VINYL INSTITUTE USGBC PVC TG DATA SUBMISSION
APRIL 2, 2004

Nigel Howard
Vice President
US Green Building Council
1015 18th Street NW
Suite 805
Washington DC 20036

By email tsac@committees.usgbc.org

Dear Mr. Howard,

The Vinyl Institute (VI) appreciates the opportunity to submit this overview and the accompanying technical data to the U.S. Green Building Council (USGBC) Technical and Scientific Advisory Committee (TSAC) for its technical assessment of vinyl (or PVC) and competing building and construction materials used in select applications.[i] We recognize that in attempting to determine the "availability and quality of the evidence as a basis for a reasoned decision about the inclusion of a PVC related credit in the LEED™ Rating System," the TSAC's PVC Task Group has undertaken a daunting task. Accordingly, and as the Task Group requested, we seek to avoid overwhelming the Task Group with an avalanche of data by summarizing and providing the select studies that are most relevant and important to the task at hand.

---

[i] The Vinyl Institute, Inc. (VI) is a U.S. trade association representing the leading manufacturers of vinyl, vinyl chloride monomer, vinyl additives and modifiers, and vinyl packaging materials. The VI's mission is to gather and communicate technical information to support the responsible manufacture, use and disposal of vinyl products, to build recognition among a wide range of stakeholders on the benefits and value of vinyl, and to maintain a level playing field with other materials. VI member companies include: CertainTeed Corporation, The Dow Chemical Company, Formosa Plastics Corporation, U.S.A., Georgia Gulf Corporation, Oxyvinyls, LP, PolyOne Corporation, and Shintech, Inc.

In addition to this overview and bibliography, we are submitting: (1) a CD-ROM which contains the referenced documents in the USGBC Additional Report Form format and those documents which were available electronically; and (2) those documents which were available in hard copies. We have not provided copies of all the potentially relevant studies. Instead we have focused on and provided the critical studies discussed in this overview. In addition, we are providing references in the requested format to over 300 additional PVC-related studies, which are available upon request. Should the Task Group wish to further explore any of the issues raised by the VI's submittal, we would be happy to discuss them with the Task Group.

OECD SIDS Reports: Given the PVC Task Group's clearly enunciated preference for governmental sources of information first, and peer reviewed studies second, and that the Task Group is currently reviewing over 60 papers and studies related to VCM, we are providing you key toxicological assessment reviews on vinyl chloride and ethylene dichloride (EDC) from the International Register of Potentially Toxic Chemicals (IRPTC).[ii]

Under the IRPTC mandate, the U.N. Organization for Economic Cooperation and Development's (OECD's) Environmental Health and Safety Division established the Screening Information Data Sets (SIDS) for High Production Volume (HPV) Existing Chemicals. The SIDS Program collects existing test data for HPV chemicals including the chemical's identity, physical characteristics, sources and levels of exposure, environmental fate and pathways, and ecotoxicological and toxicological data. Once a chemical has been selected for SIDS review, the sponsor country collects the available data and determines whether or not additional testing is needed to complete the data set. Needed testing is conducted and the results are included in the SIDS dossier. A SIDS Initial Assessment Report (SIAR) is then prepared and reviewed by the

---

[ii] The IRPTC was established by the United Nations Environmental Programme (UNEP) in 1976, following a recommendation of the 1972 United Nations Conference on the Human Environment held in Stockholm. The IRPTC aims to help the world community make better use of existing global resources and to give developing countries the information base to manage chemicals effectively by implementing five main goals:

- make it easier to obtain existing information on production, distribution, release, disposal and adverse effects of chemicals;
- identify the important gaps in knowledge of the effects of chemicals and call attention to the need for research to fill those gaps;
- help identify potential hazards from chemicals and wastes and to improve awareness of the dangers;
- provide information about national, regional and global policies, controls and recommendations on potentially toxic chemicals;
- help implement policies for the exchange of information on chemicals in international trade.

OECD. The conclusions from this meeting represent the initial assessment conclusions of OECD member countries concerning the chemical at issue, and the need for additional work. EPA's Office of Pollution Prevention and Toxics is the U.S. Representative to the SIDS program. The United States was the sponsor country for the vinyl chloride assessment, which was managed by EPA. Following completion of the SIAR process, reviewed chemicals are referred to EPA's risk management process for integration into the U.S. chemical program.

In November 2001, the OECD concluded an extensive review of vinyl chloride, and concluded that vinyl chloride is:

> *currently of low priority for further work in the SIDS Program as human exposures are controlled due to the chemical's genotoxicity and cancer hazard and based upon OECD risk reduction measures.*

The OECD reached a similar conclusion for EDC. Accordingly, the VI strongly recommends and submits the SIAR on vinyl chloride and EDC to the PVC Task Group.[1] (***Note*****:** Superscripted Arabic numbers are end note citations to the overview bibliography and submitted documents, while Roman numerals refer to footnotes.) This is the most current and thorough toxicological assessment of vinyl chloride to date. The report is based on a review of over 330 references on vinyl chloride and has been closely scrutinized by the OECD.

Key Conclusions of the OECD SIDS Review of Vinyl Chloride: The data collected for SIDS elements were found to be sufficiently complete and considered adequate for hazard identification. With respect to health effects of vinyl chloride, there are several important conclusions from this review that may help the USGBC PVC Task Group in their review.

- The SIDS data indicates that the primary route of exposure for vinyl chloride is by inhalation.
- Long-term occupational exposure of workers to vinyl chloride prior to 1973 has been associated with cancer in humans while other cancers in humans have not been clearly linked to vinyl chloride exposure.
- Since 1977, steady improvements in manufacturing facilities, engineering controls and workplace practices have substantially reduced workplace exposures in the U.S. to below the Occupational Safety and Health Administration (OSHA) action level of 0.5 ppm.

NIOSH health hazard evaluation studies after 1977 have primarily shown non detectable levels of vinyl chloride.

- The weight of evidence suggests that vinyl chloride is not a reproductive toxicant or a developmental toxicant below maternally toxic levels in animals.
- Studies addressing the hypothesis that members of communities with nearby vinyl chloride polymerization facilities have significantly greater incidences of some forms of developmental toxicity have failed to demonstrate a statistically significant correlation between developmental toxicity and either parental occupation or proximity to the facility.[2]
- Results of both retrospective and prospective studies indicate that pregnancy outcomes of mothers occupationally exposed to vinyl chloride are not altered by exposure.[3] Human studies have not linked vinyl chloride exposure with negative reproductive outcomes.

I. PVC and VCM Manufacturing Industry and Process Description

PVC processing begins with vinyl chloride, a gas which is itself produced from ethylene, oxygen and hydrogen chloride (and their combination, ethylene dichloride). To produce PVC, vinyl chloride is pressurized and agitated in a reactor and as a result is polymerized, meaning the molecules of vinyl chloride combine into larger molecules of the same constituents in a repeating pattern. (Vinyl chloride gas is also referred to as vinyl chloride monomer (VCM) to distinguish it from its polymerized form.) Through polymerization, vinyl chloride can be transformed into a variety of resins, which are generally solids suspended in liquid or in a slurry form. Vinyl chloride also can be combined with other substances during polymerization, resulting in the formation of products generally classified as copolymers. PVCs and copolymers are plastics, and are used in a variety of applications, including latex paints, adhesives, clear plastics, rigid plastics (e.g., PVC pipe) and flooring. For a more detailed description of the PVC manufacturing process, please refer to the enclosed *Overview of EDC/VCM/PVC Manufacturing Industry and Processes*.[4]

A. Industry Size and Safety

The USGBC also requested in their email of March 18, 2004, from Kara B. Altshuler to D'Lane Wisner, that stakeholders would identify the number of workers in PVC and VCM manufacturing and estimates of production output. The stated capacity of the industry is approximately 14 billion pounds of PVC, and of course, a correspondingly equivalent number of pounds of VCM are produced annually. The VI estimates that 3,000 to 4,000 workers are directly involved in VCM and PVC resin production, with approximately one-third of the workers involved with VCM manufacturing and two-thirds with PVC manufacturing. With respect to the safety of these workers, for 2002, VI member facilities manufacturing PVC and VCM worked 7.14 million man-hours with a performance in OSHA recordable incident rates of 1.19, again attaining one of very best safety performances in the country as compared to 7.2 recordable case for general manufacturing and 3.3 recordable cases for chemical manufacturing.[5]

II. Overview of Monomer and Polymer Regulatory Issues (EDC/VCM/PVC)

The manufacture of vinyl in the United States is closely regulated to minimize its impact on the environment and to protect human health. The U.S. Occupational Health and Safety Administration (OSHA) regulates workplace exposures to vinyl chloride monomer (VCM) to 1 part per million (ppm) VCM calculated as a time-weighted average over 8 hours.[iii] In compliance with the OSHA standard, vinyl chloride and PVC manufacturing facilities must undertake workplace and employee monitoring programs, including notifying the employee in writing of the results of the exposure measurement. The standard requires that a program of medical surveillance must be instituted for each employee exposed to vinyl chloride above the action level of 0.5 ppm and must allow each employee an opportunity for appropriate examinations and tests.

Under Section 112 of the Clean Air Act, the U.S. Environmental Protection Agency (EPA) regulates air emissions resulting from the process. These regulations are normally enforced by state environmental agencies that can and have imposed even more stringent limits on emission sources. These federal daily emission limits have been in effect since 1976 when EPA established a national emission standard for hazardous air pollutants (NESHAP) for facilities producing VCM and PVC.[iv]

[iii] 29 C.F.R. § 1910.1017.

[iv] 41 Fed. Reg. 46,560.

In 2002, EPA promulgated a new rule for PVC and copolymer production facilities based on the agency's determination that the hazardous air pollutant control level resulting from compliance with the 1976 NESHAP already reflected the application of maximum achievable control technology (MACT) and, thus, met the requirements of CAA section 112(d).[v] Under the 2002 PVC MACT, existing sources were required to be in compliance by July 2002. Depending on the type of facility, other Federal MACTs, including the hazardous organic NESHAP (HON), the hydrochloric acid (HCl) production MACT, and Organic Liquids Distribution MACT may also apply to EDC/VCM/PVC facilities.[vi] For example, facilities subject to the HON must comply with Leak Detection and Repair (LDAR) requirements for process vents, storage vessels, transfer operations, and wastewater discharge to manage fugitive emissions.

Under the Resource Conservation and Recovery Act (RCRA), heavy ends from the distillation of vinyl chloride are a listed hazardous waste (K020), as are a number of other waste streams (e.g., K174, K175). Any other solid waste at or above 0.2 mg/l in vinyl chloride content is considered to be a characteristic hazardous waste, and is regulated under RCRA. Such waste must meet Universal Treatment Standards (UTS) prior to land disposal.

Under section 103 of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), EDC/VCM/PVC facilities are required to report releases of VCM at or above a one pound reportable quantity (RQ), EDC at or above a 100 pound RQ, and other hazardous substances at or above their designated RQ to the National Response center.[vii] Moreover, under section 304 of the Emergency Planning and Community Right-to-know Act (EPCRA), EDC/VCM/PVC facilities must report immediately to the appropriate State Emergency Response Commissions and local emergency planning committee any VCM, EDC or other hazardous substance release into the environment that is at or above the RQ.[viii] In addition to the federal requirements, vinyl industry facilities can also be subject to supplemental and even more stringent state limitations.

[v] *National Emission Standards for Hazardous Air Pollutants for Polyvinyl Chloride and Copolymers Production*, 67 Fed. Reg. 45,886, 45,887-45,888 (July 10, 2002).

[vi] 40 C.F.R. Part 63, subparts F-I; subpart NNNNN; and subpart EEEE.

[vii] 42 U.S.C. § 9603.

[viii] 42 U.S.C. §11004.

A. Federal Daily Versus State Annual or Quarterly Average RVCM Limits

The current federal residual vinyl chloride monomer (RVCM) limit for PVC slurry is 400 parts per million (ppm), except for dispersion/emulsion resins which have a permissible exposure limit of 2,000 ppm.[ix] State permit limits for individual facilities, however, can be significantly lower. During the 2002 PVC MACT rulemaking, EPA conducted an extensive review of recent state permits and state emission limits for the PVC industry.

EPA determined that annual or quarterly averages in some state permits and the daily average in the EPA standard reflect different but complementary limits that encourage lower RVCM levels but provide flexibility of production.[x] Variations in state permit levels reflected the differences in the types of resins produced by the facilities in the state. The Agency's task under Section 112(d) of the Clean Air Act is to define the maximum achievable control technology used by the best performing sources within the source category. In the case of the non-dispersion PVC and copolymers source category, all existing sources use the same control technology to reduce RVCM levels, that is, steam stripping. Although MACT controls are being applied, the efficiency of the stripping technology varies with the polymer's molecular weight and the shape and surface characteristic of the resin being produced.

B. Louisiana

As part of its submittal, the VI has provided here and in Section II (D) and III information specific to Louisiana in response to data presented at the February 18, 2004, PVC TSAC public hearing concerning the regulatory performance of VCM and PVC facilities and the potential community health effects resulting from releases of VCM at these facilities. As the Task Group only released these presentations on March 29, 2004, the VI is limited in its ability to respond specifically, but will do so as expeditiously as possible. Nevertheless, we take these matters quite seriously.

With regard to vinyl industry operations in Louisiana, it is important to note the stringent requirements under which our industry operates in the state. Since 1991, Louisiana has required major stationary sources to operate in accordance with MACT requirements if the source emits a

[ix] 40 C.F.R. § 61.64. This should not be confused with finish product RVCM levels which are typically less than 1 ppm.

[x] 67 Fed. Reg. 45,889.

Class I or Class II toxic air pollutant at a specified rate.[xi] Louisiana listed VCM as a "Class I: Known and Probable Human Carcinogen" with a minimum emission rate of 240 pounds/year.[xii] For all the Class I and a few select Class II chemicals, the state of Louisiana established an Ambient Air Standard (AAS) based on unit risk factors and a residual risk of one in ten thousand. This is the level considered an "acceptable risk" by EPA when the agency is performing or evaluating risk assessments.

The state's MACT requirements prohibits facilities from emitting pollutants that exceed ambient air quality standard, unless: (1) compliance with the ambient air standard is economically infeasible; (2) the emissions do not pose a threat to public health or the environment; and (3) the emissions are being controlled to a level that is MACT.[xiii] Louisiana has set an ambient air standard for VCM of 1.19 micrograms per cubic meter ($\mu g/m^3$), **averaged annually**. Therefore vinyl facilities in Louisiana were required to meet MACT requirements and demonstrate compliance with the AAS since before December 20, 1996.

Vinyl facilities are required to demonstrate compliance with the AAS through dispersion modeling programs developed by EPA, which using the facility's potential emissions of each toxic pollutant, must prove that the maximum impact on ambient air would be less than the AAS. If the modeled results are more than a certain fraction of the AAS, then all the other emission sources of that particular pollutant in a certain radius (called the area of inclusion (AOI)) must be added to the individual facility's emissions and modeled as well. In other words, cumulative emissions from areas that have more than one source of emissions are accounted for.

In fact, these requirements did reduce emissions as indicated by the most recent state Toxic Emission Data Inventory (2002), which indicates that vinyl chloride emissions from VCM/PVC manufacturing and other sources were 78,987 lbs out of total emissions of 53,275,510 lbs in the

[xi] La. Admin. Code tit. 33, § 5109A.

[xii] La. Admin. Code tit. 33, Chapter 51, Table 51.1.

[xiii] La. Admin. Code tit. 33, § 5109B.

state.[xiv] We are providing to you a report by Sage Environmental, which should further clarify Louisiana's use of ambient air quality standards in its permitting of facilities.[6]

C. U.S. Environmental Releases

Although EDC and VCM are released from EDC/VCM and PVC manufacturing processes, levels have been drastically reduced by manufacturing and pollution prevention practices implemented since the 1970's. Releases of EDC and VCM are closely monitored by EPA and are subject to public reporting under the annual Toxic Release Inventory (TRI) reporting requirements mandated by Section 313 of EPCRA.[xv]

Compliance with state and federal regulations and industry voluntary efforts to further reduce emissions reported under TRI requirements have significantly reduced the VCM emissions to the environment from the vinyl industry. As Table 1 indicates, air emissions account for ≥99% of total on-site emissions. In addition, total emissions have been steadily reduced by about 40% over the past dozen years, even as annual production has increased by about 35%.

Table 1: Vinyl Chloride Emissions Reported for the Toxic Release Inventory (TRI)[1]

Year	No.[2]	On-Site Emissions					Transfers to Off-Site Waste Mgmt.[3]	Total On- and Off-Site Emissions[3]
		Total Air Emissions[3]	Total Release to Water[3]	Under-ground Injection[3]	Total Releases to Land[3]	Total On-Site Emissions[3]		
1988	53	1,439,189	2,051	53	4,409	1,455,702	4,555	1,450,257
1995	48	1,044,665	525	33	1	1,045,224	15,645	1,060,869
1998	55	885,687	78	154	0	885,919	69,214	955,133
1999	51	848,576	106	405	1	849,088	14,015	863,103
2000[4]	51	773,239	177	43,650	0	817,066	623	817,689
2001[4]	52	732,219	102	96,042	1	829,366	1,002	829,366

[1] Source: EPA 2001 TRI Report
[2] Number Reporting
[3] In pounds
[4] Underground injection was reported by one company.

[xiv] Calculated from the Louisiana Toxic Emission Data Inventory Data Sets, sorted Chemical Name -- In Lbs/Yr, With Parish Subtotals and sorted by Parish Code & Sub-sorted by Facility Name, available from http://www.deq.state.la.us/evaluation/airmon/tedi.htm.

[xv] 42 U.S.C. 11011 et seq.

The EDC/VCM/PVC industry realized similar improvements in environmental releases of EDC.. For example total on-site EDC releases decreased from 1,719,598 pounds in 1988 to 248,090 pounds in 2001.[xvi] The USGBC PVC task group should gather and analyze TRI data for alternative processes.

D. Ambient Air Concentrations in Communities Near Manufacturing Facilities

As the enclosed Federal Register notice indicates, when EPA first established emission limits for VCM from vinyl manufacturing facilities, it estimated that industry's VCM emissions would be reduced by 95 percent.[7] In fact, emissions to air from U.S. vinyl production facilities have decreased more than 99 percent since 1976.[xvii] The 1976 EPA standard for VCM estimated that the annual average ambient air concentration within five miles of an EDC, VCM, or vinyl manufacturing plant would not exceed 1 part per billion (ppb).[xviii]

Since the 1970s, a number of programs have monitored ambient air in locations surrounding manufacturing facilities to identify potential exposures of nearby residents resulting from the vinyl and other production process.[8] The enclosed reports indicate that for VCM, the concentrations found were generally below the limit of detection and averaged below 1 ppb (2.56 $\mu g/m^3$), which is consistent with EPA's projections.

The state of Louisiana also has had an ambient air monitoring program at 15 sites, monitoring the air for 55 air toxics including VCM and EDC and reporting these results to the public annually. As part of this program, Louisiana compares the results of this program to the Ambient Air Standards (AAS) for air toxics, including the 1.19 µg/m3 (.49 ppb) for VCM based on the 24 hr sampling mentioned above. Most are located near the more heavily industrialized areas of the state. The monitoring is done using gas chromatographs with automatic samplers, a well established and proven technology.

What is often missed, or misinterpreted when looking at monitoring information, is that one instantaneous value above the AAS does not constitute a "violation" of the standard. As all of

---

[xvi] Calculated from the 2001 TRI data set from http://www.epa.gov/triexplorer/.

[xvii] Calculation based on total air emissions of 770,447 pounds (349.47 Mg) for SIC Code 28, Chemicals and Allied Products as reported in the 2000 TRI database at http://www.epa.gov/triexplorer/.

[xviii] ". . . the average exposure around these plants before installation of controls to meet the standard is 17 parts per billion." 41 Fed. Reg. 46,560.

the AAS levels are based on either an 8-hour average (Acute or non-carcinogenic toxics) or an annual average (Known and Probable Human Carcinogens), a one-time result above the AAS often averages out to much less than the AAS when other readings are taken into account and averaged. In fact, these single spikes are most useful in indicating that some unusual event may have taken place, therefore initiating action into identifying potential causes. Calling a single reading above the AAS a violation is misrepresenting the facts and ignoring how the standards were set.

E. Workplace Exposure

In the 1970s, a link was made between high, prolonged exposure to VCM among vinyl production workers and a rare form of liver cancer, angiosarcoma of the liver (ASL). ASL has also been linked to thorium dioxide and arsenic, which had been given medically and possibly to the use of anabolic steroids. In 1997, the U.S. Centers for Disease Control (CDC) conducted a review of its 1974 report on VCM to "illustrate the public health process in occupational safety and health – progressing from the initial observation of a new problem . . . to a targeted regulatory response, which virtually eliminated the newly recognized problem." As the enclosed report indicates, the CDC concluded that the development and acceptance by the PVC industry of a closed loop polymerization process "almost completely eliminated worker exposures" and that "new cases of hepatic angiosarcoma in vinyl chloride polymerization workers have been virtually eliminated."[9]

Likewise, the OECD SIDS report concluded that "[s]ince 1977, steady improvements in manufacturing facilities, engineering controls and workplace practices have substantially reduced workplace exposures in the U.S. to below the OSHA action level of 0.5 ppm." NIOSH health hazard evaluation studies after 1977 have primarily shown nondetectable levels of vinyl chloride.

We are not of any confirmed cases of angiosarcoma of the liver among vinyl chloride manufacturing plant workers whose careers in the industry began after the new regulations were promulgated.[10] Levels of exposure consistent with the current permissible exposure limit of 1 ppm have thus far proven effective in protecting workers.[11]

Indeed, EPA recently published an updated Toxicological Profile and Summary Health Assessment for VCM in its Integrated Risk Information System (IRIS) database, which lowers

EPA's previous risk factor estimate by a factor of 20. Moreover, EPA's IRIS profile now states that "[b]ecause of the consistent evidence for liver cancer in all the studies . . . and the weaker association for other sites, it is concluded that the liver is the most sensitive site, and protection against liver cancer will protect against possible cancer induction in other tissues."[12]

III. Community Health Concerns

With regard to concerns raised that VCM releases from vinyl industry facilities may be affecting the surrounding communities, particularly facilities in the State of Louisiana, a number of independent studies have been conducted to identify any association between historic community exposure to VCM (prior to the revised workplace practices instituted in the 1970s) and angiosarcoma of the liver (ASL) or other types of cancer in the general population.[13] In no case could a correlation be found with ASL. However, these studies were limited by the rarity of angiosarcoma in the general population, possible exposures to other factors linked to the disease, and difficulty in diagnosing the disease. Nevertheless, the industry continues to diligently monitor its employee workforce and communicate with communities surrounding their facilities.

The State of Louisiana recently reviewed its Tumor Registry data and concluded that neither the Calcasieu Parish area nor the river parishes (where a number of EDC/VCM/PVC facilities are located) show excess cancer levels. Instead, overall cancer rates in these parishes are similar to state and/or national averages.[14]

IV. Resin Processing and Materials Handling-Compounding and Fabrication

There are few studies in the USGBC database that address processing emissions or worker exposure and safety during plastic fabrication. Most historic studies on PVC fabrication have focused on potential vinyl chloride exposure from RVCM in the resin and decomposition products at temperatures above normal processing conditions.

A. Fabrication Workplace Exposure and Emissions

The residual vinyl chloride in resin produced in the United States declined dramatically from pre-1970 levels (>500ppm) following the changes in processing that occurred in the late 1970's, to the current levels below 1 ppm.[15] Likewise, atmospheric VCM levels in work areas during storage, shipment, and thermal processing of PVC resins experienced a commensurate reduction.

Predictive Diffusion models have estimated that workplace ambient air levels would be < 0.05 ppm when processing today's resins (typically below 1 ppm RVCM),[16] and actual reported levels have been shown to be non-detect.[17]

The study by Forrest, et al. (USGBC study number 1027) investigated emissions produced during the processing of several thermoplastics, including plasticized PVC, nylon 6, acrylonitrile-butadiene- styrene (ABS) high impact polystyrene (HIPS), low density polyethylene (LDPE) and high density polyethylene (HDPE).[18] Conducted to represent "real life" workplace conditions, the study concluded that although a wide range of chemicals were detected in each of the process environments, no individual chemical was found at a concentration above the existing occupational exposure limit in any of the situations that were examined. Hydrochloric acid, a know decomposition product of polyvinyl chloride was not detected. Nor could the study detect VCM near the equipment processing the rigid and flexible vinyl polymers.

In 1995 the VI commissioned a study on extrusion processing of rigid vinyl materials.[19] The study examined the processes and equipment typically used to blend and extrude PVC rigid compounds used for the fabrication of vinyl pipe, window lineals, and siding. The sampling and testing was conducted in accordance with EPA test reference methods and specifications and was reviewed by the Agency. As the enclosed results indicate, volatile organic emissions for processing rigid PVC were approximately 0.054 g/kg, but no hazardous pollutants including vinyl chloride, benzene and toluene were found at the levels of detection.

A third study, Schaper et al. investigated the effects of thermal decomposition products (TDP) released from acrylonitrile butadiene styrene (ABS), polypropylene-polyethylene copolymer (CP), polypropylene homopolymer (HP), or plasticized polyvinylchloride (PVC) on mice.[20] Based on their research, the authors determined that RD_{50} mass values (based on particulate concentrations) were 21.1, 3.51, 2.60, and 11.51 mg/m3 for ABS, CP, HP, and PVC, respectively. Exposure limits of 0.63, 0.11, 0.08, and 0.35 mg/m3 were recommended for TDP's of ABS, CP, HP, and PVC to protect workers from their irritating properties that would occur at temperatures above the normal processing temperatures and during thermal decomposition.

During the 30-min isothermal heating of ABS, CP, HP, and PVC at temperatures below 200° C no major decomposition of the polymers occurred, and it was necessary to heat large masses of each polymer in order to elicit significant effects on animal respiration. In addition, concentration-response curves had to be extrapolated to determine respective RD_{50} values. On the basis of these single exposures, the researchers concluded that molding operations conducted at normal processing conditions would not result in adverse respiratory effects among workers. However, as furnace temperatures increased to between 200-300°C (temperatures above normal processing temperatures), this conclusion was no longer supported by the data.

B. Safety

The product fabrication segment of the industry actively promotes worker safety. In 2002, the Occupational Safety and Health Administration (OSHA) and the Society of the Plastics Industry, Inc. (SPI) agreed to establish an Alliance to promote safe and healthful working conditions. This Alliance focuses on providing employers with information and guidance that will help them protect employees' health and safety, particularly in identifying and eliminating hazards, with particular emphasis on avoiding amputations and reducing and preventing exposure to ergonomic hazards.[xix]

The work product of this Alliance includes an injection molding machine safety course, which helps identify the types of injuries that can occur while operating an injection molding machine and ways to avoid those injuries. The Alliance also cooperatively developed a number of OSHA eTools, such as the "Plastics Module of the Machine Guarding eTool." These materials discuss guidelines and safety measures for horizontal injection molding machines.[xx]

V. PVC Dust

In 2001, the Vinyl Institute commissioned the Sapphire Group, Inc. to review the existing toxicological literature on PVC dusts. The Sapphire Group reviewed over 120 papers, many of which have already been included in the Task Group's *PVC Reports List*, and which are summarized in the enclosed report.[21] The Sapphire Group concluded that the animal and epidemiology data indicate that the lung is the primary target organ affected by exposures to

---

[xix] A copy of the SPI-OSHA agreement appears at http://www.osha.gov/SLTC/ergonomics/alliance_plastics.html.

[xx] For more information on these industry and OSHA efforts, visit the Plastics Focus portion of OSHA's Web site at http://www.osha.gov/SLTC/plastics/index.html.

respirable dusts and that prolonged exposures to high concentrations of PVC dusts can overwhelm the clearance mechanisms of the lung, resulting in a benign pneumoconiosis.

The Sapphire Group noted that the majority of the PVC produced in the U.S. occurs by suspension polymerization (96%), which results in particle sizes that are generally too large to be respired. Suspension PVC resins are primarily used for the manufacture of PVC pipes, windows, siding, and vinyl composition tile. PVC dusts can contain one or more adjuvant or impurities that may affect its toxicity, particularly the PVC dusts from the emulsion polymerization process. Because of their unique material properties, emulsion resins are used in only certain specialty applications, and these smaller particle size resins only account for 4% of all polyvinyl chloride production. The total number of workers potentially exposed to emulsion resins is correspondingly limited relative to the universe of workers handling PVC resins generally. On the other hand, emulsion resins often are shipped in smaller packaging containers and may require more manual handling operations than suspension resins, which are more likely to be shipped and handled in bulk containers.

The Sapphire Group concluded that the quantitative data available for both emulsion and suspension PVC dusts, including epidemiological and toxicological studies from which an occupational exposure limit could be derived, are extremely limited. Epidemiology studies, while providing suggestive evidence of pulmonary function changes, radiographic abnormalities, and subjective symptoms, generally do not provide adequate information regarding exposure to allow an adequate characterization of an exposure-response relationship.

Two animal studies which serve as potential candidates for deriving a recommended occupational exposure limit include: (1) a study in rats, guinea pigs, and monkeys that identifies a chronic lowest observed effect level of 13 mg/m^3 for benign pneumoconiosis without change in pulmonary function;[22] and (2) a study in rats that reports a concentration dependent increase in lung inflammation and hyperplasia following chronic exposure to 3.2-20 mg/m^3. [23]The strengths of the Groth study include its use of primates as one of the test species, thereby making the results potentially of greater relevance to human exposures. The primary weakness of this study, however, is that only a single test concentration of PVC dust was examined. The strengths of the Takenaka study include the testing of three dust concentrations and the availability of kinetic information in a companion study, which could be used to assess the importance of lung burden and clearance in toxicity.[24]

The American Conference of Governmental Industrial Hygienists (ACGIH) established a Threshold Limit Value (TLV) for respirable particulates not otherwise specified (PNOS) (ACGIH, 2001) of 10 mg/m^3 for inhalable particles and 3 mg/m3 for respirable particles. These TLV values are considered to be protective of "*toxicity caused by physical overloading of the normal clearance mechanisms of the respiratory tract*" (ACGIH, 1997). Based upon a consideration that the toxicity database that supports the PNOS TLV values is much stronger than the limited toxicity database for PVC particulates, Sapphire Group concluded that occupational health and safety decisions regarding PVC dusts continue to be made using these existing PNOS TLV levels. These levels are similar to limits for many insoluble "nuisance" dusts and can be met in the workplace with standard particulate control equipment and industrial hygiene work practices. US OSHA sets enforceable regulatory limits for dusts of this type at 15 mg/m3 TWA for inhalable dust and 5 mg/m3 for respirable dusts.

There has been continued research into the cytotoxicity of PVC dusts made from the emulsion polymerization. In 2003 the Vinyl Institute commissioned Sapphire Group to review the new studies by Xu et al.[25] The Sapphire Group has advised us that these new studies do not change their original recommendations. A review of each paper is included for the Task Group's consideration.[26]

The Sapphire Group also reviewed a recent case control study by Mastrangelo et al., (USGBC Study No. 8) which evaluated the potential relationship between PVC dust exposure and lung cancer.[27] Thirty-eight lung cancer cases and 224 controls were selected from among 543 claimants in a lawsuit. Holding the influence of smoking and age constant, the authors found that the risk of lung cancer for PVC dust baggers who are exposed to high levels of PVC particles in the workplace increases 20% for each extra year of work. In addition, the study found that recent PVC exposure has a more profound effect on the lung cancer odds ratio than distant exposure. By contrast, the authors found no relation between lung cancer and cumulative vinyl chloride monomer ("VCM") exposure.

The results of the Mastrangelo study must be carefully qualified. First, the choice of test cases was questionable. The potential existed for selection bias, since all cases and controls were participants in a lawsuit. Second, PVC baggers affected by PVC exposure could have been exposed to other chemicals in the workplace in addition to PVC. Third, the study focused on a small number of subjects, in particular the most exposed baggers. Finally, other factors- such as cigarette smoking- could contribute to an increased risk of lung cancer. Indeed, any increase in lung cancer mortality among PVC baggers could be related to smoking frequency and bagging years, not necessarily PVC dust exposure. The study demonstrates that tobacco is carcinogenic and that smoking in combination with exposure to other types of pollution, not only PVC dust, can increase the risk of lung cancer. PVC dust as a tumor promoter is purely speculation, and the study fails to prove the nature of its role if any.

VI. Dioxins

The vinyl industry, while never a significant source of dioxin, has reduced these emissions still further. EPA has published an Inventory of Sources of Dioxin in the United States based on emissions data up to 1995 (see chart below), and developed estimates of dioxin emissions for 2002-2004.[28] The Agency determined that total calculated emissions in 1995 were 3,252 g TEQ, and would decline to 1,106 g TEQ by 2002/2004. The decline is accounted for primarily by significant reductions in emissions from municipal and medical incinerators, cement kilns and secondary copper smelting.

A. Dioxins From Vinyl Manufacturing

The manufacture of polyvinyl chloride (PVC or vinyl) has been associated with extremely low emissions of dioxin. In the year 2000, U.S. industrial facilities began reporting their emissions of dioxin to the environment for inclusion in EPA's Toxic Release Inventory (TRI). Aggregating facility-by-facility reports for that year and converting congener specific data to toxic equivalents (TEQ) shows that total emissions of dioxin to air, water and land from the U.S. chlorine chemistry sector as a whole (which includes vinyl manufacturers as well as other chorine-related processes) were approximately 33 grams on a TEQ basis. Data for 2002 indicate that dioxin emissions for this same sector were approximately 10 grams TEQ. Thus, emissions of dioxin from the chlorine and vinyl chain have been reduced by nearly 70 percent from the already low levels.[29]

EPA's Dioxin Inventory does not compare with TRI data exactly because (aside from the different time frames) the data are reported in different ways. The dioxin Inventory is based on dioxin emissions from specific processes whereas the TRI is based on data by facility.[xxi] Nevertheless, the chlorine chemistry sector's total emissions of 10 grams TEQ favorably compares against other dioxin sources listed in the Inventory. Dioxin sources larger than chlorine manufacturing for 1995 and projected for 2002/2004 include residential wood burning (i.e., fireplaces; 62.8 grams in both time frames), coal-fired utilities (60.1 grams in both time frames), diesel trucks (35.5 grams in both time frames) and others, including manufacturers of a number of materials used in the building and construction industry.

B. Alternatives to Vinyl May Increase Dioxin Emissions

The Healthy Building Network has proposed reducing vinyl use to eliminate dioxin. Reducing vinyl would not reduce dioxin releases to the environment. In fact, many of the possible alternatives for PVC are equivalent or larger sources of dioxin releases to the environment. Even products like linoleum can be large sources of dioxins due to their energy and transportation requirements which are sources of dioxin releases to the environment.[30] As the table summarizing the most comprehensive U.S. study on releases of dioxin to the environment indicates, substituting alternatives to vinyl could increase, rather than decrease, dioxin releases:[31]

[xxi] In 2002, the vinyl industry concluded its study of its U.S. facilities for emissions of dioxin resulting from the ethylene dichloride (EDC), vinyl chloride monomer (VCM) and polyvinyl chloride (PVC) production processes. This characterization program was conducted with guidance from the U.S. EPA and used EPA-approved protocols, and results were reviewed by an independent third-party panel of international scientific experts and are included in the EPA's pending Dioxin Reassessment documents. The program determined that vinyl production contributed to air, water, and land surface approximately 13 of 3,000 grams TEQ that EPA estimated were produced annually from human sources based on 1995 data. This was less than one-half of one-percent of EPA's estimate of total U.S. dioxin emissions to these media at the time. The characterization data is included in the EPA Inventory under "EDC/Vinyl chloride, air;" "EDC/Vinyl chloride, water;" and "EDC/Vinyl chloride, land."

Inventory of Sources of Dioxin-Like Compounds in the United States - 1987 and 1995

Source	1987 Emissions (g TEQdf-WHO98/yr)	1995 Emissions (g TEQdf-WHO98/yr)	Percent Reduction 1987 - 1995
Municiple Solid Waste Incineration, air	8877.0	1250.0	86%
Backyard Refuse Barrel Burning, air	604.0	628.0	-4%
Medical Waste Incineration, air	2590.0	488.0	81%
Secondary Copper Smelting, air	983.0	271.0	72%
Cement Kilns (hazardous waste burning), air	117.8	156.1	-33%
Sewage Sludge/land applied, land	76.6	76.6	0%
Residential Wood Burning, air	89.6	62.8	30%
Coal-fired Utilities, air	50.8	60.1	-18%
Diesel Trucks, air	27.8	35.5	-28%
Secondary Aluminum Smelting, air	16.3	29.1	-79%
2,4-D, land	33.4	28.9	13%
Iron Ore Sintering, air	32.7	28.0	14%
Industrial Wood Burning, air	26.4	27.6	-5%
Bleached Pulp and Paper Mills, water	356.0	19.5	95%
Cement Kilns (non-hazardous waste burning)	13.7	17.8	-30%
Sewage Sludge Incineration, air	6.1	14.8	-143%
EDC/Vinyl chloride, air	NA	11.2	NA
Oil-fired Utilities, air	17.8	10.7	40%
Crematoria, air	5.5	9.1	-65%
Unleaded Gasoline, air	3.6	5.6	-56%
Hazardous Waste Incineration, air	5.0	5.8	-16%
Lightweight ag kilns, haz waste, air	2.4	3.3	-38%
Commercially Marketed Sewage Sludge, land	2.6	2.6	0%
Kraft Black Liquor Boilers, air	2.0	2.3	-15%
Petrol Refine Catalyst Reg., air	2.24	2.21	1%
Leaded Gasoline, air	37.5	2.0	95%
Secondary Lead Smelting, air	1.29	1.72	-33%
Paper Mill Sludge, land	14.1	1.4	90%
Cigarette Smoke, air	1.0	0.8	20%
EDC/Vinyl chloride, land	NA	0.73	NA
Primary Copper, air	0.5	0.5	0%
EDC/Vinyl chloride, water	NA	0.43	NA
Boiler/industrial furnaces	0.78	0.39	50%
Tire Combustion, air	0.11	0.11	0%
Drum Reclamation, air	0.1	0.1	0%
Carbon Reactivation Furnace, air	0.08	0.06	25%
TOTALS	13,998	3,255	77%
Percent Reduction from 1987 to 1995		77%	
NA=Not Available; (+)=reduction from 1987 to 1995; (-)=increase from 1987 to 1995; (0)=no change from 1987 to 1995.			

Dioxin emissions associated with vinyl production are reported in the lines for EDC/Vinyl Chloride Air, Land and Water. According to the EPA study, total dioxin emissions from vinyl production were about 13 grams TEQ, which accounts for less than 1 percent of dioxin releases to the environment for 1995. It is interesting to note that many of the alternative materials being reviewed by the PVC Task Group were larger sources of dioxin than PVC manufacturing in 1995.[32] For example:

Iron

Iron ore sintering	28 grams WHO TEQ
Coke production	7 grams WHO TEQ (Poorly characterized according to EPA)
Ferrous Foundries	20 grams WHO TEQ (Poorly Characterize according to EPA)

Cement

Cement Kilns (Hazardous Waste)	156.1 grams WHO TEQ
Cement Kilns (Non Hazardous Waste)	17.8 grams WHO TEQ

Aluminum

Secondary Aluminum	29.1 grams WHO TEQ
Primary Aluminum	no data reported by EPA

The United Nations Environmental Programme (UNEP) has also characterized dioxin emissions from a variety of sources on a per ton of product basis.[33] Based on current U.S. industry practices, the UNEP calculated emissions factor for dioxin releases to the environment from PVC manufacture to be approximately 1.5 µg TEQ/ton of PVC. The UNEP reports a wide range of emissions factors for alternative processes such as aluminum ranging from 0.5 µg TEQ/ton to 150 µg TEQ/ton of aluminum. According to UNEP, current European practices report an emissions factor of 3.5 µg TEQ/ton for a well controlled modern aluminum plant. Clearly, substituting alternative materials for vinyl could result in dramatically increased dioxin emissions, depending not only on the substitute material used but also the manufacturing technology. The PVC Task Group should give due and careful consideration to the UNEP report as it develops emissions factors for PVC alternative and their manufacturing processes.

Additionally, other building materials and sources have not been adequately characterized for their contribution to dioxin emissions and thus may be larger sources than comparable vinyl products. For example, linoleum is suggested as an alternative to vinyl; however, the shipment of linoleum from Europe to the United States is likely to be on a diesel burning ship releasing dioxin emissions to the environment. In addition, combustion of fuels in the manufacture of alternatives is a likely source of dioxin emission. According to Dwain Winters, Director, Dioxin Policy Project, EPA Office of Pollution Prevention and Toxics, other poorly characterized sources of dioxin include secondary steel electric arc furnaces, coke production, ceramic manufacturing, clay processing, ferrous and non-ferrous foundries, asphalt mixing plants, primary magnesium, and titanium Dioxide.[34]

C. Vinyl Incineration and Dioxins

With respect to the incineration of vinyl, most scientific studies on the issue indicate that the most important variable affecting dioxin emissions from incinerators is the design and operation of the incinerator unit, not the feedstock. In its Dioxin Reassessment, EPA concluded:

> *Although chlorine is an essential component for the formation of dioxins and furans in combustion systems, the empirical evidence indicates that, for commercial scale incinerators, chlorine levels in feed are not the dominant controlling factor for rates of dioxin and furan stack emissions*.[35]

In one of the largest studies ever conducted on dioxin generation, the American Society of Mechanical Engineers (ASME), a professional society representing 125,000 mechanical engineers worldwide, found little or no correlation between chlorine input and dioxin emissions from municipal incinerators.[36] The ASME study evaluated 100 combustors to determine the impact of chlorine in the feed (as measured by HCl in the combustion gases) on dioxin generation as measured upstream of the scrubbers. Of the 100 incinerators evaluated, 80% showed no significant effect of chlorine, 10% showed that dioxin increased with chlorine, and 10% showed that dioxin decreased with chlorine. In addition, these statistics demonstrate that temperature and incinerator design were important in dioxin generation.

The above conclusions from EPA and others indicate that reducing the use of vinyl will not reduce dioxin emissions to the environment. Instead, EPA has imposed strict regulations on municipal incinerators which have resulted in dioxin emissions reductions from nearly 9,000 grams TEQ in 1987 to an estimated 12 grams in 2002/2004. Emissions of dioxin from medical waste incinerators are estimated to have dropped from nearly 2,600 grams TEQ in 1987 to 7 grams when current regulations are fully implemented.[37] However, it is generally recognized that building materials are rarely incinerated because of their low BTU value. Those materials that cannot be recycled would predominantly be disposed of in landfills. Vinyl building products, however, are recyclable. The Vinyl Institute website identifies over 200 companies around the country that recycle vinyl products.[38]

D. Uncontrolled Combustion of Vinyl

In addition to their conclusion that reducing the use of vinyl is not an effective way to reduce dioxin emissions from incinerators, EPA scientists have reached a similar conclusion concerning the uncontrolled combustion of vinyl such as occurs in backyard burning of trash. A study conducted by EPA dioxin experts and published in 2003 examined the impact of higher chlorine contents of waste--as might be expected from increased vinyl content—on dioxin emissions.[39] The authors concluded that there was "no statistically significant effect on emissions from the Chlorine content of waste except at high levels, which are not representative of typical household waste." Accordingly, reducing vinyl use would not be an effective way to reduce dioxin emissions from uncontrolled burning. This compelling scientific evidence has led the Binational Toxics Strategy Burn Barrel Work Group to conclude:

> *There is always enough chlorine in the waste stream, even from natural materials such as salt and wood, to generate dioxins when garbage is burned. Burn conditions, such as operating temperature, seem to be a better indicator of dioxin emissions than chlorine content of waste. The smoldering, high particulate combustion of open burning offers ideal conditions for dioxin formation.*[40]

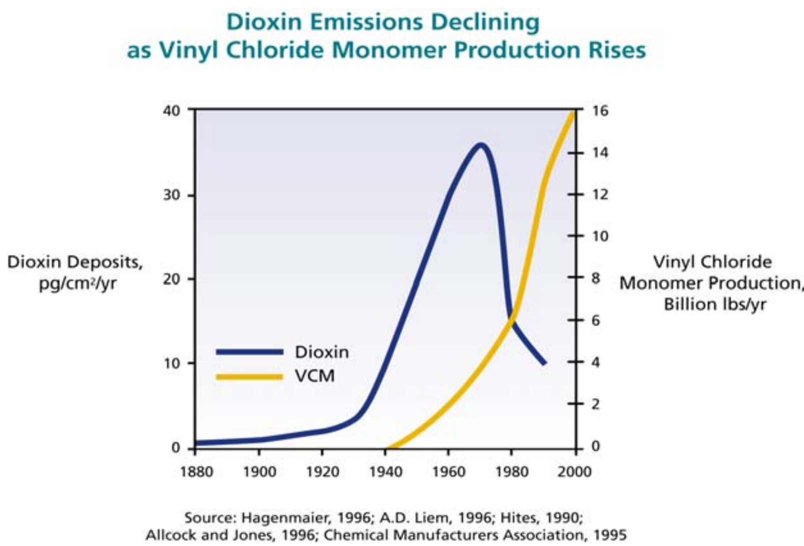
E. Building Fires and Dioxin

Dioxin is generated when burning virtually any fuel. This is certainly the case when burning a mixed load as in a building fire. Two studies examined the amount of dioxin generated by the combustion of vinyl in house fires in the United States (about 1 gram per year).[41, 42] They also compared the amount of dioxin generated from burning vinyl to the amount generated from burning wood in a typical house (approximately equivalent). Fire loads from articles in houses,[43] interior finishes,[44] roofing and insulation materials all have the potential to generate dioxins and furans as well. It follows that reducing the use of vinyl would not reduce dioxin production from building fires.

Moreover, vinyl is one of the least combustible of the organic materials in the built environment. As a result, it resists the spread of fire. Indeed, chlorinated PVC (CPVC) is one of the few materials listed in fire codes for use in sprinkler pipe. It is particularly useful for retrofitting older buildings. Eliminating the use of vinyl could eliminate a cost-effective means of preventing fire spread. Prudence and responsible building design, instead, strongly suggest anticipating and preventing fires through the use of devices for early detection (smoke and carbon monoxide detectors) and suppression (sprinklers).

F. Dioxin Emissions Declining as Vinyl Use Soars

As the chart below clearly demonstrates, dioxin emissions have been declining for the past several decades.[45, 46] Yet during this time, production of vinyl has dramatically increased. This simple fact indicates that there is no relationship between vinyl use and aggregate dioxin releases to the environment.



A similar conclusion was reached by EPA in 1997 when it stated:

> *[T]he effectiveness of a pollution prevention program directed at reducing dioxin emissions through shifting of waste composition from chlorinated plastics to nonchlorinated polymers would be questionable.*[47]

And, just this year EPA reiterated this finding in a statement currently posted on the Hospitals for a Healthy Environment Web site:

> *Although chlorine is an essential component for the formation of CDDs (dioxins) and CDFs (furans) in combustion systems, the empirical evidence indicates that for commercial scale incinerators, chlorine levels in feed are not the dominant controlling factor for rates of CDDs and CDFs stack emissions. There are complexities related to the combustion process itself, and types of air pollution control equipment which tend to mask any direct association. Therefore, the chlorine content of fuel and waste feeds to a combustion source is not a good indicator of levels of CDDs and CDFs emitted from the stack of that combustion source*[xxii]*…reducing or eliminating the overall mass of waste burned can be a*

[xxii] These findings are fully supported by both an independent peer review panel and the U.S. Environmental Protection Agency Science Advisory Board.

useful approach, more so than concentrated efforts to minimize chlorine in the medical waste stream.[48]

G. The Stockholm Convention and PVC

Finally, several presenters at the PVC TSAC public meeting urged the PVC Task Group to establish an "intent" for a PVC elimination credit based on the Stockholm convention on Persistent Organic Pollutants (POPs). As TSAC members have repeatedly emphasized, the VI recognizes that such"intent" is beyond the PVC Task Group's mandate. We nevertheless address this proposal, because we believe a LEED PVC elimination credit based on the POPs Treaty: (1) mischaracterizes the intent of the Stockholm Convention; (2) is impractical and unwise; and (3) premature.

First, the Stockholm Convention does not list or directly address PVC. Moreover, it takes a practical approach to unintentional byproducts like dioxin. The Convention calls on countries to "*reduce the total releases [of unintentional POPs] with the goal of their continuing minimization and, **where feasible**, ultimate elimination.*" Since dioxins are byproducts of both natural and man-made sources, the Convention recognizes that complete elimination of these substances is simply not achievable.

More significantly, if the Stockholm Convention required the use of alternatives for any material associated with the generation of dioxin, then it would apply to hundreds of products used in building and construction, including iron and steel, cement, aluminum, copper, brick and glass as indicated in the UNEP document referenced above. Given the number of industries with higher emissions of unintended dioxins and other POPs, reliance on the Stockholm Convention seems an unwarranted and thinly veiled attempt at de-selecting PVC. Finally, the Convention will not go into force until May 17, 2004, and in the U.S., must be implemented at both the legislative and regulatory level. Moreover, an Expert Group under the Stockholm Convention is currently working to develop guidance that will help countries address unintentional byproducts with the goal of achieving major reductions. Accordingly, it would be premature for the USGBC to establish a POPs based credit where a regulatory system is not yet in place.

VII. Fire

After reviewing the data in the USGBC database, the VI does not understand the analytical framework under which USGBC plans to assess fire performance. Nonetheless, the VI is submitting 14 studies and reviews to supplement the database and better characterize the performance of vinyl products in a fire. The studies have been conducted under appropriate protocols and are particularly relevant to the issue of the fire safety of vinyl which, as demonstrated by numerous data, is reasonably well-understood. In addition, the VI is providing USGBC with several examples of building codes and standards that relate to fire safety and include vinyl building products.

A. Fire Performance of PVC

The overall fire performance of a building product is based not only on the fire properties of the material such as flammability, ignition temperature, contribution to heat load, and flame spread, but also on its intended use, expected mass amount and location in the building. For example, pipes, which are usually behind fire resistant walls, would not contribute to fire fuel loads and flame spread until later in a fire. The later stages of building fires typically involve the combustion of many types of materials that can cause exposure to many hazardous toxins, all of which require similar precautions to avoid or reduce exposure. Below we list several important fire performance characteristics of vinyl and known references:

- *Flammability*: Rigid PVC does not support combustion and neither does flexible PVC when compounded, as is usually found in the built environment. Note various test data demonstrating this for rigid and most types of flexible PVC.[49]

- *Decomposition temperature*: Thermogravimetric analysis (TGA) in Matlack shows onset of PVC decomposition (HCl generation) at ca 230-250 deg C and maximum rate of decomposition ca. 300 deg C.[50] This is well above normal processing temperature.

- *Combustion Toxicology*: HCl and carbon monoxide (CO) have about the same specific toxicity and same capability for impairment.[51,52] HCl is a small contributor to fire atmospheres. HCl is not always detected in fires, and when it is, the concentration is usually low.[53]

- HCl is not a persistent gas in fire atmospheres, particularly remote from the source of combustion where air is cool enough for a human to breathe without injury. HCl adsorbs on surfaces and is not available for inhalation.[54,55,56,57,58]

- CO is a much more important gas in fires because it remains in the atmosphere until diluted or combusted itself. Deaths occurring with low carboxyhemoglobin (COHb) levels in blood are not unusual and do not suggest "supertoxic" agents in fire atmospheres.[59]

In summary, combustion products of PVC are no more toxic than combustion products other building materials.

- *Products of Incomplete Combustion*: Polychlorinated dibenzodioxins and furans (PCDD/F) are produced in fires, whether PVC is present or not. Complete combustion of a normal house containing PVC and wood at a mass ratio of about 1 to 100 generates about equal amounts of dioxin from each.[60] This, however, assumes equivalent complete combustibility. Since PVC is less combustible than wood, however, the previous statement may be quite conservative if flammability and the largely exterior application of vinyl is taken into account.

- *Major Fires*: Most of the major fires involving large loss of life occurred over twenty years ago (Beverly Hills Supper Club, MGM Grand, etc.). None of the scientific reviews of these fires, regardless of product liability settlements, implicated PVC.[61] Statements to the contrary are based on indirect evidence such as pulmonary edema, but such pathology was also present in victims of fires prior to the common use of PVC,[62] and the aforementioned low COHB level. Early detection and suppression has helped to halve the number of fire deaths in the U.S. in the last 20 years.[63] This, and adherence to fire codes, is the correct approach to fire safety.

B. Building Codes and Standards That Include Vinyl Products

The fire safety of building materials is an issue that has been carefully studied and considered over the years. Typically, building materials are selected to meet the fire performance requirements of local building codes and authoritative codes and standards-setting organizations like National Fire Protection Association (NFPA). In fact, NFPA's 300 life safety codes and standards influence every building, process, service, design, and installation in the U.S. as well as many of those in other countries.

Strict building codes and standards criteria related to fire performance exist for several types of vinyl building products, illustrating their fire safety and wide acceptance. We highlight below a few examples of fire requirements applicable to products in the USGBC matrix, including vinyl windows, vinyl backed floor coverings, resilient flooring, vinyl siding and DWV Pipe.

C. Vinyl Windows

Recent building code approvals include:

Metro-Dade County Building Code Compliance (1998) of AAMA-certified vinyl window profiles, meeting the following standards:[64]

- Flame Spread Index (FSI) < 75 (ASTM E84)
- 650°F self ignition temperature (ASTM D1929)
- CC1 or CC2 Rate of Burning (ASTM D635)
- Smoke Density (SDR) < 75 (ASTM D2843)
- For durability ± 10 % tensile strength retention (ASTM D638) after 4,500 hours xenon arc exposure (ASTM G26)

County of San Diego (unincorporated areas) and Rancho Santa Fe Fire Protection District (2001):[65]

- Acceptance of windows certified and labeled to ANSI/AAMA/NWWDA 101/I.S.2-97 for structural requirements.
- Acceptance followed extensive testing by the Forest Products Laboratory at U.C. Berkeley to determine vinyl window fire performance in the wildland/urban interface environment.

D. Carpets

1. The Pill Test

Vinyl backed floor coverings meet requirements mandated since 1971 that a carpet not spread a flame during a Stage 1 fire. These Federal regulations, also known as the "pill test," require carpets to pass Federal flammability requirements under DOC-FF-170. The test screens out carpets that are easily ignited by a small incendiary source, which was demonstrated in a series of experiments conducted by the National Bureau of Standards that confirmed that "[c]arpet systems, used in rooms will not normally spread fire provided they meet the requirements of DOC FF 1-70, (the pill test)."

2. The Radiant Panel Test

Vinyl backed floor coverings meet or exceed the minimum critical radiant flux value (0.45 watts/cm^2) required by the NFPA 101 Life Safety Code. The radiant panel test determines the critical radiant flux value (measured in watts per square centimeter) that is the lowest level of radiant energy necessary for a fire to continue to burn and spread. This minimum critical radiant flux value is recommended for corridors and exit ways of hospitals and nursing homes to provide a level of safety for the carpeted corridor which is greater than or equal to that required in the NFPA 101 Life Safety Code. It is based on the assumption that nonambulatory occupants (patients) require a higher level of protection than mobile occupants capable of rapid escape. In a building completely protected by an automatic sprinkler system, the likelihood of a Stage 2 fire developing or a floor covering burning becomes remote.

3. Building Code Performance

Vinyl backed floor coverings for commercial use have a "Class I" flammability rating and meet the flammability requirements for the following nationally recognized building codes for floor coverings:

- NFPA 101 Life Safety Code
- Standard Building Code
- Uniform Fire Code
- BOCA National Fire Prevention Code

4. The Pittsburg Protocol

The "Pittsburgh Protocol" is a standard test method for evaluating the combustion toxicity of floor covering products. This method analyzes the elements of the combustion gases that are emitted when a product is burned and compares them to known or suspected toxic chemicals. Testing of vinyl backed floor coverings under the Pittsburgh protocol has shown that they are less toxic than red oak when burning.

E. Resilient Flooring

Resilient floor coverings are usually exempt from model building code flammability requirements because they are not considered to be an unusual fire hazard. However, some building code officials, government agencies and other regulatory authorities require test information on the fire performance of resilient flooring. The most widely used test for flammability is based on the Flooring Radiant Panel test (ASTM E648). Another standard commonly used is ASTM E662 (Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials). The current editions of Building Officials and Code Administrators International (BOCA), Standard Building Code and the NFPA 101 Life Safety Code reference the Flooring Radiant Panel Test.

F. Vinyl Siding

Vinyl siding is widely accepted by the various building codes, including the International Conference of Building Officials (ICBO), Building Officials and Code Administrators International (BOCA), and the Southern Building Code Congress International (SBCCI). Vinyl siding properties are also specified and referenced by various codes to ASTM 3679, which includes flammability testing requirements. In addition, vinyl siding suppliers have evaluated their products and found they will meet Class A on flame spread under ASTM E-84.

G. Drain, Waste, and Vent Pipe

Drain, waste, and vent (DWV) pipes manufactured from PVC are widely accepted by the major plumbing codes and various government agencies in the U.S. To illustrate, we include a number of codes and standards that accept DWV pipe in the list below. PVC DWV pipe is usually installed behind a fire rated wall. When penetrations are made, they are required to meet ASTM

E-814 (Standard Test Method for Fire Tests of Through Penetration Firestops). In addition, rigid PVC DWV has excellent fire properties. In fact, the Plastic Pipe and Fittings Association evaluated rigid PVC piping products and found they meet a Class A rating on flame spread under ASTM E-814.

The major plumbing codes that accept PVC drain, waste and vent piping include:

- NATIONAL PLUMBING CODE, Building Officials and Code Administrators International (BOCA)
- UNIFORM PLUMBING CODE, International Association of Plumbing and Mechanical Officials (IAPMO)
- INTERNATIONAL PLUMBING CODE (ICC), International Codes Council
- STANDARD PLUMBING CODE, Southern Building Code Congress International (SBCCI)
- ONE AND TWO FAMILY DWELLING CODE, Council of American Building Officials
- NATIONAL STANDARD PLUMBING CODE, National Association of Plumbing, Heating, Cooling Contractors
- ANSI A40, SAFETY REQUIREMENTS FOR PLUMBING, ANSI
- NFPA 501, STANDARD FOR MANUFACTURED HOUSING, National Fire Protection Association
- ICC/ANSI 2.0-1998, International Codes Council (formerly CABO Manufactured Housing Construction Safety Standard)

U.S. Government agencies that accept PVC drain, waste and vent piping include:

- U.S. Department of Housing and Urban Development
- U.S. Federal Housing Administration
- U.S. Department of Energy
- U.S. Federal Emergency Management Agency
- U.S. General Services Administration
- U.S. Army Corp of Engineers
- U.S. Navy

Finally, the Vinyl Institute has maintained a compendium of related fire science papers, fifty-nine of which are referenced in the enclosed Fire and Polyvinyl Chloride.[66] Should the Task Group require, we can make these studies available as well.

VIII. Life Cycle Assessments

The Task Group's *PVC Reports List* contains a number of life cycle inventories and life cycle assessment (LCI/LCA) studies of vinyl building products. There are relatively few LCI studies on the alternative materials for the applications listed in the USGBC matrix. Many of these studies were conducted in Europe and are limited to comparing the manufacturing phase of competing materials. For the most part, these studies fail to address the installation and use phase, which for building products can be the most significant portion of the life cycle, yet nevertheless produce impacts that are difficult to characterize.

The VI recognizes that the USGBC PVC Task Group has expertise in life cycle methodology, and we expect that it will take the appropriate cautious steps in developing the product comparison matrix. Recognizing that different studies may use widely varying approaches and data sources, we urge the Task Group to develop a list of LCI/LCA reports which identifies the studies' characteristics, particularly their scope and boundaries. One of the reviews already in the *PVC Reports List*, Krahling, et al., attempts such a summary for a number of LCAs on pipe, window and flooring applications also on the list.

The following points are made by Krahling:

- Information from LCA studies has become increasingly meaningful in the discussion on the environmental profiles of various products.
- The data is dynamic as improvements in manufacturing efficiencies have reduced impacts
- Use phase impacts for windows and flooring can be significant, as example in one study on windows, 60-95% of the environmental pollution arises from the use phase.

An earlier report by Ecobalance (1996),[67] which reviewed 22 vinyl LCAs, several of which were included in the *PVC Reports List*, found that across all PVC applications, and even within automotive applications, LCA's have not shown consistent findings against or in favor of PVC.

A key consideration in conducting accurate life cycle analyses must be the determination of the service life during which to evaluate competing building products. Service life is not only important for comparing the useful life of building products, but also in evaluating the ability to recycle building products after a long period of first use. We are submitting several papers that discuss the physical properties of exhumed vinyl products after decades of service life. For example, house wiring that was removed from a number of residences after thirty years of service retained the same properties as when originally installed, indicating no loss or change in the composition. Following accelerated weather tests, the analysis determined that these 30-year old cables and sheathings retained a technical quality and service life suitable for reuse or mechanical recycling.[68] Examinations of exhumed PVC pipes after 30 years of service produced similar results.[69]

Although the plastics industry is relatively young compared to other building material sectors, production of industrial volumes of PVC polymer and PVC-U pipes is now in its seventieth year. A paper to be presented this year concludes that the production history of PVC pipe is very close to the predicted 100-year service lifetime of PVC pipe applications, and allows:

> *a comparison to be made between the theoretical lifetime of pipes (based on extrapolation of results from long term hydrostatic burst pressure tests of up to 10,000h with the application of safety factors) with real life experience and actual test results. The comparison shows that the actual performance of the pipes has comfortably exceeded the performance predicted by the long term pressure tests more than 60 years ago. The conclusions which can be drawn are that the extrapolation of 10,000 hour pressure testing is, in fact, very conservative and that the actual service life of PVC-U pipes is likely to be more than double the original 50 year design life.*[70]

We are also submitting additional LCAs to the *PVC Reports List* that are not summarized in this overview.

IX. Data selection methodology and concerns

In selecting the documents accompanying this overview and those listed in the bibliography, the VI assumes that, in addition to conducting a general screening for relevance, the Task Group will: (1) weigh or evaluate the data it receives; (2) consider the soundness of the underlying test protocols used; and (3) apply any other relevant data quality considerations. Accordingly, the VI has not attempted to review or address all of the approximately 2,000 studies in the Task Group's PVC Reports list.[xxiii] Instead, the VI searched for articles relevant to the analysis of vinyl and to supplement the Task Group's PVC Reports List as needed. Although this narrative is generally organized along the framework of a PVC life cycle to contextualize the data submission, it is not intended to be a life cycle assessment or a complete exposition of the issues.

[xxiii] http://www.usgbc.org/Docs/LEED_tsac/TSACpvcTG_PVCreportslist_rev01-23-04.xls.

A. Data Selection Process

Our submission endeavors to address gaps in the existing PVC Reports Lists and correct misconceptions. Our silence on a study, however, should not be construed as a concurrence with its findings or an acceptance of its validity. The lack of organization to the PVC Reports List makes it extremely burdensome to attempt to review every study.

The VI also wishes to emphasize that it is not expert on other industries, and therefore, did not review studies or critique life cycle analyses (LCAs) for competing materials. The VI is not familiar with the processes used by these industries nor is it in a position to characterize the appropriateness of the relevant information. It is the responsibility of these industries to step forward with the appropriate life cycle and other information for their products. We hope the Task Group will encourage such submittals.

The PVC Task Group, however, must establish some basis for inter-industry comparisons. For example, we include information from the Environmental Protection Agency's Dioxin Reassessment which demonstrates that the manufacture of some competing materials generates more dioxin than PVC manufacturing. We also include some relevant PVC LCAs, which are summarized in Section VII. We expect that the Task Group will prepare or obtain comparable analyses for competing materials to benchmark comparison, for, in isolation, the data gives little perspective or guidance. At a minimum, the Task Group might consider using EPA's Building for Economic and Environmental Sustainability (BEES) or similar material comparison tools.

B. Data Quality and Sufficiency Concerns

We continue to have significant concerns about the "data" provided to the Task Group and the "precautionary approach" by which the Task Group has proposed to deal with data gaps and uncertainty. When comparing vinyl, which is one of the most closely scrutinized and regulated materials on the planet, to other materials, the Task Group cannot assume that the absence of evidence for these materials is evidence that they have a benign impact on the environment. Early in its review of vinyl chloride, EPA agreed that:

> *substitutes do exist or could be manufactured for most polyvinyl chloride uses. However, in general, these substitutes do not have some of the more desirable characteristics of polyvinyl chloride, such as nonflammability. If vinyl chloride*

> *and polyvinyl chloride were banned, other substitutes with these more desirable characteristics would likely be developed. There is a risk that these substitutes would also have adverse health or environmental effects. Since control measures are available which can reduce vinyl chloride emissions by 90 percent or more, it does not seem prudent to reduce emissions by the remaining percentage and take the risk of introducing new untested chemicals into the environment.*[xxiv]

This Gordian knot remains today, and is exacerbated by increasingly frequent "green" claims for products whose lifecycle have not undergone as rigorous an evaluation as PVC. The VI strongly urges the Task Group to look for the underlying substantiation in all environmental benefit claims, and indeed, to reject any unsubstantiated data.

In that vein, the VI remains concerned that the PVC Task Group only recently posted or made available to commenters the transcript, comments, and all presentations from the February 18, 2004 public meeting. We will need reasonable time and opportunity to review and comment on this data and any changes to the methodology. Accordingly, the VI reserves the right to supplement this submission at a later date.

X. Conclusion

The VI appreciates the opportunity to submit technical and scientific information on vinyl building products. We are available to discuss any issues raised by this overview or to respond to any questions you may have. In the meantime, please do not hesitate to call if you require any additional information or if we can be of assistance in any way.

Sincerely,

Tim Burns
President and CEO

[xxiv] National Emission Standards for Hazardous Air Pollutants: Standard for Vinyl Chloride, 41 Fed. Reg. 46,560, 46,561 (October 21, 1976).

BIBLIOGRAPHY

[1] SIDS Assessment Report from proceedings of 13th SIAM Bern Switzerland Nov. 6-9, 2001. Organisation For Economic Co-Operation and Development Web site. 2000. Available at: http://cs3-hq.oecd.org/scripts/hpv/.

[2] *Id.*

[3] *Id.*

[4] Vinyl Institute, Volume 1, Chapter 3, The Vinyl Institute Dioxin Characterization Program, Final Report (July 1, 2002).

[5] OSHA recordable case, Table 1: Incidence rates of nonfatal occupational injuries and illnesses by industry and case types. 2002. Available at: http://www.bls.gov/iif/oshwc/osh/os/ostb1244.pdf.

[6] Sage Environmental, Executive Summary: Louisiana Air Toxics Regulations, History and Application for the Vinyl Institute, March 31, 2004.

[7] *National Emission Standards for Hazardous Air Pollutants: Standard for Vinyl Chloride*, 41 Fed. Reg. 46,564 (Oct. 21, 1976). Based on reducing emissions from 96,000 megagrams per year (Mg/yr) as measured in 1974 to an estimated 4,910 (Mg/yr). *See National Emission Standards for Hazardous Air Pollutants; Vinyl Chloride*, 50 Fed. Reg. 1,182 (Jan. 9, 1985).

[8] The Houston Regional Monitoring Corporation (HRM), a consortium of more than forty companies with facilities in the Houston Ship Channel area in east Harris County, Texas, has been monitoring over 150 specific compounds in ambient air since 1988 using EPA protocols (24-hour composite every six days), including vinyl chloride. The other two programs were the *Houston Area Source Toxic Emissions (HASTE) Project; Health Effects Evaluation*, Texas Natural Resource Conservation Commission, Office of Air Quality/Toxicology & Risk Assessment Section (SFR-33) (February 1996), EPA Docket A-97-44, No. II-A-14; and the *Calcasieu Parish Air Sampling Project Information Bulletin*, EPA, June 2001.

[9] Epidemiologic Notes and Reports Angiosarcoma of the Liver Among Polyvinyl Chloride Workers – Kentucky, Centers for Disease Control and Prevention Web site. 1997. Available at: http://www.cdc.gov/epo/mmwr/preview/mmwrhtml/00046136.htm.

[10] Boeckx M. Presented at Medichem. Baltimore, MD; October 2002.

[11] Storm JE, Rozman KK. Evaluation of Methods for Establishing Safe Levels of Occupational Exposure to Vinyl Halides. *Regulatory Toxicology and Pharm*. 1997;25:240.

[12] EPA. Toxicological Review of Vinyl Chloride in Support of Information on the IRIS. May 2000.

[13] Popper H et al. *American J Path.* 1978;92:349. Falk H et al. *Env. Health Prospect*. 1981;41:107. J. Brady et al. *J Nat Cancer Inst.* 1977;59:1383. Fiechtner J et al. Morbidity, Mortality Weekly Report. Centers for Disease Control. 1976;25:57. Baxter PJ et al. *British Medical J*, 1977;II:919. (updated in the *Br. J. Ind. Medicine.* 1980;37:213). Saric M et al. *Env. Health Perspective.* 1976;17:189. Elinder CG, Pershagen G. *Pilot Study Concerning the Mortality in Njurunda Community.* Swedish Nature Conservancy Board. April 1978. Dalderup LM et al. *Lancet*. 1976;I:246. *See also, J Occupat. Med.* 1975;17:285. Iturra H. Proceeds of the Air Environment Specialty Conference, Pittsburgh, 96, 1976; Brady J et al. *J Nat Cancer Inst*. 1977;59:1383. *Also* Heath CW, Landrigan PS. *Hemangiosarcoma of the Liver.* Connecticut Public Health Service. Centers for Disease Control. Report EPI 74-104-2. October 9, 1974.

[14] Calcasieu Cancer Rates Similar to State/National Averages. *News Release, State of Louisiana Dept. of Health and Hospitals.* January 17, 2002.

[15] SIDS Assessment Report, *supra* note 1.

[16] BF Goodrich Chemical Group, Technical Service Bulletin No. 12, Vinyl Studies, November 1983.

[17] Forrest MJ, Jolly AM, Holding SR, Richards SJ. Emissions from Processing Thermoplastics. *Ann. Occup Hygiene.* 1995;39:35-53.

[18] *Id.*

---

[19] Process emissions for vinyl pipe industry. *J Vinyl & Additives Technology.* 1996;2.

[20] Schaper MM, Thompson RD, Detwiler-Okabayash KA. Respiratory responses of mice exposed to thermal decomposition products from polymers heated at and above workplace processing temperatures. *Am. Ind. Hyg. Assoc. J*. 1994;55:924-934.

[21] *TLV for PVC Dusts.* The Sapphire Group, Inc. April 10, 2002.

[22] Groth DH, Lynch DW, Moorman WJ, et al. Pneumoconiosis in animals exposed to poly (vinyl chloride) dust. *Environ Health Perspect.* 1981;4:73-81.

[23] Takenaka S, Rittinghausen S, Bellmn B, et al. Morphological effects of 'nuisance' dusts on the respiratory system in rats. *J Aerosol Sci.* 1987;18(6):717-720.

[24] Muhle H, Bellmann B, Creutzenberg O, Heinrich U, Ketkar M, Mermelstein R. Dust overloading of lungs after exposure of rats to particulates of low solubility: comparative studies. *J Aerosol Sci.* 1990;21:374-377.

[25] Xu et al. In vitro toxicity assessment of polyvinyl chloride particles and comparison of six cellular systems. *J Toxicol Environ Health A.* 2002;65(16):1141-59. Xu et al. Role of residual additives in the cytotoxicity and cytokine release caused by polyvinyl chloride particles in pulmonary cell cultures. *Toxicol Sci*. 2003;72(1):92-102. Xu et al. Pulmonary toxicity of polyvinyl chloride particles after a single intratracheal instillation in rats, time course and comparison with silica. *Toxicol Appl Pharmacol*. 2004;194(2):111-21. Xu et al. Pulmonary toxicity of polyvinyl chloride particles after repeated intratracheal instillations in rats, elevated CD4/CD8 lymphocyte ratio in bronchoalveolar lavage. *Toxicol Appl Pharmacol* 2004;194(2):122-31.

[26] Letter from the Sapphire Group, Inc, dated February 5, 2004.

[27] Mastrangelo et al. Lung cancer risk in workers exposed to polyvinyl chloride dust: a nested case-referent study. *Occup Environ Med.* 2003;60:423-428.

[28] Winters D. *Presentation to the North American Commission on Environmental Cooperation for 2002/ 2004 Estimate*. U.S. EPA. *See also* Database of Sources of Environmental Releases of Dioxin like Compounds in the United States. U.S. EPA National Center for Environmental Assessment Web site. 2001. Available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=20797.

[29] Toxics Release Inventory Demonstrates Chlorine Industry Success in Reducing Dioxin Emissions. TRIfacts.org Web site. Available at: http://www.trifacts.org/.

[30] National Institute of Standards and Technology, Building for Environmental and Economic Sustainability. Version 3.0C. October 2002.

[31] Database of Sources of Environmental Releases of Dioxin-Like Compounds in the United States. U.S. EPA National Center for Environmental Assessment Web site. 2003. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=20797.

[32] Sources of Dioxin-Like Compounds in the United States. U.S. EPA Web site. September 2000. Available at: http://www.epa.gov/ncea/pdfs/dioxin/part1/volume2/volume2.pdf.

[33] United Nations Environment Programme. *Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases.* May 2003. UNEP Chemicals. Geneva, Switzerland.

[34] Winters, Dwain, Director Dioxin Policy, U.S. EPA, Reassessment of Dioxin Science and Management of Dioxin Risks, Untitled Power Point Presentation 2003.

[35] Sources of Dioxin-Like Compounds in the United States. U.S. EPA Web site. September 2000. Available at: http://www.epa.gov/ncea/pdfs/dioxin/part1/volume2/volume2.pdf page I-22.

[36] American Society of Mechanical Engineers. *The Relationship Between Chlorine in Waste Streams and Dioxin Emissions From Waste Combustor Stacks.* (CRTD-Vol. 36) (1995). The design, oversight, and peer review of the study by 25 combustion experts from around the world was conducted by ASME. (Currently in USGBC Database.)

[37] Winters, Dwain, Director Dioxin Policy, U.S. EPA, Reassessment of Dioxin Science and Management of Dioxin Risks, presentation to North American Commission on Environmental Cooperation, North American Regional Action Plan for Dioxin, 10/24/2001.

[38] http://vinylinfo.org/database/vinyldata2/.

[39] Lemieux PM, Gullett BK, Lutes CC, Winterrowd CK, Winters DL. Variables affecting emissions of PCDD/Fs from uncontrolled combustion of household waste in barrels, *J Air & Waste Manag. Assoc.* 2003.

[40] Burn Barrell Work Group Strategy/Implementation Plan for Reducing the Prevalence of Household Trash Burning (Barrel Burning) in Rural Areas of the Great Lakes. Great Lakes Binational Toxics Strategy (GLBTS) Web site. 2004. Available at: http://www.c2p2online.com/documents/BurnBarrelStrategy-finalFeb04f.pdf.

[41] Carroll, Jr. WF. *Fire Mater*. 1996;20:161-166.

[42] Carroll, Jr. WF. *Chemosphere.* 2001;45:1173-1180.

[43] Ruokojarvi P, Aatamila M, Ruuskanen, J, *Chemosphere*. 2000;41:825-828.

[44] Zelinski V, Wichmann H, Lorenz W, Bahadir M, *Fresenius Envir. Bull*. 1994;3:449-453.

[45] Hagenmaier H, Walczok M, *Organohalogen Compd*. 1996;28:101-104.

[46] Alcock RE, Jones KC. *Environ. Sci. Tech*. 1996;30:3133-3143.

[47] *Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Hospital/Medical/Infectious Waste Incinerators*, 62 Fed. Reg. 48,359 (Sept. 15, 1997).

[48] http://www.h2e-online.org/tools/dioxin.htm.

[49] Fire and PolyVinyl Chloride. 1996. Retrieved from www.vinylinfo.org/publicationscenter/fire_pvc.pdf.

[50] Matlack, JD, Metzger AP *Thermal stability of modified poly(vinyl chloride) by TGA*, *J. Applied Polym. Sci*. 1968;12:1745-1750.

[51] Kaplan, HL; Grand AF; Switzer WG, Mitchell, DS, Rogers WR, Hartzell GE. Effects of combustion gases on escape performance of the baboon and the rat, *J. Fire Sciences* 1985;3:228-244.

[52] Hinderer RK, Hirschler MM. Update on smoke toxicity of vinyl compounds. *J. Vinyl Tech*. 1989;11:50-58.

[53] Treitman R, Burgess WA, Gold A. Air contaminants encountered by firefighters. *Am. Ind. Hyg. Assoc. J.* 1980;41:796-802.

[54] Beitel JJ, Bertelo CA, Carroll WF, Gardner RA, Grand AF, Hirschler MM, Smith GF. Hydrogen chloride transport and decay in a large apparatus: I. Decomposition of poly(vinylchloride) wire insulation in a plenum by current overload, *J. Fire Sciences.* 1986;4:15-41.

[55] Beitel JJ, Bertelo CA, Carroll WF, Grand AF, Hirschler MM, Smith GF. Hydrogen chloride transport and decay in a large apparatus: II. Variables affecting hydrogen chloride decay. *J. Fire Sciences*. 1987;5:105-145.

[56] Bertelo CA, Carroll WF, Hirschler MM, Smith GF. In: Grant CE, Pagni PJ, Eds. *First International Symposium on Fire Safety Science*. Washington, DC: Hemisphere; 1986:1079-1088.

[57] Galloway FM, Hirschler MM, Smith GF. Model for the generation of hydrogen chloride from the combustion of poly(vinyl chloride) under conditions of forcefully minimized decay. *Eur. Polymer J*. 1989;25:149-158.

[58] Galloway FM, Hirschler MM, Smith GF. Surface parameters from small scale experiments used for measuring HCl transport and decay in fire atmospheres. *Fire Mater*. 1992;15:181-189.

[59] Debanne SM, Hirschler MM, Nelson GL. In: Hirschler MM, ed. *Fire Hazard and Fire Risk Assessment ASTM STP 1150*. Philadelphia, PA: American Society for Testing Materials (ASTM); 1992:9-23.

[60] Carroll, Jr. WF. The relative contribution of wood and poly(vinyl chloride) to emissions of PCDD and PCDF from house fires. *Chemosphere*. 2001;45:1173-1180.

[61] Best RL. *Reconstruction of a Tragedy.* Boston, MA: National Fire Protection Association; 1977.

---

[62] Beller D, Sapochetti J. Searching for answers to the cocoanut grove fire of 1942, *NFPA J*. 2000;85-90.

[63] Karter MJ. *2000 United States fire loss report. NFPA J*. 2001;82-87. Available at: http://www.nfpa.org/research/nfpafactsheets/homefire/homefire.asp.

[64] *Checklist Number 0295 for Approval of Windows and Pass-through Devices*. Miami – Dade County, Building Code Compliance Office.

[65] Letter from Rancho Santa Fe Fire Protection District and County of San Diego Department of Planning and Land Use, Building Division. August 27, 2001.

[66] *Supra*, note 49.

[67] Search and Critical Review of Existing Life Cycle Studies on Vinyl and Selected Alternative Materials. Ecobalance, Inc. April 2, 1996.

[68] Jakabowicz I, Yarahmadi N, Gevert T. Effects of accelerated and natural aging on plasticized polyvinyl chloride (PVC), *Pol. Degradation and Stability.* 1999;66:415-421.

[69] Stahmer MW, Whittle AJ. *Long Term Performance of PVC Pressure Pipes in a Large Rural Water Supply Scheme.* Proceedings of Plastics Pipes XI, Munich, Germany. September 3-6, 2001.

[70] Huelsmann T. *70 years of experience with PVC pipes*. European Vinyl Corporation (Deutschland) Gmbh, Reinhard E. Nowack, ALPHACAN Omniplast GmbH. 2004.