UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

MAY 28 1991

MEMORANDUM

SUBJECT: Release of the Fluff Pilot Study

FROM: Linda J. Fisher
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TO: Regional Administrators

The Office of Pesticides and Toxic Substances (OPTS) and the Office of Solid Waste and Emergency Response (OSWER) have released the "Fluff Pilot Study" (attached). The Pilot Study was initiated in 1988 to determine the extent of PCB, lead and cadmium contamination in appliance and auto shredder residue, commonly known as "fluff."

The results of the pilot study indicate that shredders may generate waste contaminated at levels above regulatory concern. However, differences in raw materials, shredding operations, and the presence of conflicting data suggest that not all shredders are generators of regulated waste materials. Information obtained to date indicates that the levels of constituents of concern associated with the generation of fluff are not uniform. The potential risk depends on the constituent makeup of the fluff and the characteristics of the sites at which the fluff is generated or disposed.

EPA supports metal recycling activities when conducted in an environmentally sound manner. As such, both OPTS and OSWER have identified a need to evaluate the current disposal requirements as they relate to fluff. OPTS will be publishing an Advanced Notice of Proposed Rulemaking to solicit public comment on an amendment to the PCB regulations, which could authorize alternative methods of disposal for fluff. The fluff issue may also be discussed during RCRA reauthorization.

In the interim, because shredding operations that are well managed and conducted in an environmentally sound manner provide valuable environmental benefits, OPTS and OSWER are recommending that enforcement be focused on shredding facilities which pose significant environmental problems. Such operations could include improper use of fluff as fill material in wetlands or other environmentally sensitive areas, or in residential settings. Other criteria to evaluate sites that generate fluff include location (e.g., sites in 100-year floodplains, near surface water or surface water discharge, over a drinking water aquifer or wellhead protection areas); and operation (e.g., the absence of activities designed to address blowing fluff piles, the absence of worker protection measures, the absence of run-on/run-off controls, and leachate generation).

This list is intended only as a guide to indicate when shredding operations and fluff disposal may warrant enforcement. It is not an exhaustive list of situations where enforcement may be appropriate. Further guidance to assist the regions in determining where to focus enforcement will be developed by the Office of Compliance Monitoring and the Office of Solid Waste and Emergency Response.

Attachment

PROJECT SUMMARY

PCB, Lead, and Cadmium Levels in Shredder Waste Materials: A Pilot Study

Authors and Research Team

Principal authors included Dan Reinhart, John Scalera, Brad Schultz, Cindy Stroup, and Joe Breen of the Exposure Evaluation Division, Office of Toxic Substances. This project summary was abstracted from a report on the Fluff Pilot Study written by Westat.

Field work was conducted by Westat, Midwest Research Institute, and Battelle Columbus Laboratories. Chemical analyses were performed at Midwest Research Institute, EPA's National Enforcement Investigation Center, and EPA's Environmental Systems Laboratory in Las Vegas, Nevada.

EPA's Office of Solid Waste, Characterization and Assessment Division co-sponsored the effort and provided design, sampling, and analysis consultation for lead and cadmium portion of the pilot study. Alexander McBride was the principal contributor.

Summary

Prior to this pilot study, the United States Environmental Protection Agency (EPA) received information from state and local environmental agencies which indicated the shredding of automobiles and other products for metal recycling may produce waste materials contaminated with polychlorinated biphenyls (PCBs), lead, and cadmium. The information available was insufficient to establish the sources and extent of the contamination or what regulatory action, if any, would be approriate. Consequently, EPA's Office of Toxic Substances and Office of Solid Waste planned and conducted this study to gain more knowledge about shredder operation and characteristics of the waste output.

Samples of shredder output material were collected at seven shredder sites from across the continental United States. Measurable concentrations of PCBs, lead, and cadmium were found in shredder output at all sites. The analyses of these samples indicated that over 98% of the PCBs found in shredder output were associated with fluff, the nonmetallic waste output. The average PCB concentration for fluff produced during the sampling visits was 43 ppm.

To obtain information on the leachability of PCBs from fluff, EPA conducted a hypothetical "worst case" hot water extraction test. In this test, only 0.0073% of the PCBs present were released from the fluff samples. The hot water leachability data indicate that PCBs adhere to fluff more strongly (less likely to leach out) than to a wide range of soils.

Leachability of lead and cadmium from shredder fluff was another major focus of the pilot study. Using the (then standard) EPTOX extraction test, EPA determined that the average lead leachate concentration was 7.2 mg/L for fresh fluff. The average cadmium leachate concentration in fresh fluff was 0.84 mg/L.

The results of this study allow EPA to make a preliminary assessment of potential PCB, lead, and cadmium contamination and to provide valuable information for the design of future studies. It is important to acknowledge that this was a pilot study and the study results may not necessarily be representative of the shredder recycling industry as a whole. Only seven shredder sites were included in the study, and some numerical estimates are based on a limited number of samples. For practical reasons, some restrictions were imposed on the random selection of sites, although EPA has no reason to believe that bias was introduced by the sampling plan.

INTRODUCTION

The United States Metal Shredding Industry generates approximately 12 to 14 million tons of steel scrap for recycling each year. About 90% of the steel output is from the 8 to 10 million cars, trucks, and vans which are disposed of every year. The remaining steel salvage results from the recycling of several million discarded household appliances and a variety of other industrial, commercial, and household scrap.

EPA recognizes the major environmental benefits of recycling as a national environmental policy and strongly fosters and supports all recycling efforts which are environmentally sound. Metal recycling results in a two-thirds to three-quarters reduction in the volume of space required in landfills to deposit waste automobiles and appliances, a substantial reduction in energy required to recycle metal instead of producing it from raw ores, and a reduction in air pollution associated with metal production. The commercial value of recycled metal, over $1.5 billion per year, is considerable.

In addition to recycled metal, shredder operations produce 3 million tons of non-metallic waste material each year. This non-metallic waste is usually referred to as "fluff" or "auto shredder residue" (ASR). The shredding of a car, for example, produces about 500 pounds of fluff on average. Fluff is typically composed of a variety of materials, including plastics, rubber, foam, fabric, wood, insulation, glass, road dirt, and small metal fragments. Little, if any, of this material is presently recycled. Most fluff is disposed of in municipal landfills.

Preliminary and anecdotal information received by the EPA before this study indicated that PCBs, lead, and cadmium are dispersed during the shredding of various scrap materials, resulting in the contamination of fluff by these substances. Some of the reported contamination levels exceeded the Federal regulatory levels set under the Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA). Shredder wastes which contain these contaminants in concentrations exceeding prescribed TSCA and RCRA regulatory levels must, under Federal regulations, be managed in approved disposal sites. This would result in considerably greater cost to the recycler (shredder operator). In addition, the TSCA landfill capacity would quickly be filled if a large proportion of shredder fluff proved to be PCB-contaminated. Similar capacity concerns exist for RCRA disposal facilities.

Since PCBs were commonly used as dielectric fluids in electrical transformers and capacitors, many scrap metal shredder operators assumed that capacitors in motorized consumer appliances (called "white goods") were the primary source of PCB contamination in shredder fluff.

These operators, therefore, stopped accepting appliances for recycling. This decision not to accept and process "white goods" created a solid waste disposal predicament in several states when refrigerators, stoves, washing machines, and other appliances frequently were abandoned and began accumulating along streets or in vacant lots.

Due to the lack of general knowledge about shredder operations and conclusive information regarding contamination sources, the EPA's Office of Toxic Substances (OTS) and Office of Solid Waste (OSW) undertook this pilot study. Of specific interest was the examination of PCB, lead, and cadmium levels in shredder output streams; the leachability of these substances; and the identification of contamination sources, if possible. The results of the pilot study will be used to evaluate the need for additional Agency action and to design future studies if they are required.

OBJECTIVES

The specific objectives of the study were:

- To estimate ranges of PCB, lead, and cadmium levels in fluff, the metallic outputs, and in soil collected from where fluff is stored by the shredder;
- To determine how readily PCBs, lead, and cadmium will leach (to dissolve out by percolation) from fluff to pose a potential threat to human health and the environment;

- To examine the relationship between shredder input materials and levels of PCBs, lead, and cadmium in the resulting fluff output; and

- To develop and test procedures for field sampling, sample preparation, and laboratory analysis which yield more precise and accurate measurement of PCB, lead, and cadmium levels in shredder output materials.

PROJECT

METHODS AND DESIGN

Site Selection and Description

Based on statistical and cost considerations, EPA decided that seven shredder sites from geographically diverse regions of the continental United States would be included in the Fluff Pilot Study. Because of the time and expense required to relocate a sampling crew in the event that a shredder operator would not or could not participate in the program (e.g. due to breakdown), it was essential that EPA prearrange conveniently located alternate shredder sites prior to the commencement of sampling.

To implement random procedures for site selection, to the extent possible, and to have substitute sites readily available, EPA began the process of selecting the seven sites to be included in the pilot study by first identifying clusters of shredder sites throughout the country. Each of the seven geographic clusters chosen for the pilot study consisted of three or more sites and all sites, within each cluster, were within about 100 miles of one another. Each cluster of sites was located in a separate EPA region (there are ten EPA regions). From within each geographic cluster, one primary and two alternate sites were randomly selected.

EPA sent advance letters to the owner/operators of selected shredder sites, asking for their cooperation with the Pilot Study, promising them anonymity if they participated. In addition, the metal recycling trade association, the Institute of Scrap Recycling Industries (ISRI), provided the sampling teams with letters endorsing the study and soliciting cooperation from its members. (All shredder sites visited were ISRI members.) The field sampling team gave these letters to site owners/operators at the beginning of sampling visits.

Four of the seven primary sites participated in the study, while three sites were unable or unwilling to take part and were replaced with alternate sites from the same geographic cluster as the primary site. While the site selection process imposed some restriction on the random selection of shredder sites, EPA has no indication that bias was introduced by this sampling plan.

Shredder Operation

Shredder operations invariably have several important features in common (see Figures 1 and 2). Automobiles, appliances, and other objects are fed to a hammermill which shreds them into fist-sized pieces. Powerful magnets and conveyor belts then separate the ferrous (iron-containing) metals from non-ferrous components. Next, using either air cyclone or water "flotation" separation, metallic components are segregated from the, generally less dense, fluff. In this way, all shredder output is divided into piles of ferrous metal, non-ferrous metal, and fluff.

EPA developed standard procedures for collecting specified quantities of shredder output (fluff, ferrous, and non-ferrous metal, etc.) before the start of sampling.

Input Runs

One of the objectives of the pilot study was to investigate the relationships between the input materials being shredded and the concentrations of PCBs, lead, and cadmium measured in the shredder output streams. In order to investigate this relationship, shredder operators segregated their input materials into three groups and made separate "runs" of the shredder, by material type, for the sampling team. Each "run" consisted of the shredding of a predetermined quantity of scrap material from one of three categories of input.

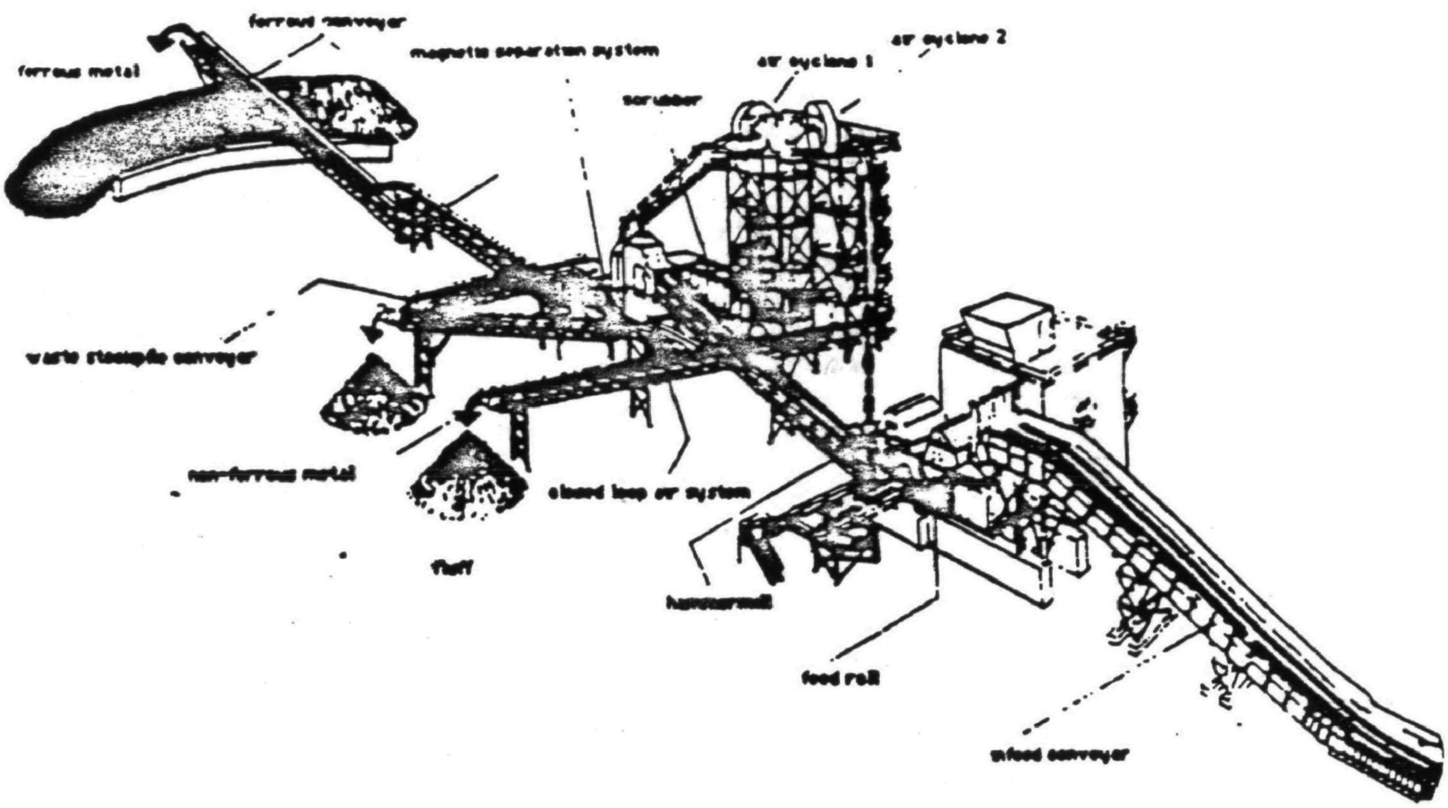
The three categories of input material were:

- Automobiles, including trucks and vans;

- White Goods, which included refrigerators, washing machines, and other similar appliances; and

- Mixed Inputs, which included a variety of mixed scrap materials, such as those which come from demolition sites and may have contained parts or all of some automobiles or white goods.

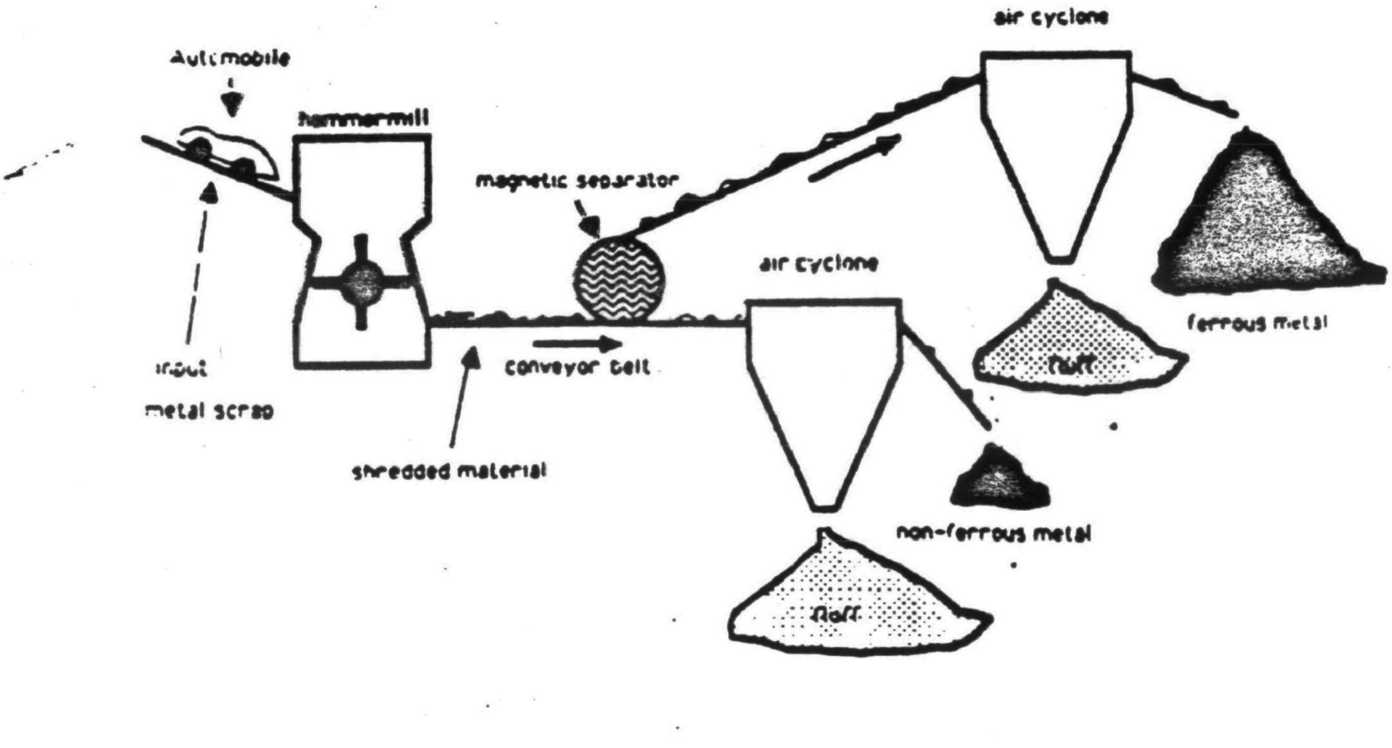
What consituted a "run" depended on the category of input material being processed. For example, the shredding of two cars was defined as one "run" for automobiles, whereas eight home appliances equaled a "run" for white goods. One 5-gallon bucket (sample) of fluff was normally collected after each "run" using the sample collection protocol developed for the study (described below).



DRY SHREDDING SYSTEM

Figure 2

Schematic illustration of the Shredding Process



Sample Collection

Because of the heterogeneous nature of the fluff output stream, considerable effort was devoted in this study to the development of methods for sampling fluff. Standard procedures for collecting specified quantities of fluff and other shredder output (ferrous or non-ferrous metal, etc.) were carefully developed prior to the commencement of sampling. For fresh fluff sampling, a front-end loader caught the fluff output stream as it tumbled off the end of a conveyor belt or dropped from an air cyclone funnel. The sampling team spread this fluff over a tarp to create a 1' deep 9' x 9' square pile. This pile was subdivided into a nine square grid of 3' by 3' squares. A five gallon sample of the fluff was collected by compositing a roughly equal portion of fluff from near the center of each of the nine squares.

Γ developed other sampling procedures for piles of stored fluff, fluff that spilled off conveyor belts (spillover), and soil from the vicinity of fluff piles. Descriptions of all sampling protocols are detailed in the full report.

The following types of samples were collected at each shredder site:

- Fresh fluff One sample of "fresh" fluff, fluff as it was produced by the shredder, was collected from each run of the shredder. Depending on what type(s) of input material were processed, there were generally between eight and twelve runs at each site.
- Ferrous metals Two ferrous metal output samples were collected from each site, one from each of two input runs.
- Non-ferrous metals Two non-ferrous metal samples were collected from each site, one from each of two input runs.
- Spillover Fluff which fell or blew off conveyor belts during processing and accumulated on the ground around shredding machinery and conveyor belts was sampled. Two samples of this spillover fluff were collected from each site.
- Stored Fluff Five of the seven shredder sites visited had piles of stored fluff that had accumulated during normal operation prior to the arrival of the sampling team. At each of these sites, the sampling team collected four samples of stored fluff.
- Soil The sampling team collected four soil samples from each site from locations where fluff typically accumulated. These samples were used to investigate the potential for migration of contaminants from fluff to soil. These samples were also taken from beneath stored fluff piles, if they were present.

Sample Analyses

Sample Preparation

Before analysis, each five gallon (sample) bucket of fluff was divided into approximately eight to ten 450 to 500 gram "representative subsamples" for chemical analysis. These subsamples were carefully constructed such that every subsample contained all the basic physical components of fluff (glass, foam, plastics, fabrics, dirt, etc.) in proportions nearly identical to those found in the original sample. The goal was to create subsamples which, in their physical composition, were very similar to the other subsamples (from the same bucket) and to the original sample. The actual steps involved in the creation of the "representative subsamples" are described in the full report.

Each 450 to 500 gram subsample was placed into a 1-gallon large mouth glass jar for storage. Depending upon the quantity of sample material required for chemical extraction/analysis, the subsamples were split further, sieved and/or milled. Additional details describing sample preparation for each type of chemical extraction/analysis can be found in the full report.

Development of PCB Extraction Procedures

Solvent Extraction

Existing laboratory procedures for the preparation and chemical analysis of fluff samples for PCBs were judged to be deficient. The conventional procedure for measuring PCB concentrations prescribes that a relatively small quantity of material (often 20 grams or less) be subjected to solvent extraction before instrument analysis. Using such a small quantity of a heterogeneous material (such as fluff) has historically resulted in high measurement variability between subsamples from the same sample, as reported by many state and independent laboratories. In practical terms, this means that the actual estimate of the PCB concentration for any sample depends to a great extent on the specific aliquot of fluff used for extraction and analysis. Different portions of fluff from the same sample often produce very different results which make overall estimates for each sample highly variable and potentially inaccurate.

Two methods were developed in the pilot program to reduce this source of sampling error: (1) the technique for creating "Representative Subsamples" from the initial 5-gallon buckets, and (2) the quantity of the subsample material subjected to chemical extraction/analysis was greatly increased.

Two innovative procedures for increasing the quantity of material subjected to hexane/acetone extraction were developed, tested, and compared for the Pilot Study. These techniques were (1) a tumbler (slurry) extraction using an agitation apparatus, and (2) a large-volume Soxhlet (500 cc Soxhlet) capable of extracting PCBs from up to 100 grams of fluff.

A systematic comparison of measurements from matched subsamples analyzed by the two procedures was conducted. On the basis of this comparison, the tumbler (slurry) procedure was selected on the basis of its overall superiority to be used as the standard extraction method for the remainder of the PCB analyses. This new technique allowed extraction of fluff samples weighing between 450 to 500 grams, as opposed to 20 gram samples used in the conventional soxhlet, or the 100 gram samples used with the large Soxhlet.

Water Extraction (PCB Leachability)

In order to evaluate the leachability of PCBs from fluff using water as the solvent, two additional extraction techniques were developed. One technique for room temperature water used a slurry extraction apparatus and the other technique for "hot" water extraction used a Soxhlet extractor. The fluff samples used in the "hot" water extraction were milled to 9.5 mm. A portion of the non-millable fraction of the fluff was included in each sample, the quantity added being based upon the appropriate weight fraction of non-millable versus millable portions (from the original sample).

For the room temperature extraction (22°C), 80 grams of fluff (particle size ≤ 9.5 mm) was placed with 2 liters of high purity water into the slurry extraction apparatus (described previously) and *tumbled* for eight continuous days. For the hot water extraction (65°C), a similar 80 gram sample was placed in a large Soxhlet extractor and extracted over a period of eight days with high purity water at a temperature of 65°C. After eight days, the extract from each of the two procedures was filtered and analyzed for PCBs.

Chemical Analyses

All chemical analyses were based on EPA methodology. The inorganic analyses were done using Methods 213.1 or 7131 for Cd and 239.1 or 7421 for Pb.

Unless otherwise stated, PCB analyses were performed using a modified gas chromatography/electron capture detector (GC/ECD) EPA Method 8080.

The modified analytical method as well as all other analytical methods used in the Pilot Study can be found in the Appendix section of the full report. Summaries are provided here.

- <u>Total PCB Concentration</u> The total concentration of PCBs in each of the subsamples analyzed was determined by extraction, using a hexane/acetone solution, then analysis using a gas chromatography/electron capture detection (GC/ECD) method. The sample particle sizes were not reduced for any of the tumbler (slurry) extractions, however the samples undergoing Soxhlet extraction were milled to ≤ 9.5 mm.

- <u>PCB Concentrations in Individual Fluff Components</u> Fluff subsamples were divided into their physical components (glass, plastics, fabrics, etc.). Each component was individually analyzed for total PCB concentration by EPA's National Enforcement Investigation Center (NEIC) in Denver, Colorado. The analytical method employed was EPA Method 600 "The Determination of Polychlorinated Biphenyls in Oil, Soil and Surface Samples". This analysis was conducted to determine whether PCB contamination was more closely associated with specific components of fluff.

- <u>PCB Leachability</u> EPA measured the extent to which PCBs leach from fluff, using water as a solvent, to estimate how likely they are to be released from shredder wastes into the environment. To represent a "worst case" scenario, EPA performed a hot water extraction of size-reduced fluff in a Soxhlet extractor. Samples were also subjected to a room-temperature water extraction, to represent something closer to a "real world" scenario. These samples were extracted using a slurry extraction apparatus. The extracts from both techniques were analyzed using the GC/ECD method.

- <u>Total Lead and Cadmium Concentrations</u> The total concentrations of lead and cadmium were determined by digesting the sample in acid and analyzing the digestate by Flame Atomic Adsorption Spectroscopy (FLAA). Samples with lead or cadmium concentrations so low that they could not be detected by the FLAA method were analyzed by Graphite Furnace Atomic Adsorption Spectroscopy (GFAA). The sample particle size used for the digestion and analysis was ≤ 9.5 mm.

- Lead and Cadmium Leachability EPA Method 1310 Extraction Procedure Toxicity Test (EPTOX) was used to measure how readily lead and cadmium will leach from fluff to estimate the potential release of these substances from shredder wastes into the environment. The EPTOX extracts were analyzed for lead and cadmium concentrations using the FLAA and GFAA methods. The sample size requirements were that the particle size be ≤ 9.5 mm and/or have a surface area to weight ratio of ≥ 3.1 cm squared per gram.

- PCBs in Ferrous and Non-ferrous Metal Metal samples were analyzed for total PCB concentration by extraction followed by analysis with the GC/ECD method. Subsamples of metal samples were also analyzed for quality assurance purposes and archived.

- Analysis of Soil Sample Soil samples were analyzed for total PCB concentration, PCB composition, and total lead and cadmium concentrations. Subsamples of soil samples were analyzed in accordance with the quality assurance program and others were archived.

Quality Assurance

The Quality Assurance Project Plan (QAPjP) presents the features of the quality assurance design for the pilot study. The QAPjP was developed in three phases: Phase I-Field Sampling, Phase II-Chemical Analysis and Phase III-Statistical Data Processing and Analysis. A more detailed description of what each phase included follows.

Field Sampling As previously described, a grid-type sampling scheme was employed to increase the likelihood of obtaining representative samples. A standard operating procedure (SOP) was also developed for the sampling of piles of stored fluff. The QAPjP also stated specific details for the tracking of field samples including the use of log books for sampling details and chain-of-custody sheets for sample tracking. Duplicate samples were taken in order to assess field sampling variability.

Chemical Analysis Before the laboratory analysis of any samples, chemical analysis methods were carefully reviewed for their adequacy in meeting the project's data quality objectives (DQOs). The DQO for accuracy was equal to or greater than 60% recovery for spiked samples. The DQO for precision was + or - 50% relative standard deviation for replicate samples. The measurement of the experimental accuracy and precision was done through laboratory quality control samples which included method blanks, replicate samples, field duplicates, and matrix spike samples. All standards used for spiking were traceable to their manufacturing source. The data quality objectives were met for all but a few samples. Splits were obtained from 10% of the samples, the splits being sent to an external laboratory for analysis (EPA Environmental Monitoring Systems Laboratory - Las Vegas) (EMSL-LV).

Statistical Data Processing and Analysis A great deal of effort was expended in order to assure that the data generated by the laboratory were correctly transferred to the contractor conducting the statistical analysis of the data. The correctness of data values generated by the laboratory was cross checked by the contractor conducting the statistical analyses once they were keyed into a matrix file.

One other important aspect of the project's quality assurance program was the use of audits. Three types of audits were conducted during the project: system audits to assure standard operating procedures were being followed, performance audits using performance audit samples so that the laboratory could demonstrate its ability to accurately analyze for the analyte(s) of interest, and data audits which reviewed portions of the data for error.

RESULTS

The results of the Pilot Study provide a preliminary evaluation of the waste characteristics of fluff and valuable information for the design of future studies. Caution must be exercised when generalizing from these findings. As noted earlier, the Pilot Study results are based on limited data and do not necessarily represent the metal shredding industry as a whole.

Total PCB Concentrations in Fluff, Metals and Soil

PCBs were detected in all shredder output materials analyzed. Over 98% of PCBs are estimated to end up in the fluff waste stream. PCB concentrations in both the ferrous and nonferrous metals were very low (means of 0.21 ppm for the ferrous metal and 0.90 ppm for the nonferrous metal). The mean PCB concentration for all fresh fluff was 43 ppm. Using a bootstrap resampling procedure, an approximate 95% confidence interval for this mean was calculated to be 22 ppm to 120 ppm. Table 1 displays the average PCB concentration in parts per million along with the standard deviation for each category of sampled material. Also presented are median, minimum, and maximum concentrations and the number of samples and sites upon which these statistics are based.

Table 1 shows that fresh fluff from mixed inputs had higher PCB concentrations than fresh fluff resulting from white goods or automobiles, and this difference is statistically significant.

PCB concentrations in the non-ferrous waste metals were roughly 50 times lower than those in fluff. PCB concentrations in ferrous waste streams were approximately 200 times lower than those in fluff. No samples from the ferrous and non-ferrous metal streams had PCB concentrations anywhere approaching the EPA TSCA disposal threshold of 50 ppm. (The highest PCB concentration for ferrous metal was 0.42 ppm and for non-ferrous metal, 2.6 ppm.) It is notable that ferrous metal output is very "clean." In contrast to non-ferrous metal which cannot be separated primarily with magnets, ferrous metal output contains practically no fluff. The non-ferrous metal typically contains much higher proportions of non-metallic waste (fluff), which may explain the somewhat higher PCB levels in the non-ferrous output.

PCB concentrations in soils were in the same range as those in stored fluff. Some soil samples had PCB concentrations exceeding the 50 ppm EPA disposal threshold, but, soil samples had PCB concentrations, on the average, slightly below the disposal threshold. How PCBs got into the soil is unclear. The PCB concentrations found in these soil samples may reflect the migration of PCBs from fluff which regularly accumulated nearby, or "soil" samples may contain a substantial amount of fluff material which had become mixed with the soil over time. The soil sampling protocol prescribed that if the demarkation between soil and fluff residues was not distinct, "soil" samples should contain a minimum of 50% soil. From the accounts of sampling crew members, the distinction between soil and fluff sometimes was unclear. Soil samples collected in accordance with the sampling protocol may often have contained some portion of fluff.

PCB Composition In Fluff

The fluff samples were analyzed for the specific concentrations of PCB Aroclors 1242, 1254, and 1260, to explore the possibility that sources of PC? ,ntamination could be identified by PCB composition. This approach was considered feasible because different PCB Aroclors were developed for specific uses. This analysis for specific PCB Aroclors revealed that Aroclor 1242 was dominant in almost every sample, making up more than half of the PCBs in each sample category. While this part of the pilot study yielded some general information on the proportions of the three most commonly used Aroclor mixtures, it produced no definite information on sources of PCB contamination.

PCB Concentrations In Individual Fluff Components

Subsamples from four fresh fluff samples (two resulting from automobile shredding, one resulting from the shredding of white goods, and one resulting from the shredding of mixed inputs) were divided into the following components:

- Metals, wire and glass;
- Soft plastics, foams, soft rubber, and vinyl;
- Fabrics, paper and wood;
- Hard materials, hard plastics, and hard rubber;
- Fine materials too small to classify, dirt, and dust; and
- Other, not classifiable, materials.

All components, except for the "Other, not classifiable" materials were analyzed separately for total PCB content. Table 2 shows the percent, by weight, of each component in the four samples, and the PCB concentrations found in each component.

Total PCB concentrations in fresh fluff samples, as well as the relative concentrations of the PCBs in different components, varied with input material. They also varied between the two samples produced from the same input material (i.e. automobile). In one sample from automobile inputs, the highest PCB concentration occurred in materials in the "Soft plastics, foams, soft rubber and vinyl" category. In the other (matching) automobile sample, the highest PCB concentrations were in materials in the "Fine materials too small to classify, dirt, and dust" category. The highest PCB concentrations in fluff from white goods were also found in materials in the "Fine materials too small to classify, dirt, and dust" category, while fluff from mixed inputs showed the highest PCB concentrations in the "metals, wire and glass" category.

Table 1. Summary of Total PCB Concentrations (ppm) by Sample Type

Sample Type	Input Type	Mean	Standard Deviation	Median	Minimum	Maximum	Number of Samples	Number of Sites
Fresh fluff	Auto	32	43	13	1.7	210	28	7
Fresh fluff	White Goods	80	190	21	0.67	760	15	5
Fresh fluff	Mixed input	180	170	88	12	500	9	3
Stored fluff		68	43	52	16	150	10	5
Spillover		28	25	28	4	65	5	5
Ferrous		0.2	0.11	0.21	0.1	0.42	8	6
Non-ferrous		1	1.1	0.9	0.13	2.6	5	3
Soil		44	38	32	0.13	100	8	4

Table 2. Total PCB Concentrations (ppm) in Five Fluff Components

	Input Material							
	Automobile Sample 1		Automobile Sample 2		White Goods		Mixed Inputs	
Concentration Component	% of Total Sample (by Weight)	PCB Concentration (ppm)	% of Total Sample (by Weight)	PCB Concentration (ppm)	% of Total Sample (by Weight)	PCB Concentration (ppm)	% of Total Sample (by Weight)	PCB (ppm)
Metals, wire, and glass	11%	13	2%	9.9	3%	0.6	2%	390
Soft plastics, foams, soft rubber, vinyl	17%	66	14%	7	8%	35	17%	260
Fabrics, paper, and wood	17%	37	28%	12	9%	24	26%	63
Hard materials, hard plastics, hard rubber	9%	11	2%	24	10%	5.5	5%	46
Fines too small to classify, dirt, dust	40%	43	38%	29	65%	62	45%	140
Other, not analyzed	6%		16%		5%		5%	
Total sample weight (gm)	1090		1260		859		1080	

PCB Extractability From Fluff

Subsamples from seven different fresh fluff samples found to have high total PCB concentrations were extracted, using hot water as solvent, to estimate how readily PCBs migrate from the fluff waste stream to the surrounding environment. The hot water (65°C) extraction provides a theoretical "worst case" estimate of PCB extractability. An average of 0.0073% of the PCBs in the samples was extracted using the hot water extraction described earlier.

Using other subsamples from the same seven high PCB fluff samples, an average of 0.0050% of the PCBs in the samples was extracted using a room temperature (22°C) water extraction. These results suggest that PCBs are less likely to leach (dissolve out by percolation) from fluff than from a wide range of soils.

Total Lead And Cadmium Concentrations In Fluff and Soil

Total lead concentrations in most fluff samples ranged from 1,000 to 10,000 ppm. Total cadmium concentrations in most fluff samples were substantially lower, falling between 10 and 100 ppm.

Table 3 presents total lead concentrations for each type of fluff and soil sample analyzed. The Table shows the mean, standard deviation, median, minimum, and maximum lead concentration values, as well as the numbers of samples and sites on which the results were based. The total lead concentration data for fresh fluff from automobiles, white goods and mixed inputs were combined to produce an average for all fresh fluff which was then compared with spillover and stored fluff. The mean total lead concentration in all types of fresh fluff (combined) is 2,800 ppm. The approximate 95% (bootstrap) confidence interval for this mean is 1,800 ppm to 4,100 ppm. Total lead concentrations in spillover fluff are greater than in stored fluff, which in turn are greater than in all types of fresh fluff combined. These differences are statistically significant. Lead concentrations in soil are statistically significantly lower than in all types of fluff combined.

Table 4 presents the total cadmium concentrations in each type of fluff and soil. It gives the mean, standard deviation, median, minimum, and maximum lead concentration values, as well as the numbers of samples and sites on which the results were based.

The data for fresh fluff from automobiles, white goods, and mixed inputs were combined to compare total cadmium concentrations in fresh, spillover, and stored fluff. The mean cadmium concentration for all types of fresh fluff combined is 47 ppm. The approximate 95% (bootstrap) confidence interval for this mean is 31 ppm to 65 ppm. Differences between cadmium concentrations in the different types of fluff are not statistically significant. Total cadmium concentrations in soil are statistically significantly lower than in all types of fluff combined.

Lead and Cadmium Leachability From Fluff

Of considerably greater interest, environmentally, than total lead and cadmium concentrations is how readily lead and cadmium leach from fluff to contaminate the environment. Lead and cadmium concentrations in leachate were measured using the EPTOX procedure for samples from all categories of fluff.

The EPTOX procedure was the standard EPA method for determining leachability at the time these lead and cadmium analyses were conducted. In March 1990, EPA replaced the EPTOX with the TCLP (Toxicity Characteristic Leaching Procedure) as the standard method for determining leachability. EPA comparison analyses have shown little difference between the results of the EPTOX and TCLP methods.

Table 5 summarizes the results for lead in leachate from the EPTOX extraction. The Table presents the mean, standard deviation, median, minimum and maximum concentration of lead in the EPTOX extract for fresh fluff from automobiles, white goods and mixed input; as well as for stored and spillover fluff. Table 6 also presents the number of samples and sites represented in the calculation of each statistic.

Lead concentration values in the EPTOX extract ranged from 0.8 to 220 ppm, with an average of above 6 ppm for every type of fluff. While the highest EPTOX lead concentrations were associated with stored fluff, fresh fluff from mixed input and spillover fluff, the differences between average concentrations as presented in the Table are not statistically significant. The mean EPTOX lead concentration for all types of fresh fluff combined is 7.2 ppm. The approximate 95% (boot-strap) confidence interval for this mean is 4.8 ppm to 13 ppm.

Table 6 summarizes the results of the EPTOX cadmium extraction. This Table gives the mean, approximate 95% confidence interval for the mean, standard deviation, median, minimum, and maximum concentrations for the different types of fluff; as well as the numbers of samples and sites represented by these statistics.

Table 3. Summary of Total Lead Concentrations (ppm) by Sample Type

Sample Type	Input Type	Mean	Standard Deviation	Median	Minimum	Maximum	Number of Samples	Number of Sites
Fresh fluff	Auto	2,700	2,200	2,400	570	12,000	28	7
Fresh fluff	White Goods	3,100	3,200	1,800	1,300	14,000	15	5
Fresh fluff	Mixed input	4,600	3,500	3,600	1,100	12,000	13	3
Stored fluff		3,900	3,500	2,600	1,300	13,000	20	4
Spillover		6,100	5,600	4,300	2,800	21,000	9	5
Soil		2,200	3,900	1,100	8.1	16,000	16	5

Table 4. Summary of Total Cadmium Concentrations (ppm) by Sample Type

Sample Type	Input Type	Mean	Standard Deviation	Median	Minimum	Maximum	Number of Samples	Number of Sites
Fresh fluff	Auto	47	36	40	14	200	28	7
Fresh fluff	White Goods	48	19	47	23	87	15	5
Fresh fluff	Mixed input	46	14	46	29	70	12	3
Stored fluff		35	13	35	16	59	20	5
Spillover		32	11	33	18	59	9	5
Soil		22	24	18	10	100	16	4

Table 5. Summary of EPTOX Lead Concentrations (ppm) by Sample Type

Sample Type	Input Type	Mean	Standard Deviation	Median	Minimum	Maximum	Number of Samples	Number of Sites
Fresh fluff	Auto	6.9	5.5	5	.8	21	28	7
Fresh fluff	White Goods	6.1	5.0	3.2	1.6	14	15	5
Fresh fluff	Mixed input	23	24	13	1	78	12	3
Stored fluff		22	47	9.5	1.6	220	20	5
Spillover		18	12	20	1.7		9	5

Table 6. Summary of EPTOX Cadmium Concentrations (ppm) by Sample Type

Sample Type	Input Type	Mean	Standard Deviation	Median	Minimum	Maximum	Number of Samples	Number of Sites
Fresh fluff	Auto	0.81	0.67	0.7	0.35	4	28	7
Fresh fluff	White Goods	1.3	0.77	1.3	0.45	1.3	15	5
Fresh fluff	Mixed input	1	0.27	1	0.48	1.4	12	3
Stored fluff		0.73	0.41	0.61	0.2	2	20	5
Spillover		0.45	0.26	0.3	0.18	0.81	9	5

The mean EPTOX cadmium concentration for all types of fresh fluff combined is 0.84 ppm. The approximate 95% (bootstrap) confidence interval for this mean is 0.53 ppm to 1.2 ppm.

CONCLUSIONS

In this pilot study, EPA's research team:

- Determined that PCBs were present in all sampled materials at all seven pilot study sites and that over 98% of the PCBs in all shredder output were associated with fluff; PCB concentrations in fluff ranged from 0.67 to 760 ppm.
- Determined that in the "worst case" scenario of leachability, a hot water extraction, only .0073% of the PCBs present leached from the sample on average. In a situation more closely resembling "real world" conditions, room temperature water extraction leached .0050% of the PCBs, on average, from the fluff. In both cases, the observed leachability of PCBs from fluff was lower than usually found in a wide range of soils;
- Could not conclude that any particular input material was the source of the PCBs, lead and cadmium found in shredder outputs. Cross-contamination of samples within sites may have masked the relationship between input material and contamination of resulting output materials.

  For example, if PCBs were released onto shredder surfaces during the shredding of PCB-containing items, fluff produced for some time after the initial release may have been contaminated as it came into contact with parts of the shredder apparatus, although no PCBs existed in the input material associated with this fluff;
- Found that lead and cadmium leachate concentrations in fluff, as determined by the EP TOX, ranged from 0.8 to 220 ppm and 0.18 to 4 ppm, respectively.
- Developed and tested field sampling and sample preparation procedures to obtain representative samples and subsamples of fluff, ferrous and non-ferrous metals and soil from shredder sites; and
- Developed and tested laboratory protocols to analyze very large fluff samples (500 grams) for PCB content. This technique reduced the sampling variability associated with conventional PCB extraction and analysis of fluff, and resulted in more reliable estimates of PCB concentration.
- Determined that the limited size of the sample precludes using the analytical results from this Pilot Study to characterize the shredder industry as a whole; also identified the need to collect and evaluate additional analytical data generated by State agencies and industry sources subsequent to completion of the Pilot Study. Care will be taken to review sampling procedures and analytical methods used in collecting data.
- Identified the need to obtain a better understanding of the economic viability of the shredder industry and to assess the economic impacts, if any, resulting from various approaches to residual waste management.