	PVC	Water	1	0	0	0	0	1	1	0	0	0	0	5	5	5	0
Colorite Specialty Resins		Burlington NJ	PVC	Water	5	15	32	47	69	19	49	25	22	12	25	9	24	9	24
OxyVinyls Deer Park - Caustic	Occidental Chemical Holding Corp	Deer Park TX	PVC & Chlorinated HC	Water	6	2.7	3.45	2	0	0	0	2	0.5	1.65	0	0	0	0	2
Westlake Vinyls	Westlake Chemical Corp	Geismar LA	PVC & Chlorinated HC	Water	0	0	0	0	0	0	0	NR	1	0	0	NR	0	0	0
Formosa Plastics	Formosa Plastics	Illiopolis IL	VCM, PVC	Water											NR	5	14	14	17
			TOTAL	Water Discharges	41	41.63	71.88	99.43	98.9	47.78	72	72	57.5	43.65	42	42	61	76	91

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