

Destruction and Disposal of PCBs by Thermal and Non-Thermal Methods

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Foreword

This book, prepared from studies by TRW, Inc., presents thermal and non-thermal methods for the destruction and disposal of polychlorinated biphenyls (PCBs). The excellent stabilities of the PCBs made them extremely useful and highly desirable for commercial applications until their adverse effects on the environment were observed. PCB manufacture is no longer allowed in the U.S., but the problem that remains is how to dispose of pre-existing supplies in the most efficient and least hazardous manner, when they are eventually removed from service. The book is intended as a guide to the available and potentially available technology for thermal and non-thermal destruction and disposal of PCBs, as promulgated by the U.S. Environmental Protection Agency regulations.

The material is presented in two parts. Part I describes fundamental processes of combustion, thermal destruction systems, sampling and analysis methodology, and flame chemistry relative to PCB incineration.

Part II provides descriptions and evaluates various alternative chemical, physical, and biological PCB removal and/or destruction technologies, including carbon adsorption, catalytic dehydrochlorination, chlorinolysis, sodium based dechlorinations, photolytic and microwave plasma destructions, catalyzed wet-air oxidation, and activated sludge, trickling filter and special bacterial methods.

The information in the book is from the following documents:

Guidelines for the Disposal of PCBs and PCB Items by Thermal Destruction, prepared by D.G. Ackerman, L.L. Scinto, P.S. Bakshi, R.G. Delumyea, R.J. Johnson, G. Richard, and A.M. Takata of TRW, Inc. for the U.S. Environmental Protection Agency, February, 1981.

Interim Guidelines for the Disposal/Destruction of PCBs and PCB Items by Non-Thermal Methods, prepared by E.M. Sworzyn and D.G. Ackerman of TRW, Inc. for the U.S. Environmental Protection Agency, October, 1981.

The table of contents is organized in such a way as to serve as a subject index and provides easy access to the information contained in the book.

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Part I

Thermal Methods

The information in Part I is from *Guidelines for the Disposal of PCBs and PCB Items by Thermal Destruction* (EPA Report 600/2-81-022), prepared by D.G. Ackerman, L.L. Scinto, P.S. Bakshi, R.G. Delumyea, R.J. Johnson, G. Richard, and A.M. Takata of TRW, Inc. for the U.S. Environmental Protection Agency, February 1981.

NOTICE

This report has been reviewed by the Industrial Environmental Research Laboratory, the Office of Toxic Substances and Regional Offices of the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency or the Publisher, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Introduction

1. BACKGROUND

Polychlorinated biphenyls (PCBs) are derivatives of the compound biphenyl in which from one to ten of the hydrogen atoms have been replaced with chlorine atoms. PCBs synthesized for commercial use are mixtures of isomers. PCBs are not naturally occurring compounds.

PCBs have extremely high thermal and chemical stability. They are of low volatility (decreases with increasing chlorine content), are relatively non-flammable, and have excellent electrical insulating characteristics. Commercial mixtures are liquids at room temperature. They are insoluble in water, have a low degree of hygroscopicity, and are soluble in most common organic solvents.

There are 209 possible PCB isomers, ranging from three monochloro isomers to one decachloro isomer. The commercial mixtures are very complex, each containing many isomers. Sissons and Welti (1) identified 69 isomers in Aroclor 1254, a commercial mixture produced by Monsanto. Aroclor is a trademark of Monsanto, the principal U.S. manufacturer of PCBs, for a series of PCB mixtures. The digits "12" refer to biphenyl as the parent compound. The digits "54" indicate that the chlorine content of Aroclor 1254 is approximately 54% by weight. From 1971 through 1974, Monsanto produced Aroclor 1016 (an exception to this nomenclature) which was similar to Aroclor 1242 but greatly reduced amounts of penta-, hexa-, and hepta-chloro isomers. Other tradenames for PCBs or PCB fluids are: Chlorextol (Allis-Chalmers), Clophen (Farbenfabriken Bayer), Dykanol (Federal Pacific Electric Co.), Fenclor (Caffaro, S.P.A.), Inerteen (Westinghouse), Kanechlor (Kanegafuchi Chemical Industry Co.), Noflamol (Wagner

Electric Corp.), Phenoclor (Prodlec), Pyralene (Prodlec), Pyranol (General Electric), and Santotherm (Mitsubishi-Monsanto).

1.2 THE PROBLEM

The excellent stability characteristics of PCBs made them highly useful in numerous commercial applications: particularly dielectric fluids in capacitors and transformers, but also in heat transfer and hydraulic systems, pigments, plasticizers, carbonless copying paper, electromagnets, components in cutting oils, and others. Their wide use coupled with a lack of recognition of their hazards has led to PCBs being ubiquitously distributed worldwide in virtually all compartments of the environment (2). Highest concentrations are found in industrialized urban areas; but PCBs are found in air, water, soils, and marine samples in remote, unindustrialized areas. Experimental evidence, summarized in Reference 2, indicates that atmospheric transport is the major means by which PCBs have been so widely dispersed.

Although PCBs have low acute toxicities, other adverse effects have been found in humans, laboratory animals, and other organisms (3). A summary of toxicological and epidemiological data on the effects of PCBs, adapted from Reference 3, is given below. More detailed discussions are given in References 2 and 3. PCBs appear to cause tumors in laboratory animals. There are limited human epidemiological data, but excess carcinogenic effects have been observed in several large groups of people exposed to PCBs. Several studies in animals have shown that PCBs cause fetal resorption, birth defects, and high offspring mortality rates at levels of 1-5 mg/kg body weight. There is evidence that PCBs produce immunosuppressive effects in laboratory animals. PCBs have been observed to cause liver damage. PCBs have caused chloracne in human workers occupationally exposed to air levels as low as 0.1 mg/m³.

Adverse effects observed in laboratory tests also occur in wild animals. PCBs are known to bioaccumulate and to biomagnify. Effects noted in mink fed PCB contaminated fish include reproductive failure, reduced weight gain, increased mortality, and enlargement of liver, kidneys, and heart.

PCB mixtures are extremely toxic to several species of aquatic invertebrates and fish. Aroclor 1254 is toxic to several shrimp species at levels of about 1 ppb. Increased mortality of sheepshead minnows was observed in water containing 0.16 ppb of Aroclor 1254. Concentrations of Aroclor 1242, 1016, and 1254 as low as 0.1 ppb have been demonstrated to depress photosynthetic activity in phytoplankton.

The principal sources (2,3) on health effects of PCBs used in this report indicate that there is very little information on the relative adverse effects (toxicity, oncogenicity, mutagenicity, etc.) of individual

isomers or mixtures. It might be argued that the more highly chlorinated isomers or mixtures are more harmful, if only by virtue of the facts that they are less readily metabolized and eliminated than the less highly chlorinated species. However, EPA has not established standards for the different mixtures because all PCB mixtures: 1) can induce toxic effects at low levels, 2) include highly persistent components, and 3) include components that are subject to significant uptake and storage.

The realization of the widespread distribution of PCBs in the environment and growing knowledge of their hazards led Monsanto in 1972 voluntarily to restrict sales of PCBs to the manufacture of electrical transformers and capacitors. Monsanto ceased all production in 1977.

A few data points serve to illustrate the magnitude of the environmental contamination problem. It has been estimated (2) that over 400,000 metric tons (mt) (900 million pounds) of PCBs were sold domestically in the U.S. during the period 1957-1974. Nisbet and Sarofim (4) have estimated that cumulative sales of PCBs in North America from 1930 through 1970 amounted to 450,000 mt (1 billion pounds). Data from Reference 2 indicate that domestic sales from 1971 through 1974 were 60,000 metric tons (133 million pounds). Total domestic sales may thus be estimated at 510,000 metric tons (1.1 billion pounds). Nisbet and Sarofim (4) also estimated that during the period 1930 through 1970 cumulative losses of PCBs to the environment amounted to 354,000 metric tons (770 million pounds) distributed as follows:

- Air - 27,000 metric tons
- Fresh and coastal water - 54,000 metric tons
- Dumps and landfills - 270,000 metric tons

EPA has estimated (5) that up to and including 1975, between 136,000 and 181,000 metric tons (300 to 400 million pounds) of PCBs had entered the environment.

Growing evidence of the problem of PCB contamination led in 1976 to the inclusion of Section 6(e) in the Toxic Substances Control Act (TSCA). Section 6(e) of TSCA required EPA to regulate the marking and disposal of PCBs already in use. It also provided for a ban on the manufacture and use of PCBs in other than a totally enclosed manner by 1 January 1978, a complete ban on manufacture by 2 July 1979, and a complete ban on distribution in commerce and processing by 1 July 1979. The latter bans include activities conducted in a totally enclosed manner. EPA was, however, authorized to grant exceptions to the ban rules under certain conditions. Regulatory implementation of Section 6(e) is summarized in (3).

On 31 May 1979, EPA promulgated the final rule ("PCB Regulations")