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Allocation of PCB Sources at a Scrap Metal Yard

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Introduction

Polychlorinated biphenyls (PCBs) have been produced on an industrial scale since 1930, with particularly large volumes made in the 1950s through the1970s. Major applications were as: insulating and cooling agents for electrical transformers and rectifiers, heat transfer fluids, hydraulic fluids, lubricants, printing inks, adhesives, flame retardants, microencapsulation of dyes for carbonless duplicating papers, plasticizers, and coatings and resins. As a result of their widespread use, PCBs are commonly found at waste sites. Their need for remediation/removal is a frequent basis for environmental litigation.

This article examines how analytical data concerning PCBs and other materials can be used to allocate costs using a contaminant mass methodology. It uses experiences at a scrap metal yard as a framework for discussing common allocation and science-based issues associated with PCB contaminated scrap metal sites. With concentrations of individual PCB congeners and other marker compounds, it often is possible to determine critical data about the facility's history, including the sources and in some cases the timing of contamination. When the data yield a calculation of contaminant mass, it frequently provides the simplest way to allocate remediation costs where similar types of waste were disposed. A critical mass of parties often view such a methodology as fundamentally fair, because it can provide a reliable, transparent and consistent basis for assigning responsibility. Thus, it has emerged as a straightforward method for allocating costs among potentially responsible parties (PRPs) who had sent capacitors, PCB contaminated transformers, and other PCB contaminated scrap materials to a facility.

To illustrate this allocation method, the article will focus on experience at a particular (but, alas, an anonymous) site. This site is a metal scrap yard that has operated from at least the 1950s. It consists of two separate yards - a "Main Yard" and a "Secondary Yard." Historically, ferrous and nonferrous metals were recycled in the Main Yard; nonferrous metals were recycled in the Secondary Yard. Site operations included collecting ferrous and nonferrous metal from industrial and domestic sources and sorting, cutting, and crushing metals. PCB containing capacitors and PCB contaminated transformers were known to have been sent to the site. Process equipment (all potentially containing PCBs) including bailers, shears, as well as a variety of ancillary equipment used to handle scrap materials are operated at the site. In addition, a copper wire reclamation incinerator was operated from 1971 to 1987.

Approaches to and Difficulties of Allocation of PCB Sources

Commercial PCB products are in fact complex mixtures of individual chlorinated biphenyls and are known as Aroclors, which come in a variety of grades and concentrations. In some cases, it may be possible to allocate remediation responsibility based on identification of the Aroclor alone. For example, the uses of Aroclor 1248 are associated largely with hydraulic and heat transfer media. PRPs that can be associated with such uses (*e.g.*, disposal of die casting equipment, heat exchangers) reasonably can be assumed to be responsible for such contamination. The real world, however, is seldom so simple. PCB contamination at most waste sites - particularly at metal scrap yards - is complex, resulting from multiple releases over time. In such cases, it was difficult to state with precision the likely source of each Aroclor grade removed from the site based on knowledge of Aroclor grade and concentration alone.

An additional complicating factor is that, while Aroclors are extremely stable compounds, there are two processes by which the compositions of PCB mixtures are changed (commonly referred to as "weathering") upon release into the environment - fractionation and biodegradation. These processes complicate the effort to identify the source of specific Aroclors in an allocation.

Historic Use of PCBs

PCBs in Capacitors: PCB containing dielectric fluids (generically known as Askarels) in liquid-filled capacitors accounts for the largest single historic use of PCBs (~40 percent). Askarels for capacitors were of three types: Type D 2233 A (biphenyl that has been chlorinated to a content of 42 weight percent); Type D 2233 B (biphenyl that has been chlorinated to a content of 54 weight percent); Type D 2233 C (a mixture of approximately 75 percent Type D 2233 B and trichlorobenzene). In 1976, 90 to 95 percent of all impregnated capacitors manufactured in the United States were of the PCB type. Before 1952, Aroclor 1254 was the standard fluid for capacitors; Aroclor 1242, which has better electrical properties, was used after 1952. Aroclor 1016, a purified version of Aroclor 1242 (having still better electrical properties), was introduced in 1971. Replacement capacitor fluids that do not contain PCBs came into use in the late 1970s and early 1980s (IPCS 1993).

PCBs in Transformers: The use of PCB containing dielectric fluid in liquid-filled transformers accounts for the second largest historic use of PCBs (~ 30 percent). Unlike the most common dielectrics for capacitors, PCB-containing transformer dielectric fluids are not pure PCBs, but are mixtures of Aroclors and chlorinated benzenes. Generally, transformer Askarel fluids are mixtures of Aroclors (45 percent - 80 percent) and trichlorobenzene or tri/tetrachlorobenzenes (20 percent - 55 percent). Additional compounds (epoxides) were also used at low concentrations as stabilizers. Askarel Type E consists solely of Aroclor 1242. Aroclor 1260 was the predominant Aroclor in use prior to September 1971 when the Aroclor component was changed to Aroclor 1254. Aroclor 1242 also found use as a transformer dielectric fluid in formulations (Inerteen) beginning in the 1970s. Trichloro- and tetrachlorobenzenes benzenes (and conceivably epoxide stabilizers) serve as marker compounds for transformer Askarels.

PCBs in Plasticizers: PCBs are highly compatible with many synthetic thermoplastic resins and plastic materials and were used to impart a wide range of properties. The use of PCBs as plasticizers represented the third largest historic use of PCBs (~ 18 percent). Aroclors were used as plasticizers in such products as paints and varnishes (particularly with chlorinated and cyclized rubber, polyvinyl chloride and acetate, cellulosics, and epoxies), adhesives (particularly in hot-melt type and adhesive tape), inks (particularly inks of the inkpad type or for carbon paper); and sealants. Marker compounds for PCBs used as plasticizers are problematic, but physical examination of samples and analysis of potentially plasticized components may serve as suitable marker compounds.

Hydraulic Media/Lubricants: The use of PCBs as hydraulic media/lubricants represents the fourth largest historic use of PCBs (~ 8 percent). Aroclor 1248 (typically with a phosphate ester such as tricresyl phosphate) was used most extensively as a hydraulic fluid. Other Aroclor products (i.e., Aroclors 1242 and 1254) were also used in hydraulic media. In addition, the chemical stability and high density of Aroclors led to their use in a variety of applications including: internal lubricants for high compression air compressors, cutting oils (as chlorinated additives in the proportion of 5 to 10 percent of the cutting oil), high temperature oils, and extreme pressure lubricants. Tricresyl and other phosphate serves as a marker compound for PCB-containing hydraulic fluids. Marker compounds for lubricants are more problematic, but high molecular weight hydrocarbons may serve as suitable marker compounds.

Heat Transfer Media: PCBs also have found extensive use in indirect heating applications. Indeed, heat transfer media were sold under the registered trademark Therminol which was Aroclor 1248. Other Aroclors - 1242 and 1254 - also found application as heat transfer media. PCB containing heat transfer media were apparently used neat and had no serious competitors as nonflammable heat transfer fluids.

PCB Contamination of the Site

Extensive soil sampling for total PCBs and individual Aroclor product was conducted at both the Main and Secondary Yards of the Site. Significant amounts of debris - pieces and shavings of metal, plastic, rubber, wood, and brick - were typically found in excavated materials and samples. In addition, thirty (30) samples were reanalyzed for the purposes of more accurately quantifying individual Aroclor product concentrations; quantifying tri- and tetrachlorobenzenes isomer concentrations (used in transformer Askarels); quantifying tricresyl phosphate concentrations (used as a component of PCB containing hydraulic fluids); and identifying the presence of additional compounds that could be used to determine other contaminant sources. Analytical data were found to exhibit acceptable levels of accuracy and precision according to U.S. EPA quality control criteria.

These data provided an unusually detailed picture of the types and amounts of PCB products present at the Site. Aroclors 1242/1248 and Aroclor 1254 were the predominant PCB contaminants at the Site. (For the purposes of this analysis, concentrations of Aroclors 1242 and 1248 were combined into a single value using the greater of the reported concentrations due to the similarity of their chromatographic patterns.) The mean and median area-weighted concentrations of total PCBs at the Main Yard were approximately 24 mg/kg and 20 mg/kg, respectively. Not surprisingly, the primary areas of PCB contamination in the Main Yards were generally associated with those areas where scrap metals were mechanically cut and crushed. The mean and median area-weighted concentrations of total PCBs at the Secondary Yard were approximately 51 mg/kg and 30 mg/kg, respectively. In contrast to the Main Yard, there was no clear delineation of Aroclor product by area. The concentration of Aroclor 1260 was quite low at both yards.

Allocation Analysis

In general, the simplest method to allocate site remediation costs where similar types of wastes have been disposed is by contaminant mass. Such models are relatively easy to use in terms of data acquisition and computation requirements; in addition, they are transparent and easy to understand. Having knowledge of materials sent to the Site by waste generators, a good understanding of the Aroclor concentrations, and the presence/absence of marker compounds made allocation by contaminant mass the best choice as the basis for allocation at this Site. The allocation logic for this Site is shown in Figure 1.

The available data were used to assess the sources of PCB contamination of the Site as follows. Although Aroclors found use as dielectric fluids for transformers, Aroclors used for this purpose, until very recently, were mixtures of Aroclors and trichloro- and tetrachloro-benzenes. Thus, the compositions of PCB containing transformer dielectric fluids were either: a mixture of Aroclor 1260 and trichlorobenzene or tri-tetrachlorobenzene; a mixture of Aroclor 1254 and trichlorobenzene; a mixture of Aroclor 1242 and tri-tetrachloro-benzene; and Aroclor 1242 (after 1970). The presence of trichlorobenzene and tetrachloro-benzene is therefore a marker for transformer fluids. Tri- and tetrachlorobenzenes were present in about 42 and 19 percent of the reanalyzed samples, indicating that capacitor/transformer fluids contributed to the PCB contamination at the Site.

Aroclors 1242, 1248, 1254, and 1260 also found significant use as hydraulic fluids. Tricresyl phosphate, a typical ingredient of PCB-containing hydraulic fluids, was found in about ten percent of the re-analyzed samples. Aroclor 1248, used principally in hydraulic and heat transfer fluids, was found unequivocally in about three percent of the re-analyzed samples. Hydraulic/heat transfer fluids therefore contributed to the presence of PCBs at the Site.

The principal purpose of this analysis was to determine the amount of PCB contamination associated with transformer disposal. Using the allocation methodology shown below, approximately 50 and 18 percent of the Aroclor 1260 was estimated to be associated with Type A and Type B transformer Askarels, respectively. Another 17 percent of the Aroclor 1260 was estimated to be associated with hydraulic fluids. With regard to Aroclor 1254, approximately 17 percent of the Aroclor 1254 was estimated to be associated with Type D transformer Askarel, approximately 14 percent with hydraulic media, and approximately 18 percent with capacitors.

Because the focus of this work was PCB containing transformer fluids, allocation of Aroclor 1242 and Aroclor 1248 was somewhat problematic, since relatively little effort was made to distinguish between weathered 1248 and 1242. While no evidence was found to indicate the presence of the Type C (1242) transformer Askarel, the Aroclor 1242/1248 found at the Site could reasonably be associated with either capacitors or heat transfer fluids based on historic usage patterns. See Figure 2.

Based on measured PCB concentrations and geostatistical analysis (i.e., kriging), the relative masses of Aroclor 1242/1248, Aroclor 1254, and Aroclor 1260 were estimated to be fifty-eight (58) percent, thirty-seven (37) percent, and five (5) percent, respectively. Together with those immediately above, these data fixed the following values for contribution by PCB use as seen in Figure 3.

Conclusions

These results comported with data for transformers and capacitors known to have been sent to the Site. In addition, the relative percentages of individual Aroclors estimated are in accordance with known uses. Thus, for Aroclor 1260 use was largely expected to be associated with PCB example, contaminated transformers. Moreover, certain trends were clear

- The mixtures of PCBs in the samples were consistent with the presence of PCB contamination resulting from multiple releases over time that were either mixed together by site operations or occurred at the same location.
- Aroclor 1242 contamination could largely be attributed to sources other than transformers. Although Aroclor 1242 has been used in transformers, its relatively late introduction as a transformer dielectric fluid and the long lifetime of a transformer (annual failure rate of about 0.2%) made it unlikely that PCB contaminated transformers accounted for a significant portion of the Aroclor 1242 contamination present at the Site.
- Aroclor 1248 contamination could largely be attributed to the presence of hydraulic or heat transfer fluids at the site.
- Aroclor 1254 contamination was associated with transformer dielectric fluids. Based on the absence of marker compounds (tri- and tetrachlorobenzenes), a minor portion of the Aroclor 1254 contamination was associated with the disposal of PCB-contaminated transformer dielectric fluids.
- Aroclor 1260 contamination was associated with transformer dielectric fluids. Based on the presence of marker compounds (tri- and tetrachlorobenzenes), it was apparent that the major portion of the Aroclor 1260 contamination (a minor component of the PCB contamination at the site) was due to the release of PCB-contaminated transformer dielectric fluids.

Beyond the immediate results for this Site, the above discussion illustrates the essential features of a useful methodology for allocating the costs associated with remediation of a PCB contaminated site. The method is straightforward, transparent, easy to apply and should be applicable to any PCB contaminated site where site where multiple releases of different Aroclors have occurred over time and allocation is necessary. A particular strength of this method is that it is neither arbitrary nor capricious and can be readily understood.

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Figure 1 - Allocation logic. Figure 2 - Historic usage patterns. Figure 3 - Contribution by PCB

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