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IMPLICATIONS OF SPECIES DIFFERENCES IN ASSESSING THE TOXICITY OF PVC COMBUSTION PRODUCTS AND IRRITANTS SUCH AS HCl TO HUMANS

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Toxicity of the Pyrolysis and Combustion Products of Poly(Vinyl Chlorides): A Literature Assessment

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Poly(vinyl chlorides) (PVC) constitute a major class of synthetic plastics. Many surveys of the voluminous literature have been performed. This report reviews the literature published in English from 1969 through 1984 and endeavors to be more interpretive than comprehensive. PVC compounds, in general, are among the more fire resistant common organic polymers, natural or synthetic. The major products of thermal decomposition include hydrogen chloride, benzene and unsaturated hydrocarbons. In the presence of oxygen, carbon monoxide, carbon dioxide and water are included among the common combustion products. The main toxic products from PVC fires are hydrogen chloride (a sensory and pulmonary irritant) and carbon monoxide (an asphyxiant). The LC_{50} values calculated for a series of natural and synthetic materials thermally decomposed according to the NBS toxicity test method ranged from 0.045 to 57 mg l^{-1} in the flaming mode and from 0.045 to > 40 mg l^{-1} in the non-flaming mode. The LC_{50} results for a PVC resin decomposed under the same conditions were 17 mg l^{-1} in the flaming mode and 20 mg l^{-1} in the non-flaming mode. These results indicate that PVC decomposition products are not extremely toxic when compared with those from other common building materials. When the combustion toxicity (based on their HCl content) of PVC materials is compared with pure HCl experiments, it appears that much of the post-exposure toxicity can be explained by the HCl that is generated.

Keywords: carbon monoxide, combustion products, hydrochloric acid, large-scale fire tests, polyvinyl chloride, pyrolysis products, small-scale fire tests, toxicity.

INTRODUCTION

Poly(vinyl chlorides) (PVC) constitute a major class of synthetic plastics and are used in a wide variety of industrial and household products. Approximately seven billion pounds of PVC resins were produced in the United States in 1984.[1] More than half of this amount, which corresponds to an average of about 30 lb per person, is used in building products, including pipe and fittings, flooring, siding, and a wide variety of other construction products.[2] Much of this goes into residential construction. Other major uses include packaging, electrical insulation for wire and cable, interior furnishings and a host of miscellaneous household products. Because of its ubiquitous presence in the built environment, PVC is a possible source of fuel in unwanted fires. In a number of fires, injuries to firemen and building occupants have been attributed to its thermal decomposition or combustion products.[3–5] This, together with PVC's wide distribution, has led to numerous studies of the nature of the products, their occurrence in fires and their physiological effects on living organisms.

A number of surveys of this voluminous literature have been performed. One of the early reviews was performed at the Underwriter's Laboratories in 1963.[6] An extensive survey was made by Tewarson at Factory Mutual in 1975–6, in which he cited 262 references.[7–9] In a supplement prepared in 1979, he cites an additional 56 references.[10] The literature has increased in volume at an accelerated pace since that time. Barrow, in his PhD thesis, provides an excellent review of the toxicity of the thermal decomposition products of PVC, with emphasis on experimental methods and physiological effects.[11] Boettner and Ball reviewed work on the composition of the volatile combustion products of PVC in 1981.[12] Kent and van der Voort described the behavior of PVC in fires in 1981.[13] Recently, Hinderer has reviewed the combustion product toxicity of PVC.[14]

Despite this volume of publications, it is difficult to obtain a clear picture of the role of PVC in fires. Reported data are difficult to compare and sometimes contradictory. A number of reasons may be cited for this difficulty:

(1) Pure PVC homopolymer (PVC resin) is almost never encountered outside the research laboratory. Most useful products are made from compositions compounded with a variety of additives designed to improve their properties. These additives include polymerization catalysts, plasticizers, lubricants, heat and light stabilizers, fire and smoke retardants, fillers and reinforcing agents.[15] The amount of plasticizer may vary from 10 parts per hundred of resin (phr) in semi-rigid PVCs to 100 phr in very flexible PVCs. Any of these additives can affect the fire properties of the material and the composition of its combustion products. It is rare that two investigators use what can be identified as the same formulation. Often the samples are not adequately identified and, in some cases, the formulation may not be known to the investigators.

(2) Methods of thermal decomposition or combustion of the samples vary widely from one study to another, particularly with respect to the thermal and atmosph-

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