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# PCBs and dioxins/furans in attic dust collected near former PCB production and secondary copper facilities in Sauget, IL

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**Abstract**

Samples of settled attic dust from fourteen buildings located within two miles of the Solutia W.G. Krummrich and Cerro Flow Products facilities in Sauget, Illinois were analyzed for PCBs and dioxins/furans using HRGC/HRMS. The facilities released vast quantities of PCBs and dioxins/furans into the environment over many decades. The concentrations and homologues present in the samples of attic dust and in samples of soil collected by U.S. EPA demonstrate atmospheric transport of PCBs and dioxins/furans from these manufacturing sites and local dumps contaminated with these pollutants. The results demonstrate that attic dust is a useful metric for assessing historical exposure to atmospheric emissions.



*Keywords*: PCBs, dioxins, persistent organic pollutants, attic dust, Monsanto, Cerro Copper, Sauget, exposure assessment

## 1. Introduction

### *1.1 Background of PCBs and Dioxins Emissions in Sauget, Illinois*

Sauget, Illinois is an industrial area that was originally incorporated as the Village of Monsanto in 1926. Two prominent manufacturing plants located in Sauget are the Solutia W.G. Krummrich chemical facility (formerly Monsanto Company) and the Cerro Flow Products facility (formerly Cerro Copper Products). Both of these facilities have operated in Sauget since the 1920s to 1930s. As a consequence of chemical manufacturing operations and waste handling practices by these facilities over many decades, vast quantities of chemical emissions from these plants were released into the local environment.

Polychlorinated biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins (dioxins) and dibenzofurans (furans) are persistent organic pollutants that were released from the Monsanto and Cerro Copper facilities into Sauget

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and other surrounding communities via atmospheric transport. Sauget is located near the Mississippi River across from St. Louis, Missouri. Sauget is surrounded by the Village of Cahokia to the south, the city of East St. Louis to the north and east, and other area communities to the north, south and east.

The Monsanto W.G. Krummrich facility in Sauget, Illinois was one of only two domestic producers of PCBs in the United States. Monsanto's Sauget facility and its sister facility in Anniston, Alabama manufactured PCBs from approximately 1929-30 until the 1970s. PCBs production peaked in 1970 with approximately 85 million pounds produced at Sauget and Anniston [1]. Monsanto produced PCBs and polychlorinated terphenyls (PCTs) under the trade name "Arochlor". Between 1957 and 1971 there were twelve different Aroclors produced by Monsanto with chlorine contents ranging from 21 to 68 percent [1]. Monsanto also produced extensive lines of other organic chemical products at its W.G. Krummrich facility, including pesticides and other chlorinated organic chemicals that are known or suspected precursors for formation of dioxins/furans during the manufacturing process [2].

The Cerro Flow Products facility is located adjacent to the W.G. Krummrich plant. Cerro Copper's operations historically have included secondary copper metal production and copper tubing production. Manufacturing operations have included the processing of copper from various sources, including copper-bearing scrap materials such as insulated copper wiring. Copper metal produced from copper scrap is referred to as secondary copper [3]. Dioxins/furans form when chlorinated plastics are heated to high temperature in smelting furnaces [3]. U.S. EPA has identified secondary copper smelters to have a high potential for dioxins/furans emissions because of the abundance of chlorinated plastics in the copper scrap that is used as feed material [3,4]. By the time the U.S. EPA developed National Emission Standards for the secondary copper smelting category in 2005, the five operating secondary copper plants in the United States, including Cerro Copper in Sauget, were already closed [3]. As an example of the dioxins/furans emissions by this industry source category, a secondary smelter facility in Carrollton, Illinois (Southwire) that closed its smelter in May 2000 was the largest reported dioxin emitter to the U.S. EPA Toxic Release Inventory that year for only five months of operation [5,6].

As a result of decades of manufacturing by Monsanto and Cerro Copper Products at these two facilities, hazardous wastes, effluents, and emissions containing PCBs and dioxins/furans were released into the local environment. Hhistorical atmospheric emissions included releases directly resulting from production operations, but also from contaminated soils/sediments and waste materials deposited in various Sauget area toxic dumps. Re-suspension of contaminated particulate matter (dust) from sediments and local dump sites is recognized as a significant source of PCBs and dioxins/furans in the area. Hazardous wastes were discharged into local dump sites within the vicinity of these facilities from the 1940s into the 1980s. In 2001, numerous toxic dump sites and a two-mile stretch of a local creek (Dead Creek) were listed to the U.S. EPA National Priorities List (NPL) as Sauget Area 1 and Sauget Area 2 [7,8]. PCBs and dioxins/furans have been detected at high concentrations in soils and sediments sampled throughout the various dump sites within Sauget Areas 1 and 2 along with a wide variety of other toxic substances such as chlorobenzenes, chlorophenols, chloroanilines, and metals that are associated with chemical products and wastes from the Monsanto and Cerro Copper facilities [9,10].

### *1.2 Background on Dioxins Toxicity Assessment and Reference Levels*

Dioxins (CDDs) make up a family of 75 different chlorinated compounds called congeners [11]. Each congener has a different chemical structure. Furans (CDFs) are a family of 135 individual congeners [12]. Polychlorinated biphenyls are mixtures of up to 209 individual congeners [13]. Evaluations conducted by the Agency for Toxic Substances Control and Disease Registry (ATSDR) suggest that PCBs and dioxins/furans are highly toxic substances that have been shown to cause a variety of adverse health effects to exposed individuals, including cancer in humans and animals, neurotoxicity, reproductive and developmental toxicity, elevated blood pressure, changes in serum chemistry, immune system suppression, liver damage, skin irritation, and endocrine disruption [11,12,13]. The toxicity of dioxins and PCBs has been extensively studied by many scientific and medical researchers over several decades.

Because dioxins/furans are comprised of many different congeners in a mixture in wastes or in environmental media (e.g., soil), the toxicity level of dioxins/furans are evaluated using a method adopted by the World Health Organization (WHO) and U.S. EPA. This method compares the toxicity equivalency of seventeen (17) dioxins/furans congeners to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) [14]. TCDD is the most

frequently researched and the most toxic species of dioxins and is considered one of the most potent toxins ever studied. PCBs mixtures have many possible congeners present in a mixture and twelve (12) PCB congeners are measured to have dioxin-like toxicity. These twelve PCBs are customarily evaluated as to their toxicity equivalent to TCDD [14]. Dioxins/furans and dioxin-like PCBs present in a mixture are assigned Toxicity Equivalency Factors (TEFs) to calculate the toxicity equivalent (TEQ) concentration of the mixture relative to TCDD [14]. The concentration of each particular congener with TCDD toxicity in a mixture is multiplied by its respective TEF to obtain a TEQ value, which is its concentration relative to the toxicity of TCDD. The individual TEQs are then summed to provide a total TEQ concentration for the mixture.

U.S. EPA has been engaged in extensive environmental and toxicological assessment of dioxins/furans since the 1980s [15]. This work has developed into a series of studies, reassessment reports and evaluations that have continued to the time of this publication. U.S. EPA is currently performing a scientific reassessment of the health risks of exposure to dioxin and dioxin-like compounds, due to significant advances in scientific understanding of mechanisms of dioxin toxicity, significant new studies of dioxin's carcinogenic potential in humans and increased evidence of other adverse health effects [15]. The most current version of the U.S. EPA draft assessment, *Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds* was transmitted to the National Academy of Sciences (NAS) in 2004. Since that time, U.S. EPA has been engaged in a series of interagency work groups, workshops, and research studies to augment their findings and in response to comments by NAS and the public [15]. It is anticipated that U.S. EPA will finalize their reassessment in late 2010 or early 2011. Because the toxicity of dioxins has been under reassessment since the 1980s, U.S. EPA has not revised its recommended preliminary remediation goal (PRG) for soil contaminated with dioxins since 1998 [16].

U.S. EPA still references a 1998 guidance developed by their Office of Solid Waste and Emergency Response (OSWER) for the PRG for dioxins in residential soil [16]. PRGs are contaminant concentrations in environmental media (soil, air, and water) that are considered by the Agency to be health protective of human exposures over a lifetime, and are used as starting points for setting cleanup levels. The existing PRG for dioxins in residential soil is 1,000 parts per trillion (ppt) as TEQs and is based on a U.S. EPA toxicity value adopted by the Agency in 1985 [16]. This value is being reassessed by the Agency and may be replaced by a residential soil PRG that is more than two orders of magnitude lower. The U.S. EPA has since developed a draft recommended interim PRG for dioxin TEQs in residential soil of 3.7 ppt in December 2009 [16]. The U.S. EPA also has established regional screening levels (RSLs) for toxic compounds in environmental media, which are based on a target cancer risk of 10-6 and intended for use in preliminary screening evaluations. The current RSL for dioxins (TCDD) in residential soil based on U.S. EPA reference tables is 4.5 ppt [17]. Several states have adopted the RSL for dioxins as a more stringent criteria over the PRG. Based on the results of the current U.S. EPA dioxin reassessment effort, it is anticipated that the draft recommended interim PRG for dioxin TEQs in residential soil (3.7 ppt) will either be revised or adopted by the Agency. It is likely that the new PRG level will be within the same order of magnitude as the draft interim recommended level of 3.7 ppt. PCBs are evaluated using similar reference values to dioxins/furans and U.S. EPA presently uses a value of 1,000 ppt as a preliminary remediation goal.

The significance of a revised dioxin PRG for residential soil from 1,000 ppt to a level probably less than 10 ppt suggests that dioxins and dioxin-like substances historically measured in community environments may not have been adequately evaluated as to levels that may represent significant exposures. U.S. EPA has stated that, "once the draft recommended interim PRGs are finalized, EPA will re-evaluate residual dioxin levels at CERCLA sites where dioxin contamination has previously been evaluated, particularly if environmental samples were previously analyzed using methods with a detection limit greater than the draft recommended interim PRGs" [16]. Because the toxicity assessment of PCBs is related to dioxins/furans, it appears likely that PCBs sites and applicable remediation goals may also be reconsidered by the Agency.

PCBs and dioxins/furans are widely distributed in the global environment via air transport [18]. The global distribution of background levels of these persistent organic pollutants in environmental media are derived from historical industrial uses and releases of PCBs and dioxins/furans, widespread atmospheric distribution in the environment, and the persistence of these substances to degradation. In 2007, U.S. EPA published a pilot survey that established concentrations of dioxins, PCBs, and mercury in rural/remote soils from 27 locations throughout the continental United States and Alaska [18]. This study found an average total TCDD TEQ of 1.76 ppt,

including small contributions from dioxin-like PCBs. Total PCBs averaged 3,089 ppt in soils, where decachlorobiphenyl was the lowest of the homologues identified [18]. The U.S. EPA pilot survey provides useful reference values for remote, non-industrial areas in the United States. These background values are also useful for evaluating elevated concentrations of PCBs and dioxins/furans detected near industrialized areas such as Sauget, where manufacturing sources such as the Monsanto and Cerro Copper facilities are located.

It is noteworthy that decachlorobiphenyl was found to be substantially elevated in soil and attic dust samples collected in community areas near the Monsanto and Cerro Copper facilities. Decachlorobiphenyl (also known as PCB 209) is a fully chlorinated PCB homologue containing ten chlorine atoms. Decachlorobiphenyl has been reportedly associated with only one Arochlor mixture (Arochlor 1268) [19]. Elevated concentrations of decachlorobiphenyl in the environment are believed to be associated with historical manufacturing or use of Arochlor 1268. The distribution of PCBs and presence of elevated concentrations of decachlorobiphenyl were noted by Stratton and Sosebee in 1976 following a 1975 U.S. EPA soil survey around the plant to suggest airborne transport of the PCBs from the manufacturing facility with deposition onto the surrounding landscape [20]. The detection of elevated decachlorobiphenyl in attic dust samples further supports the conclusion that atmospheric transport of PCBs from the Monsanto facility and area dump sites has occurred in the surrounding community..

### *1.3 Results of Soil Investigations in Community Areas Near the Facilities*

The U.S. EPA conducted extensive studies into the environmental occurrence of PCBs starting in the mid-1970s [1,19]. It is noteworthy that manufacturing and phasing out of most PCBs uses were banned by Congress in 1979. U.S. EPA initiated a field sampling program in 1975 to assess the effectiveness of voluntary controls by industry in eliminating the release of PCBs. U.S. EPA's studies included the collection of fifteen soil samples from areas in the vicinity of the Monsanto W.G. Krummrich plant in Sauget in July 1975 [19,20]. Surface soil samples were collected from the plant boundary and to a distance of 1,450 meters in four directions [19,20]. The locations of the soil samples collected are illustrated in Figure 1 [19]. The results of analytical testing of the soil samples for PCBs are provided in Table 1 [20].

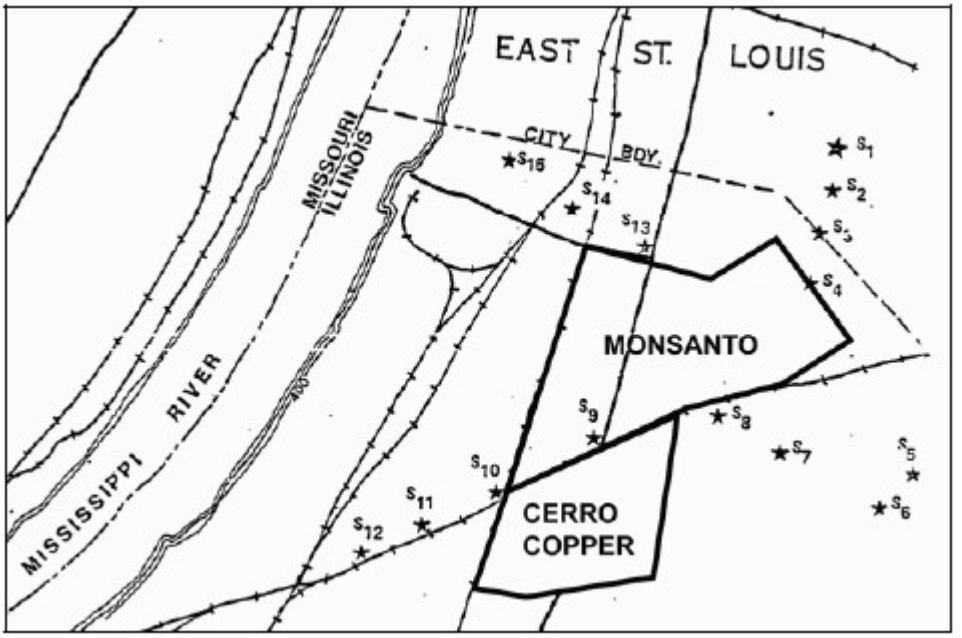


Figure 1. Locations of Soil Samples Collected Near Monsanto Facility by U.S. EPA in 1976. Modified from the original figure presented in the 1976 report by U.S. EPA [20].

Table 1. Soil Samples Collected Near Monsanto Facility by U.S. EPA in 1976 [20]

| Sample Station | Arochlor 1260 (ppb) | Arochlor 1242 (ppb) | Decachlorobiphenyl (ppb) | Total PCBs (ppb) |
|---|---|---|---|---|
| 1 | 50 | <10 | 97 | 147 |
| 2 | 120 | <10 | 610 | 730 |
| 3 | 1,400 | <10 | 900 | 2,300 |
| 4 | 310 | 680 | 380 | 1,370 |
| 5 | 200 | <10 | 270 | 470 |
| 6 | 1,300 | 820 | 1,600 | 3,720 |
| 7 | 2,900 | 3,000 | 1,300 | 7,200 |
| 8 | 9,600 | 6,100 | 2,400 | 18,100 |
| 9 | 650 | <10 | 120 | 7,700 |
| 10 | 280 | 450 | 81 | 811 |
| 11 | 100 | <10 | 49 | 145 |
| 12 | 260 | <10 | 81 | 341 |
| 13 | 9,600 | 10,000 | 1,100 | 20,700 |
| 14 | 30 | <10 | 400 | 430 |
| 15 | 390 | 460 | 120 | 970 |
| Average* | 1,813 | 1,437 | 634 | 4,342 |
| UCL** | 4,506 | 2,988 | 1,119 | 9,026 |
| RSL for Residential Soil*** | 220 | 220 | NA | 220 |

PCBs values are in units of micrograms per kilogram (ug/kg) or parts per billion (ppb). *Concentrations of <10 ppb were treated as 5 ppb for calculation of the average. **UCL (upper confidence limit) concentrations were determined using U.S. EPA software ProUCL 4.00.02. ***RSL for Arochlor 1260 = RSL for Arochlor 1242 = RSL for Polychlorinated Biphenyls (high risk) = 220 ppb.

U.S. EPA concluded in 1976 that the soil sampling results near Monsanto indicate that "the distribution of all PCBs analyzed appears to be higher near the plant site and generally decreasing with distance from the site" [20]. Stratton and Soseby also evaluated the 1976 EPA data and concluded that, [the results] "suggest airborne transport of the PCB's, including decachlorobiphenyl, from the manufacturing facility, with subsequent deposition onto the surrounding landscape [19]." These findings are important considering that the samples were collected around one of only two domestic PCBs manufacturing facility in the United States and represent data collected more than 30 years ago. As indicated in Table 2, the PCBs levels found around the Monsanto facility in 1976 were significantly elevated above the existing U.S. EPA cleanup reference level (1,000 ppt or 1 ppb).

PCBs and dioxins/furans have been found in environmental media samples in and around Sauget, Illinois at hundreds of locations near the Monsanto and Cerro Copper facilities, including Dead Creek and numerous local toxic dump sites listed as NPL sites Sauget Area 1 and Area 2. These areas have been investigated by Illinois EPA, U.S. EPA and the responsible parties since the late 1980s and into recent years. The records of these extensive investigations are documented in regulatory agency case files and are too extensive to summarize in this present article. However, the extent of the PCBs and dioxins/furans contamination in the area of Sauget has been approximately summarized in U.S. EPA administrative documents for these sites from the early 2000s [7,8,9,10].

PCBs can be transported in the atmosphere as vapors and/or as particulate matter. During the period of active manufacturing at the Monsanto facility, direct releases of PCBs to the atmosphere occurred as emissions of both vapors and particulates. PCBs have different vapor pressures depending on the degree of chlorination; therefore, volatilization of PCBs depends on the types of PCBs present in emissions, wastes and environmental media. Cycling of PCBs through the environment involves volatilization into the atmosphere, with subsequent removal from the atmosphere by wet or dry deposition, then revolatilization [13]. PCBs and dioxins/furans are typically entrained as contaminants in soils and sediments, which can be resuspended by winds and transported as particulate matter. PCBs and dioxins/furans can be redistributed in the environment as vapors and/or particulates when erosion or ground-breaking activities exposes contaminated materials.

The Monsanto facility itself has undergone various remedial investigations to assess the nature and extent of contamination at the site. The facility has been widely impacted by a variety of hazardous substances including

extensive contamination by PCBs. For example, it has been acknowledged that the site contains at least 60,000 pounds of PCBs in the upper 15-feet of soil in a four acre area [21]. It is also noteworthy that a sample of soil reported in a *Description of Current Conditions* report for the facility found dioxins at 2,811,000 ppt TEQs [22].


Figure 2. Location Areas for Soil Samples Collected Near the Monsanto and Cerro Copper Facilities by U.S. EPA in November 2009 [23]

In late 2009, U.S. EPA responded to concerns in the community about contamination and as a follow-up to their 1975 sampling of soils for PCBs in the area of Sauget. U.S. EPA Region 5 sampled surface soil at seventeen residences and a park in Sauget and fifteen residences, one church yard, and one playground in the Rush City neighborhood of East St. Louis in November 2009 [23]. This work was performed to "find out whether PCBs and dioxin pollutants carried by the wind or released from past industrial activity were present in the soil" [23]. U.S. EPA reported to the public that soil at six properties had PCBs concentrations at or above the preliminary cleanup goal of one part per million (ppm) [23]. Three residential yards and a park in Sauget and two residential yards in the Rush City neighborhood contained soils with PCBs between one and five parts per million [23]. U.S. EPA indicated that the health risks associated with PCBs/dioxins levels in residential soil below 1 ppm are considered to be low [23]. However, the Agency's recommended PRGs for PCBs and other dioxin-like compounds in residential soil are based on the 1998 OSWER soil dioxin guidance level, which is currently being reassessed and likely will be lowered significantly. Given the probability that the Agency will adopt an updated soil dioxin PRG using current toxicity information, it appears likely that elevated risks of exposure to PCBs/dioxins exist in areas surrounding the Monsanto and Cerro sites based on the results of U.S. EPA soil sampling and generic exposure assumptions. The potential risk of exposure to residents cannot be quantified because the activities of current and future occupants of the properties is unknown. U.S. EPA recommended residents follow measures to reduce exposure to soil contaminants [24].

Documents and data generated from the U.S. EPA Region 5 sampling effort conducted in Sauget and East St. Louis were obtained for our evaluation [25]. The majority of locations of the soil samples collected by U.S. EPA

in November 2009 were confirmed based on documents and data received from the Agency. However, the remaining locations could not delineated. Accordingly, the locations of the soil sampling have been depicted as two generalized areas as shown in Figure 2. The analytical results for soil sampling are summarized in Table 2. The Rush City neighbourhood of East St. Louis is indicated on Figure 2 as "Area 1" and the residential area of Sauget that was sampled is indicated on Figure 2 as "Area 2".

Table 2. Results for Soil Samples Collected Near the Monsanto and Cerro Copper Facilities by U.S. EPA in November 2009 [23]

| Sample Station | Area | Dioxins/furans (TEQs, ng/kg) | Total PCBs (ug/kg) | PCBs (TEQs, ng/kg) | Total TEQs (ng/kg) | Deca-PCBs (ug/kg) |
|---|---|---|---|---|---|---|
| 1 | Area 1 | 12.4 | 180 | | 12.4 | 180 |
| 2 | Area 1 | 16.4 | 320 | | 16.4 | 320 |
| 3 | Area 1 | 36.1 | 0 | | 36.1 | 0 |
| 4 | Area 1 | 61.6 | 4,400 | 56.5 | 118.1 | 1,300 |
| 5 | Area 1 | 11.5 | 0 | | 11.5 | 0 |
| 5 (dup) | Area 1 | 13.4 | 0 | | 13.4 | 0 |
| 6 | Area 1 | 49.8 | 690 | | 49.8 | 690 |
| 7 | Area 1 | 72.2 | 910 | | 72.2 | 910 |
| 8 | Area 1 | 52.9 | 220 | | 52.9 | 220 |
| 9 | Area 1 | 9.5 | 0 | | 9.5 | 0 |
| 10 | Area 1 | 58.6 | 0 | | 58.6 | 0 |
| 11 | Area 1 | 46.2 | 143 | | 46.2 | 110 |
| 12 | Area 1 | 80.6 | 210 | 31.3 | 111.9 | 61 |
| 13 | Area 1 | 40.2 | 450 | | 40.2 | 450 |
| 14 | Area 1 | 26.9 | 140 | 15.9 | 42.8 | 0 |
| 15 | Area 1 | 182.8 | 1,600 | 259.8 | 442.6 | 330 |
| 16 | Area 1 | 71.1 | 570 | | 71.1 | 570 |
| 17 | Area 2 | 224.2 | 1,050 | 48.9 | 273.1 | 450 |
| 18 | Area 2 | 274.7 | 143 | | 274.7 | 110 |
| 19 | Area 2 | 58.6 | 96 | 11.0 | 69.6 | 52 |
| 20 | Area 2 | 88.0 | 202 | 11.7 | 99.7 | 68 |
| 21 | Area 2 | 486.3 | 1,360 | 58.5 | 544.8 | 840 |
| 22 | Area 2 | 3.2 | 0 | | 3.2 | 0 |
| 23 | Area 2 | 87.7 | 311 | 16.1 | 103.8 | 230 |
| 23 (dup) | Area 2 | 58.0 | 393 | 14.4 | 72.4 | 260 |
| 24 | Area 2 | 95.9 | 140 | | 95.9 | 140 |
| 25 | Area 2 | 115.0 | 113 | 17.5 | 132.5 | 77 |
| 26 | Area 2 | 35.9 | 35 | | 35.9 | 35 |
| 27 | Area 2 | 130.7 | 252 | | 130.7 | 190 |
| 28 | Area 2 | 173.5 | 160 | | 173.5 | 160 |
| 29 | Area 2 | 710.5 | 0 | | 710.5 | 0 |
| 30 | Area 2 | 160.9 | 120 | | 160.9 | 120 |
| 31 | Area 2 | 667.5 | 1,990 | 80.7 | 748.2 | 310 |
| 32 | Area 2 | 548.7 | 1,010 | 67.5 | 616.2 | 200 |
| 33 | Area 2 | 167.6 | 268 | | 167.6 | 110 |
| 34 | Area 2 | 20.7 | 64 | | 20.7 | 64 |
| Mean | | 137.5 | 487.2 | 53.1 | 156.7 | 237.7 |
| UCL** | | 192.7 | 1088 | 90.3 | 220.9 | 453.9 |
| RSL for Residential Soil*** | | 4.5 | 220 | 4.5 | 4.5 | NA |

TCDD TEQ values are in units of nanograms per kilogram (ng/kg) or parts per trillion (ppt). PCBs values are in units of micrograms per kilogram (ug/kg) or parts per billion (ppb). *TEQs were calculated using WHO 2005 TEFs. Non-detects were treated as one-half of the detection limit. **UCL (upper confidence limit) concentrations were determined using U.S. EPA software ProUCL 4.00.02. ***RSL for 2,3,7,8-TCDD = 4.5 ng/kg. RSL for Polychlorinated Biphenyls (high risk) = 220 ug/kg.

As indicated in Table 2, dioxins/furans TEQs ranged from 3.2 ppt to 710.5 ppt. The average dioxins/furans TEQ was 137.5 ppt and the 95% upper confidence limit (UCL) for TCDD TEQ was calculated to be 192.7 ppt. PCBs provided small contributions to the total TEQs in the samples. Total PCBs ranged from non-detected to 4,400 parts per billion (ppb). The existing residential soil PRG used by U.S. EPA for evaluating dioxins is 1,000 ppt as TEQs. The existing reference level for evaluating PCBs in residential soil is also 1,000 ppt. As indicated above, only six soil samples exceeded the 1,000 ppt level for PCBs. None of the dioxins TEQ results exceeded 1,000 ppt. The U.S. EPA RSL values listed in the table have been provided for purposes of comparison. It is also noteworthy that the contribution of decachlorobiphenyls to the total PCBs in the samples was significant and ranged from 20% to 100% (see Table 2). The average contribution of decachlorobiphenyls to total PCBs in the soil samples was 70%, which suggests a source of deca-PCBs within the Sauget area that is likely associated with historical PCBs manufacturing and use.

### *1.4 Background on Attic Dust Sampling*

Undisturbed attics can act as archives of atmospheric dust, providing a useful tool to researchers interested in studying historic air pollution. The use of attic dust has the advantage of being a measurement, albeit indirect, of historical air pollution over time [26,27]. Because atmospheric dust settles in attics and may be undisturbed for many years to decades, it can provide an accumulated measure of historical air pollution. Atmospheric dust is primarily derived from external sources and enters attics through ventilation ducts intended to allow air flow through structures. Sajn [28] noted that, “attic dust is derived from external sources as aerosols deposit and as a result of soil dusting and less from household activities”. Cizdziel and Hodge [29] in their study of trace elements and pesticides in attic dust also stated that, “undisturbed attics may act as archives of atmospheric dust, by preferentially trapping and preserving airborne particulate matter, and should be considered by researchers interested in study of past atmospheric dust and/or reconstructing exposure histories”. Ilacqua, et al. [26] similarly stated that, “potentially, the most distinctive advantage attic dust offers is its ability to be used as a surrogate for human exposure to ambient air pollutants”. Thus, attic dust provides a useful metric for evaluating historical air pollution. Assessment using attic dust has been used in numerous studies published in the scientific literature [26,27,28,29,30].

This present study is focused on historical PCBs and dioxins/furans releases from the Monsanto and Cerro Copper facilities and the assessment of historical pollution using settled attic dust as a metric for evaluation. PCBs and dioxins/furans released from historical manufacturing operations and waste disposal areas in Sauget migrated in air currents into surrounding community areas where they were deposited with particulate matter or dust. Analytical testing of attic dust samples collected within the vicinity of these facilities provides an insight into the historical emissions and atmospheric dispersion of these pollutants. The results can also be compared to soil sampling investigations conducted in the area by U.S. EPA and others. It is noteworthy that tree barks and bores have also been investigated in this same area, while the information concerning this work cannot be reported at this time.

## 2. Materials and Methods

In April and June of 2008, fourteen samples of indoor attic dust were collected from seven residential dwellings and seven churches located in Cahokia and East St. Louis, Illinois, at locations within two miles of the Monsanto and Cerro Copper facilities. Church buildings initially selected for attic dust sampling were determined based on their geographic spatial distribution and telephone interviews with owners/occupants. The completed sampling locations, including residential homes, were based on obtaining access to the structures from willing participants at the time of the field work. Houses were also sampled based on interviews with property occupants and information concerning the age of structure, improvements and renovation history and attic usage. Funding for collection and analysis of attic dust samples was provided by Environmental Litigation Group, P.C., based in Birmingham, Alabama. The fourteen attic dust sampling locations and their proximity to the Monsanto and Cerro Copper facilities are depicted in Figure 3.

Samples were collected using a vacuum method developed for collecting bulk dust from limited access areas such as in attics and for assessment of dioxins/furans and other environmental persistent organic pollutants

(POPs). The method has been described in depth by Wu et al. [31]. The method was adapted from and is similar to the method used by the U.S. EPA for the World Trade Center (WTC) Indoor Air Task Force Working Group for the WTC Screening Methods Study in New York City [32]. The simplicity of sampler design, low cost, portability, and ease-of-use, decontamination procedures, allows for efficient and effective collection of bulk samples of dust.

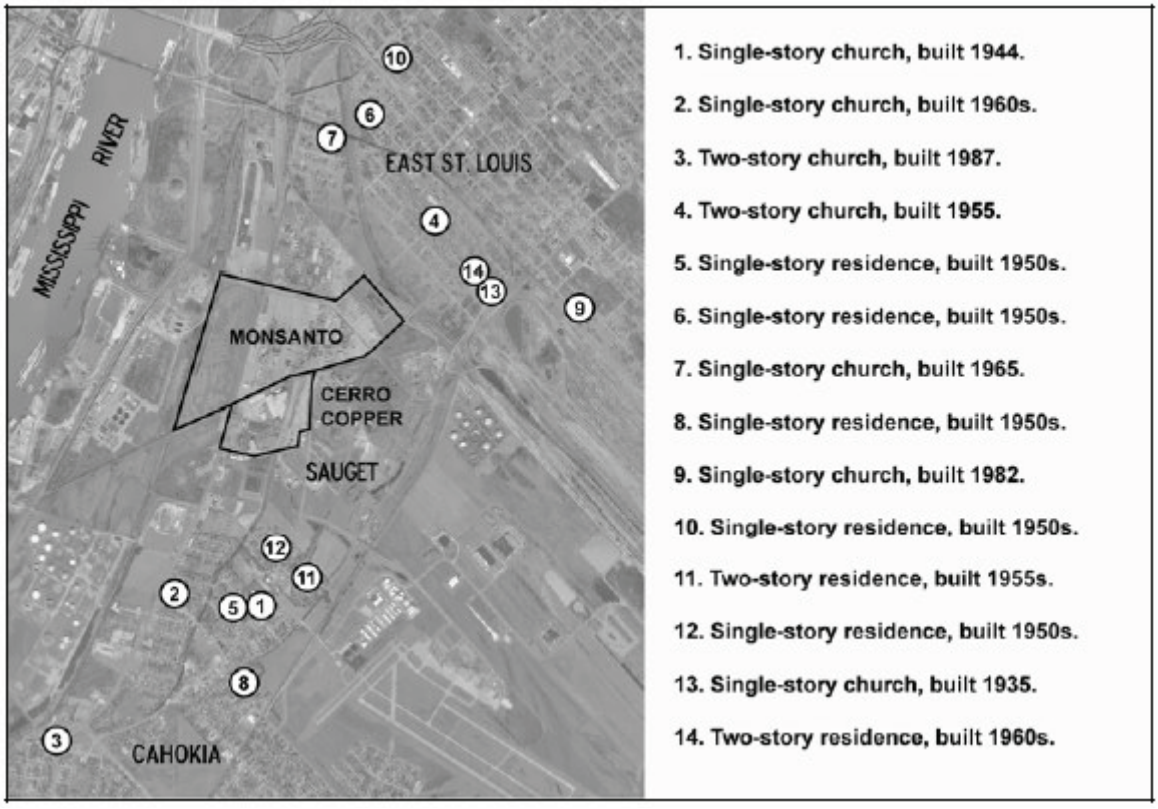


Figure 3. Attic dust sampling locations in Cahokia and East St. Louis, Illinois

Individual attic dust samples were collected using a Dewalt Model DC515K portable vacuum and single-use, high-efficiency particulate air (HEPA) filter sampling cartridges. Each filter cartridge was comprised of a Black & Decker Model VF100H HEPA filter and two 8.5-centimeter, inner-diameter polyethylene bottles, which were cut and pressed together around the filter media to form a solid structure. Standard duct tape was utilized to seal and fix all components. For each attic dust sample, a pre-assembled filter cartridge unit was fitted onto the air intake hose of the vacuum unit. A crevice tool was then fitted onto the front of the filter cartridge. These materials were also fitted together using standard duct tape. Crevice tools used as part of the sampling apparatus consisted of either new or reused units that have been thoroughly decontaminated using standard decontamination procedures. Decontamination procedures involve multiple scrubbing and rinsing cycles using 91% isopropyl alcohol. The outlines of the method are described in Wu et al. [31]. Attic dust samples were analyzed by TestAmerica Laboratories, Inc. of West Sacramento, California for dioxins/furans in accordance with U.S. EPA Method 8290 using High Resolution Gas Chromatography/High Resolution Mass Spectroscopy (HRGC/HRMS). PCBs were analyzed in accordance with U.S. EPA Method 1668 using HRGC/HRMS.

## 3. Results

The Results of the attic dust sampling assessment are presented in Table 3. Concentrations of dioxins/furans and PCBs identified in each sample are provided; along with summary statistics for the fourteen dust samples,

including minimum, maximum, mean, and Upper Confidence Limit (UCL) TEQ concentrations. The UCL concentrations were determined using ProUCL 4.00.02, the U.S. EPA software developed in response to U.S. EPA's requirements that risk assessments be based on an estimate of the Reasonable Maximum Exposure, such as the 95% upper confidence limit.

As shown in Table 3, dioxins/furans were present in attic dust samples at TEQ concentrations ranging from 29.39 to 136,964 nanograms per kilogram (ng/kg) or ppt. The mean TEQ concentration in the fourteen (14) samples is 10,203 ng/kg. The UCL TEQ concentration in the samples is 107,229 ng/kg.

PCBs as dioxin-like TEQs were detected in attic dust samples at concentrations ranging from 6.85 to 116.9 ng/kg. Concentrations of total PCBs range from 199 to 43,540 micrograms per kilogram (ug/kg) or ppb. The mean TEQ concentration of all samples is 42.23 ng/kg and the mean total PCBs concentration is 4,950 ug/kg. The UCL TEQ concentration of all samples is 58.29 ng/kg and the UCL total PCBs concentration is 10,530 ug/kg.

Concentrations of dioxins/furans and PCBs found in attic dust were compared to U.S. EPA Regional Screening Levels (RSLs). RSLs, historically referred to as PRGs, are chemical-specific screening levels developed for residential and industrial soils, residential and industrial air, and drinking water. The RSLs are applicable to CERCLA and RCRA Corrective Action sites such as the Monsanto facility and off-site contamination sourcing from the site(s). The screening levels are risk-based concentrations derived from standardized equations combining exposure information assumptions with U.S. EPA toxicity data, and are intended to be protective of human health. For carcinogens such as PCBs and dioxins/furans, the screening levels correspond to a fixed level of cancer risk of one-in-one-million ($10^{-6}$).

Table 3. Concentrations of Dioxins/Furans and PCBs in Attic Dust Samples

| Attic Dust Sample | Dioxins/furans (TEQs*, ng/kg) | PCBs (TEQs*, ng/kg) | Total PCBs (ug/kg) |
|---|---|---|---|
| 1 | 768.76 | 60.15 | 3,419 |
| 2 | 90.15 | 13.09 | 592 |
| 3 | 29.39 | 11.11 | 522 |
| 4 | 136,964 | 75.67 | 4,417 |
| 5 | 477.12 | 24.36 | 1,824 |
| 6 | 320.19 | 25.31 | 1,584 |
| 7 | 679.48 | 116.91 | 6,261 |
| 8 | 327.95 | 10.6 | 630 |
| 9 | 84.98 | 6.85 | 199 |
| 10 | 151.18 | 46.84 | 1,673 |
| 11 | 1,740.9 | 58.63 | 2,653 |
| 12 | 595.09 | 41.87 | 1,483 |
| 13 | 367.9 | 12.14 | 508 |
| 14 | 239.51 | 87.75 | 43,540 |
| Minimum | 29.39 | 6.85 | 199 |
| Maximum | 136,964 | 116.9 | 43,540 |
| Mean | 10,203 | 42.23 | 4,950 |
| UCL** | 107,229 | 58.29 | 10,530 |
| RSL for Residential Soil*** | 4.5 | 4.5 | 220 |

TCDD TEQ values are in units of nanograms per kilogram (ng/kg) or parts per trillion (ppt). PCBs values are in units of micrograms per kilogram (ug/kg) or parts per billion (ppb). *TEQs were calculated using WHO 2005 TEFs. Non-detects were treated as one-half of the detection limit. **UCL (upper confidence limit) concentrations were determined using U.S. EPA software ProUCL 4.00.02. ***RSL for 2,3,7,8-TCDD = 4.5 ng/kg. RSL for Polychlorinated Biphenyls (high risk) = 220 ug/kg.

The mean and UCL TEQ concentrations are 2,267 and 23,829 times, respectively, the U.S. EPA RSL for

2,3,7,8-TCDD in residential soil. In terms of TEQs, the mean and UCL PCBs concentrations are 9 and 13 times, respectively, the RSL for 2,3,7,8-TCDD in residential soil. In terms of total PCBs concentrations, the mean and UCL PCBs concentrations are 23 and 48 times, respectively, the RSL for PCBs in residential soil.

## 4. Discussion

The analytical results indicate that concentrations of PCBs and dioxins/furans present in attic dust samples are many times greater than the U.S. EPA RSLs for these contaminants in residential soil. Soil samples collected by U.S. EPA in the same or similar areas surrounding the Monsanto and Cerro Copper facilities were also found to contain elevated levels of dioxins/furans and PCBs greatly exceeding contemporary RSLs. While U.S. EPA has not finalized its reassessment of the toxicity of dioxins and dioxin-like compounds, it appears likely that the applicable PRGs for dioxins/furans and PCBs will be drastically lowered. Comparison of levels of dioxins/furans and PCBs to background levels measured by U.S. EPA in rural/remote soils across the United States demonstrates that these compounds are present at low concentrations in non-industrial areas.

Generic regulatory cleanup levels and/or guidelines such as PRGs for toxic chemicals in attic dust have not been developed by U.S. EPA, largely because attic dust contamination has not been fully recognized by the Agency as an exposure risk until recent years. However, U.S. EPA has recently recognized exposure risk to attic dust and has ordered remediation of attics in some cases. For cases where an attic cleanup was determined by U.S. EPA, the sites involved a community setting in proximity to a major contamination source such as a smelter site. Notable examples of U.S. EPA cleanups where attic dust remediation was conducted are the Woolfolk Chemical Works Site in Fort Valley, Georgia and the Silver Bow Creek/Butte Area NPL Site in Montana [33,34]. For these cases, cleanup levels were established based on background and/or an established threshold concentration value. The potential risk of exposure to current occupants of the sampled buildings and other buildings in the community that may be similarly contaminated cannot be quantified because the behavior patterns and activities of current and future occupants of the properties is unknown. U.S. EPA has studied risk of exposure to chemicals in the home resulting from renovation and remodeling activities [35] and has also concluded that an exposure pathway is complete when occupants access the attic space [34].

Air pollutants emitted from industrial sources such as PCBs and dioxins/furans are transported into the community by atmospheric dispersion and deposition. Particulate deposition of these contaminants can increase concentrations of these contaminants in residential soil and in living spaces and attics of homes and other properties in the surrounding community (e.g., churches). Because established PRGs do not exist for attic dust, comparison of chemical levels in attic dust to regulatory screening levels established for soil (e.g., PRGs) is a reasonable practice for determination of reference concentrations for evaluating background and for evaluation of potential exposure risk. In this study, high levels of PCBs and dioxins/furans were found in the attic dust of buildings in the vicinity of known industrial sources of historical emissions of dioxins/furans and PCBs and numerous hazardous waste disposal areas contaminated with these pollutants.

Because attic dust can be seen as a surrogate for human exposure to ambient air pollutants over time, the contamination found in the attic dust samples also demonstrates that residents of the community were historically exposed to these contaminants. Previous studies evaluating dioxin exposure to communities in the vicinity of industrial facilities have demonstrated not only elevated concentrations of contaminants in attic dust, but also elevated concentrations of the same contaminants in the residents' blood [36,37,38], demonstrating pervasive community exposure has occurred.

It should be acknowledged that there are a variety of unknown sources of dioxins/furans and PCBs in the environment that contribute to the global distribution of these pollutants and to levels in the environment around Sauget, Illinois. However, it is clear in the results of testing of soils in the community by U.S. EPA and attic dusts as part of this study that highly elevated concentrations of dioxins/furans and PCBs are present in this specific study area. The detection of highly elevated decachlorophenols in attic dust and soil samples strongly suggests atmospheric transport of these pollutants from the Monsanto facility and Cerro Copper facility and contaminated area dump sites. The magnitude of the releases that occurred from the Monsanto and Cerro Copper facilities also presents the conclusion that any other sources of these contaminants are minor.

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