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G&L RECOVERY SYSTEMS, INCORPORATED
ASHTABULA, OHIO

NIOSH INVESTIGATORS:
Michael S. Crandall, M.S., CIH
Steven Galson, M.D.
Richard W. Hartle, M.S., CIH

I. SUMMARY

On December 17, 1986, the National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance from the U.S. Environmental Protection Agency, Region 5, Chicago, Illinois. The EPA was concerned about the potential health risk to workers exposed to volatile organic chemicals during the operation of a vapor/solvent decontamination system for polychlorinated biphenyl (PCB) contaminated transformers at G&L Recovery Systems, Incorporated, Ashtabula, Ohio.

Initial environmental and medical evaluations were conducted June 22-24, 1987. The medical survey included (a) a personal interview, (b) a physical examination, and (c) measurement of serum PCB concentration. Follow-up environmental evaluations were conducted in October and November 1987. Air samples were collected for trichloroethylene (TCE), PCBs, polychlorinated dibenzo p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs). Surface concentration samples were collected for PCBs and PCDD/PCDF. All of these compounds are suspected to be human carcinogens by NIOSH.

Average personal (breathing zone) exposures to TCE ranged from 5.3 to 11.8 parts per million (ppm) during the initial evaluation and from 20.8 to 29.2 ppm during the follow-up evaluations. The decontamination technicians had the highest average exposures (11.8 and 29.2 ppm) to TCE. However, the highest personal TCE exposure concentrations measured (34.2 and 35.5 ppm) were collected from the breathing zones of the stripper technicians during the first follow-up survey. NIOSH recommends that exposure be controlled to the lowest feasible limit (<25 ppm).

Average personal exposures to PCBs ranged from 14.5 to 20.8 ug/m^3 during the initial survey and from 9.9 to 25.9 ug/m^3 during the follow-up surveys. The higher average exposures were experienced by the decontamination technician during the initial survey, and by the stripper technicians during the follow-up surveys. All of the personal exposures measured exceeded the NIOSH criterion of <1.0 ug/m^3, suggested as the lowest feasible limit.

PCB concentrations on "high-contact" surfaces outside the containment area ranged from 10 to 1080 ug/m^2. All but two were near or greater than the evaluation criterion of 100 ug/m^2. The surface concentrations in the production area ranged from 1,000 to 72,000 ug/m^2. The EPA surface cleanup standard for high- and low-contact surfaces in a restricted access area is 1,000 ug/m^2.

Surface concentrations of PCDDs and PCDFs (reported as 2,3,7,8-TCDD equivalents) ranged from 0.2 to 3.0 nanograms per square meter (ng/m^2) on painted concrete floors outside the containment area. The recommended exposure evaluation criterion is 1 ng/m^2. Within the restricted access area, concentrations of 16.0 and 19.0 ng/m^2 of 2,3,7,8-TCDD equivalents were measured during the initial survey. The concentrations measured during the follow-up evaluations ranged from 4.7 to 13.5 ng/m^2.

Area air concentrations of PCDDs/PCDFs (reported as 2,3,7,8-TCDD equivalents) in the production areas ranged from none detected to 4.2 picograms per cubic meter (pg/m^3). The highest value was measured in the stripper room and exceeds the evaluation criterion of 2.0 pg/m^3.

The serum PCB concentrations (reported as Aroclor 1260) for the seven participating workers were 12, 12, 13, 13, 17, 26, and 211 ppb. Persons without occupational exposure generally have concentrations less than 20 ppb, usually less than 10 ppb. The three long-term processing area workers had a mean serum PCB level of 19 ppb. The two short-term processing area workers had a mean blood PCB level of 12. None had head or neck skin lesions suggestive of chloracne.

Measured worker exposures to TCE and PCBs exceeded the NIOSH RELs, as did surface concentrations of PCBs and PCDD/PCDF. Surface concentrations of PCBs that exceeded the EPA Standard were also measured. The general area air concentration of 2,3,7,8-TCDD equivalents exceeded the recommended criterion in the wire stripping area. The medical findings indicate that PCBs are being absorbed by the workers. These results suggest that current work practices and environmental controls are not effective in preventing exposures to workers. Recommendations are made to control environmental exposures.

KEYWORDS: SIC 9999 (nonclassifiable establishments, electrical transformer decontamination), polychlorinated biphenyls (PCBs), trichloroethylene, polychlorinated dibenzo p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs)

II. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request for technical assistance on December 17, 1986 from the U.S. Environmental Protection Agency (EPA), Region 5, Chicago, Illinois. In July 1986 the EPA, Region 5, authorized G&L Recovery Systems, Incorporated (G&L), Ashtabula, Ohio, to conduct research and development work on a vapor/solvent degreaser decontamination system as an alternative method for disposal of PCB transformers. The EPA was concerned about the potential health risk associated with workers' exposures to volatile organic chemicals used in this process. The potential exposures included polychlorinated biphenyls (PCBs), trichloroethylene (TCE), polychlorinated dibenzo-p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs).

Medical and environmental evaluations were conducted on June 22-24, 1987. The medical evaluation included brief medical interviews and the collection of blood samples to determine serum PCB levels. The environmental evaluation included the collection of air samples for TCE, PCBs, PCDDs, and PCDFs, and surface wipe samples for PCBs, PCDDs, and PCDFs. Interim Report No. 1, issued in October 1987, discussed the results of this first evaluation.

The environmental results from the initial evaluation revealed significant worker exposures to airborne PCBs and surface residues of PCBs and 2,3,7,8-TCDD equivalents, indicating a need for the application of more stringent worker exposure control methods. The control technologies recommended in the interim report, as being applicable to this production process and facility, included process isolation, local and general area exhaust ventilation, and as an interim measure, supplied-air personal respiratory protection.

To further evaluate the exposures found during the initial survey, particularly potential airborne exposures to PCDDs/PCDFs, a second environmental evaluation was scheduled for on October 27-30, 1987. Technical problems with the air sampling method for the PCDDs/PCDFs were encountered during this survey. However, limited data for airborne and surface PCBs and surface PCDD/PCDF were collected on October 28, 1987. A second follow-up evaluation was conducted on November 10-13, 1987.

The results of all environmental and medical evaluations will be discussed in this report.

III. BACKGROUND

A. Process Description

G&L was granted limited authorization by the EPA for the decontamination of PCB-containing and PCB-contaminated transformers, and the disposal of all reusable metal components of the dismantled transformers by eventual smelting, provided that the PCB residues remaining on the metal surfaces after cleaning and decontamination do not exceed 10 micrograms per 100 square centimeters (10 ug/100 cm^2). Following is a generalized description of the process used, as reported in the EPA conditional permit:

1. Upon receipt at the facility each transformer shall be tagged with an identification number and logged into the transformer book.

2. Each unit will be drained of all free flowing dielectric fluid and the liquid stored in properly constructed and labeled containers for subsequent incineration. All required recordkeeping shall be maintained on the liquid.

3. Processing of each drained transformer will begin with a primary decontamination cycle. Units and their removed lids, placed in the primary decontamination station, will be subjected to three complete vapor/spray cycles (30 minutes each) using TCE as the solvent.

4. After allowing evaporation of residual TCE from the transformer surfaces, the coil and core are detanked and then disassembled and separated in the dismantling area.
    a. Core steel components will be place into baskets.
    b. Coils will be stripped of insulation and also placed into baskets.
    c. The transformer tank will be cleaned in the primary decontamination station.
5. All drained dielectric fluids and nonreclaimable components such as wood, insulation paper, etc., will be stored for subsequent disposal.
6. All metal components contained in baskets will undergo sequential washes in each of the three TCE wash tanks of the secondary station for periods of approximately 30, 15, and 15 minutes respectively. Each tank will be coupled with a thermal separator which will continuously clean the fluid in each of the tanks.
7. Concurrently, the transformer tank and lid will be returned to the primary decontamination station for three complete vapor/spray cycles (30 minutes each).
8. Every transformer tank will be wipe sampled to determine completeness of decontamination. Also, routine quality control tests will be performed by randomly selecting a cleaned metal piece from a processed basket for wipe sampling.
9. Daily Process Reports will track all work.

B. Workforce and Facility

At the time of the initial evaluation, G&L had been in operation intermittently for about 20 months (since September 1985). Seven workers were employed, including the owners. Four worked in the production area full-time.

The processing area of the G&L plant measures 6,150 square feet. An area of 5,000 square feet is surrounded by a 12-inch dike as a containment area for the PCB decontamination process. A five ton overhead crane services this area with regard to material transport.

Material flow through the decontamination area begins at the transformer drain station. This station is a 12-inch diked pan, measuring 8 feet by 12 feet, where the opened transformers are located for draining any fluid that remains in them. Generally, this is less than one gallon. Residual fluid is pumped and metered into a 55-gallon drum. The drained transformer is then lowered into the primary decontamination unit, a vapor/liquid TCE degreaser deep enough for most conventional transformer units, where the initial cleaning takes place. It is estimated that 99% of the PCBs on exposed surfaces is removed in this process step. The decontamination tech's job is to run the primary and secondary degreasers. This job also involves material transfer from the drain pad to the primary degreaser, to teardown, to the secondary degreaser, then to decontaminated material storage.

Following primary decontamination the transformers are disassembled. Manual disassembly, or teardown, is carried out in a four-inch diked pan measuring 8 feet by 12 feet. Here the internal parts of the transformer are removed and dismantled in preparation for secondary decontamination.

Parts removed during teardown are either stacked or placed into baskets for secondary decontamination. The exception is the induction coil, which consists of many turns of heavy guage copper wire, or copper sheeting, which are coated with an insulation material (cotton, paper, or varnish). This insulation must be removed prior to secondary decontamination. This is done by feeding the copper wire from the induction coil through a machine that removes the insulation material by abrasion, called stripping. Upon exiting the machine, the copper wire is manually bent and compacted, then loaded into baskets for secondary decontamination. The copper sheet-type coil is unwrapped manually and the insulation is scraped off with hand tools. This does not disperse particulate into the air as the stripper machine does. Two workers were required to operate the stripper.

Secondary decontamination consists of a single pass through a three-stage liquid TCE degreaser for all transformer parts except the outer casing, which, because of its size, goes into the primary decontamination unit once again. Following secondary decontamination the parts are randomly wipe-sampled and then, if sufficiently cleaned, removed to an uncontaminated area of the plant for final disposition.

C. Control Technology

Environmental control systems in use at G&L at the time of the original investigation included local exhaust hoods on both primary and secondary degreasers and on the stripper. The degreasers were vented to the outside, and the stripper was vented into the workplace air through a carbon adsorbent. The thermal separators for the recycled TCE are sealed, enclosed units. General room ventilation consisted of a large exhaust fan in the south wall of the building. Replacement air entered through open doors at the north end.

Workers at G&L wore Tyvek suits, steel-toed rubber boots, hard hats with splash shields, and double gloves (inner of latex, outer of butyl-nitrile) whenever inside the containment area. All gear was removed upon exiting the containment and donned upon entering. Respirators with course filters and charcoal cartridges were available if needed (at the workers discretion). Workers wore these primarily when performing the primary decontamination, since the parts are manually sprayed with liquid TCE during this process, and sometimes during the stripping operation. Cartridges were changed weekly, or more frequently if desired by the worker. Inner gloves were changed whenever they were removed or when contacted by liquid. The outer gloves were changed when torn or whenever liquid was allowed inside. The workers removed the outer gloves to perform tasks that required dexterity.
In response to recommendations made following the initial evaluation by NIOSH, several changes were made in the production area of the G&L plant in an attempt to lower worker exposure potential. These included cleaning and painting all flooring in the production area of the plant; and coating the floor inside the containment area with a material resistant to PCB permeation (identified by the company as a polymer coating PC 4500).

The stripper operation was moved into a room in the production area to isolate the process and reduce its contribution of contaminants to the general plant environment. This room was made a respiratory protection area. Local exhaust on the stripper and large general area air filtration systems were installed in an effort to control the particulate generated by the stripping operation. The air for these systems is drawn through filters and activated carbon and then recirculated to the room. There is no exhaust to the outside and no outside air introduced into this room. Storage for induction cores with material to be stripped was changed to closed bins instead of open production area.

Several air-cleaning devices, of the same type as in the stripper room, which draw room air through coarse filters and a packed carbon bed before recirculating it into the work area, were installed in the decontamination production area. Adjustments were made to the ventilation system servicing the business offices to make this area positively pressurized with repect to the production area.

IV. EVALUATION DESIGN AND METHODS

A. Environmental Evaluation

The environmental evaluations consisted of determining potential inhalation exposures by collecting full-shift personal exposure and general area air samples. During all of the evaluations, exposures to TCE and PCBs were monitored. Airborne exposures to PCDDs/PCDFs were measured during the second follow-up evaluation. Also, to determine the potential for dermal exposure to PCBs, PCDDs and PCDFs, a number of wipe samples were obtained from various working surfaces and tools during the site visit. Personal exposure samples were collected from the breathing zone of production area workers. General area air samples were collected in offices, break room, and at key points within the production containment. The wipe samples were collected from the same areas.

1. Trichloroethylene (TCE)

Air samples for TCE were collected by drawing air through glass tubes containing 150 milligrams (mg) of activated charcoal at a flow rate of 50 milliliters (ml) per minute using calibrated, battery-operated sampling pumps. For analysis (NIOSH Method 1501[1]), the samples were desorbed with 1 ml of carbon disulfide containing 1 microliter of ethyl benzene as an internal standard. They were analyzed by gas chromatography with a flame-ionization detector. The limit of detection (LOD) for TCE, using this method, is 0.01 mg/sample, and the limit of quantitation (LOQ) is 0.03 mg/sample.

2. Polychorinated Biphenyls (PCBs)

A. Air Samples

General area and breathing zone (personal) air samples were collected by drawing air through 150 mg florisil tubes attached to battery-operated sampling pumps at a pre-calibrated flow rate of one liter per minute for the duration of the shift.

For analysis (NIOSH Method 5503[1]), the florisil tubes were separated into their primary and backup sections. Each section, along with the glass wool plug which precedes the front section, was desorbed in one ml of hexane with sonication for 1/2 hour. The gas chromatographic analysis was performed on a Hewlett-Packard Model 5730A gas chromatograph equipped with an electron capture detector and accessories for capillary column capabilities. A 30m x 0.31mm fused silica WCOT capillary column coated internally with DB-5 was used with temperature programming from 210°C (held for two minutes) to 310°C at a rate of 8°C/minute. Five percent methane in argon was used as the carrier gas. The injector was operated in the splitless mode. The presence of an Aroclor was determined by comparison with standard samples of Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260 obtained from the EPA. Quantitation was performed by summing the peak heights of the five major peaks of the standards and comparing those sums to those of the same peaks on the sample.

Only three Aroclors were found during the entire evaluation. These were 1242, 1254, and 1260, with Aroclor 1254 being found in an air sample only on the second survey. The respective analytical LODs for Aroclors 1254 and 1260 were 0.08 and 0.03 micrograms per sample (ug/sample). The LOD for Aroclor 1242 was was variable and ranged from 0.009 to 0.12 ug/sample. The LOQs for Aroclors 1254 and 1260 were 0.26 and 0.1 respectively, and ranged from 0.03 to 0.41 for Aroclor 1242.

b. Surface Wipe Samples

A wet-wipe protocol was used to assess the surface concentrations of PCBs. The surface wipe samples were collected using 3" x 3" Soxhlet extracted cotton gauze pads which had been wetted with 8 ml of pesticide-grade hexane. The sampling procedure consisted of marking the boundaries of a 0.25 m^2 area (unless otherwise noted) on the desired surface and wiping this area with the gauze pad. The sample pad was held with a gloved hand; a fresh non-linear polyethylene, unplasticized glove was used for each sample. The surface was wiped in two directions (the second direction orthogonal to the first). Each gauze pad was used to wipe only one area. The gauze pad sample was then placed in glass sample container equipped with a Teflon-lined lid.

The gauze samples were prepared for analysis by extraction in 40 ml of hexane with shaking for 30 minutes. The hexane was transferred to a concentrator tube, and the gauze was rinsed twice with 10 ml of hexane. The concentrated hexane eluent was cleaned on a florisil column, and the sample was brought to a final volume of 3 ml. GC analysis was the same as previously described for the florisil tube PCB samples.

Two Aroclors were consistently found on the surface samples, 1242 and 1260. The anlaytical LODs for these varied, and were respectively, 0.03-0.23 and 0.05-0.17 ug/sample. Similarly, the LODs were 0.09-0.77 and 0.16-0.55 ug/sample.

3. <u>Polychlorinated Dibenzodioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDFs)</u>

a. Air Samples

The air sampling device for PCDD/PCDF compounds consists of two stages. The first stage is a 47 millimeter (mm) glass microfiber filter (EM 2000, 0.3 micrometer) for collecting particulates. The second stage is a glass cartridge containing eight grams of 140°C activated 30/70 mesh silica gel absorbent. The silica gel cartridge is generally spiked with 2,3,7,8-tetrachlorodibenzo-p-dioxin -$^{13}C_{12}$ and 2,3,7,8-tetrachlorodibenzofuran -$^{13}C_{12}$ before sampling for quantification and to account for any retention losses during sampling. The glass cartridge containing the spiked silica gel absorbent is sealed in a rugged Teflon housing with fluorelastomer Viton "O" rings.
For sample collection the sampler is placed in a vertical position and attached via Tygon tubing to a 20 liter/minute rotary vane vacuum pump. Flow rates are regulated using precision control valves and appropriate flow measurement devices. Samples were collected over two eight-hour workshifts.

b. Surface Wipe Samples

To attain an acceptable detection limit, each PCDD/PCDF wipe sample consisted of a composite of four 0.25/m^2 wipe samples, for a total area of 1.0 m^2. These are collected using the same technique as described for the PCB wipe samples. The wipe samples are extracted with toluene for 16 hours using a Soxhlet apparatus to dissolve the PCDD and PCDF from the samples. The resulting toluene solution is concentrated to near dryness on a rotary evaporator. An extensive purification process is then used to prepare the samples for analysis.

The air and surface samples are analyzed by a gas chromatograph/mass spectrometer equipped with a DB-5 (screening) column and by DB-17 and SP 2331 columns in tandem (for isomer confirmation). Selected ^{13}C- and ^{37}Cl-labeled PCDD and PCDF isomers are included as internal standards and recovery (surrogate) standards.

Analyses are performed to measure total tetra-, penta-, hexa-, hepta-, and octachlorinated dibenzofurans; total tetra-, penta-, hexa-, hepta-, and octachlorinated dibenzodioxins; and specific PCDD and PCDF isomers containing chlorine substitution in the 2, 3, 7, and 8 positions. The analytical limits of detection were variable and ranged between 0.001 and 0.062 nanograms per sample.

B. Medical

Seven G & L employees participated in the medical survey, which included (a) an interview regarding previous work potentially involving PCB exposure, (b) an examination of the skin of the head and neck for signs of chloracne, and (c) measurement of serum PCB concentration. Additional information on work histories was obtained from company personnel.

Venous blood was obtained using a multiple-draw Vacutainer system. The blood was allowed to clot, and serum was separated, frozen, and sent to the Center for Environmental Health (CEH), Centers for Disease Control, Atlanta, Georgia, for analysis. The CEH laboratory measures PCB by gas chromatography/electron capture detection using Webb McCall quantitation factors according to the method of Burse et. al.[2]

V. EVALUATION CRITERIA

A. Toxicology

1. TCE

Trichloroethylene is a colorless, volatile, nonflammable liquid that is immiscible in water, has a vapor density of 4.45 and a boiling point of 87°C. It is a powerful degreasing and dry cleaning agent and has been used in commercial products such as printing inks, paints, lacquers, varnishes and adhesives. A pharmaceutical grade of TCE was formerly used as a general anesthetic in surgical and obstetrical procedures and as an analgesic for short operative procedures. It has also been used to extract caffeine from coffee.

The predominant physiological response is one of central nervous system depression. This is particularly true as a response from acute or short-term exposure. Visual disturbances, mental confusion, fatigue, incoordination, and sometimes nausea and vomiting have been observed. Prolonged skin contact may cause local irritation and blister formation. Under industrial conditions, repeated immersion of the hands in TCE has caused paralysis of the fingers. Although TCE will penetrate intact skin, it is unlikely that absorption of toxic quantities would occur by this route. TCE is absorbed readily from the gastrointestinal tract, but this is not usually a route of occupational exposure. Liver and kidney injuries in humans attributable to overexposure to TCE are rare.[3]

Intolerance to alcohol is also a well-characterized phenomenon among TCE-exposure workers. Not only do many TCE workers become inebriated with consumption of small quantities of alcoholic beverages, but they also are subject to vasodilatation of superficial skin vessels, resulting in skin blotches, a condition known as "degreasers flush". Flushing is most prominent on the face, neck, shoulders, and back. This condition appears to be a benign phenomenon of short duration but has lasted for up to 6 weeks after exposure to TCE for 5 days at 200 ppm.

On March 21, 1975 the National Cancer Institute reported preliminary results of a carcinogen bioassay for TCE which indicated no carcinogenic effects in rats but the induction of hepatocellular carcinomas in mice. After reviewing the NCI study, NIOSH recommended that TCE be considered a suspect human carcinogen and transmitted this message to industry in a Special Occupational Hazard Review with Control Recommendations.[4]

2. PCBs

PCBs are chlorinated aromatic hydrocarbons that were manufactured in the United States from 1929 to 1977 and primarily marketed under the trade name Aroclor.[5] They found wide use because they are heat stable; resistant to chemical oxidation, acids, bases and other chemical agents; stable to oxidation and hydrolysis in industrial use; and have low solubility in water, low flammability, and favorable dielectric properties. Additionally, they have low vapor pressure at ambient temperatures and viscosity-temperature relationships that were suitable for a wide variety of industrial applications. PCBs have been used commercially in insulating fluids for electrical equipment, hydraulic fluids, heat transfer fluids, lubricants, plasticizers, and components of surface coatings and inks.[6]

The different PCB mixtures marketed under different trade names are often characterized by a four-digit number. The first two digits denote the type of compound ("12" indicating biphenyl), and the latter two digits giving the weight percentage of chlorine, with the exception of Aroclor 1016. In other commercial preparations the number code may indicate the approximate mean number of chlorine atoms per PCB molecule (Phenoclor, Clophen, Kanechlor) or the weight percentage of chlorine (Fenclor).

Dietary PCB ingestion, the major source of population exposure, occurs especially through eating fish, but PCB residues are also found in milk, eggs, cheese, and meat. PCB residues are detectable in various tissues of persons without known occupational exposure to PCBs. Mean whole blood PCB levels range from 1.1 to 8.3 parts per billion (ppb), while mean serum PCB levels range from 2.1 to 24.2 ppb for persons without known occupational exposure.[7] Mean serum PCB levels among workers in one capacitor manufacturing plant studied by NIOSH ranged from 111 to 546 ppb, or approximately 5 to 22 times the background level in the community. Mean serum PCB levels among workers in transformer maintenance and repair typically range from 12 to 51 ppb, considerably lower than among workers at capacitor manufacturing plants.[8]

PCB toxicity is complicated by the presence of highly toxic impurities, especially the polychlorinated dibenzofurans (PCDFs)[9], which vary in amount depending on the manufacturer,[10] and percent chlorination,[11] and which are found in increased concentrations when PCBs undergo incomplete pyrolysis.[12,13] As well, different animal species, including man, vary in their pattern of biologic response to PCB exposure.[14]

Two human epidemics of chloracne, "Yusho" and "Yu-cheng," resulted from ingestion of cooking oil accidentally contaminated by a PCB heat-exchange fluid used in the oil's pasteurization.[15,16] Although PCBs were initially regarded as the etiologic agent in the Yusho study, analyses of the offending cooking oil demonstrated high levels of PCDFs and polychlorinated quarterphenyls, as well as other unidentified chlorinated hydrocarbons, in addition to PCBs.[17]

The results of individual studies of PCB-exposed workers are remarkably consistent. Among the cross-sectional studies of the occupationally exposed, a lack of clinically apparent illness in situations with high PCB exposure seems to be the rule. Chloracne was observed in recent studies of workers in Italy,[18] but not among workers in Australia,[19] Finland,[20] or the United States.[8,21-23] Weak positive correlations between PCB exposure, or serum PCB levels, and SGOT [18,20-22], GGTP[8,18,22,23], and plasma triglycerides have been reported.[8,24,25] Correlations between plasma triglycerides[26] and GGTP[27] have also been found among community residents with low level PCB exposures. Causality has not been imputed to PCBs in these cross-sectional studies.

The International Agency for Research on Cancer has concluded that the evidence for PCB carcinogenicity in animals and humans is limited. "Certain polychlorinated biphenyls are carcinogenic to mice and rats after their oral administration, producing benign and malignant liver neoplasms. Oral administration of polychlorinated biphenyls increased the incidence of liver neoplasms in rats previously exposed to N-nitrosodiethylamine.'[28]

In a mortality study among workers at two capacitor manufacturing plants in the United States[29] a greater than expected number of observed deaths from cancer of the liver and cancer of the rectum were noted. Neither increase was statistically significant for both study sites combined. In a recent update of this study[30], however, with follow-up through 1982, an excess in liver/biliary tract cancer was statistically significant (5 observed vs. 1.9 expected). The excess in cancer of the rectum was still elevated but not statistically significantly so. In this mortality study, the personal time-weighted average exposures in 1976 ranged from 24 to 393 ug/m^3 at one plant, and from 170 to 1260 ug/m^3 at the other. During the time period (1940-1976) when most of the workers were exposed, the levels were probably substantially higher. At one of the plants, the geometric mean serum PCB levels in 1976 were 1470 ppb for 42% chlorinated biphenyls and 84 ppb for 54% cholorinated biphenyls.

In a mortality study among workers at a capacitor manufacturing plant in Italy,[31] males had a statistically significant increase in the number of deaths from all neoplasms. When these were analyzed separately by organ system, death from neoplasms of the digestive organs and peritoneum (3 observed vs. 0.88 expected) and from lymphatic and hematopoietic tissues (2 observed vs. 0.46 expected) were elevated. This study was recently expanded to include vital status follow-up through 1982 for all workers with one week or more of employment.[32] In the updated results, there was a statistically significant excess in cancer among both females (12 observed vs. 5.3 expected) and males (14 observed vs. 7.6 expected). In both groups there were statistically non-significant excesses in lymphatic/hematopoietic cancer and a statistically significant excess in digestive cancer among males (6 observed vs. 2.2 expected).

3. PCDDs and PCDFs

PCDDs and PCDFs are two series of tricyclic aromatic compounds. The number of chlorine atoms can vary between 1 and 8 (mono- through octa-chloro homologs), resulting in 75 PCDDs and 135 PCDF positional isomers.

The toxic effects of these compounds are associated with the number and specific placement of the chlorine atoms in the molecule. The tetra-, penta- and hexachlorinated isomer groups exhibit greater toxicity than the other chlorinated forms.[33-35] PCDDs and PCDFs with chlorine at positions 2,3,7, and 8 are particularly toxic.[36-38] PCDDs and PCDFs are highly toxic in experimental animals when administered acutely subchronically, or chronically.[38-46] Toxic effects include severe weight loss, liver necrosis, and hypertrophy, skin lesions, immunosuppression, reproductive toxicity, teratogenesis and death. Of the 75 PCDD and 135 PCDF isomers, only 2,3,7,8-TCDD and a mixture of hexachlorinated dibenzo-p-dioxins with four of the six chlorines in positions 2,3,7, and 8 have been tested for carcinogenicity. Two independent studies of 2,3,7,8-TCDD showed significant increases in the incidence of liver and/or lung tumors in exposed rodents.[46,47] A mixture of two 2,3,7,8-substituted hexachlorinated dibenzodioxins was found to produce an increased incidence of liver tumors or neoplastic nodules in exposed rats and mice.[48] Exposure to PCDD can cause chloracne and liver toxicity in humans.[44,49] There is suggestive evidence of an association between increased incidence of cancer in people exposed to PCB containing substantial amounts of PCDF[50,51] and in people exposed to phenoxyacetic herbicides contaminated with PCDD, including TCDD.[52,53] Definite causal relationships between exposure and carcinogenic effects in humans remain unclear, however, due to the inadequately defined study populations and the influences of mixed exposures.

B. Environmental Evaluation Criteria

As a guide to the evaluation of the hazards posed by work place exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other work place exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the work place are: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor (OSHA) Permissible Exposure Limits (PELs). Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA PELs. The NIOSH RELs and ACGIH TLVs are usually based on more recent information than are the OSHA standards. The OSHA PELs may also be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures.

1. TCE

NIOSH's initial recommendation for a TCE standard was issued in 1973.[54] This recommended standard, and the current OSHA standard, both 100 ppm, were based upon TCE's known toxic properties at that time and did not include an assessment of its carcinogenic potential. In 1978, NIOSH recommended that TCE be controlled as an occupational carcinogen.[4] Information at that time regarding engineering feasibility indicated that TWA personal exposures of 25 ppm could be readily attained. However, it was not felt that this should serve as a final goal. Rather, industry should pursue further reductions in worker exposure as advancements in technology research allowed. Since there is no known safe level of exposure to a carcinogen, the goal should be to minimize exposure to the lowest extent possible.

2. PCBs

a. Airborne exposure

In February 1986, NIOSH reiterated its previous recommendation that exposure to PCB in the workplace not exceed 1 ug/m^3 (based upon the recommended sampling and analytical method in use at the time), determined as a TWA for up to a 10-hour workday, 40-hour workweek.[55] This recommended exposure limit was based on the findings of adverse reproductive effects in experimental animals, on the conclusion that PCBs are carcinogens in rats and mice and, therefore, potential human carcinogens in the workplace, and on the conclusion that human and animal studies have not demonstrated a level of exposure to PCBs that will not subject the worker to possible liver injury.[56]

In 1971, based on the 1968 ACGIH TLVs, OSHA promulgated its permissible exposure limits of 1 mg/m^3 for airborne chlorodiphenyl products (PCB) containing 42% chlorine and 0.5 mg/m^3 for chlorodiphenyl products containing 54% chlorine, determined as 8-hr TWA concentrations (29 CFR 1910.1000). The TLVs, which have remained unchanged at 1.0 and 0.5 mg/m^3 through 1988, are based on the prevention of (non-carcinogenic) systemic toxicity.[57] The OSHA PEL and the ACGIH TLV values include a "skin" notation, which refers to the potential contribution to overall exposure by the cutaneous route, including the mucous membranes and eyes, by either airborne or direct skin contact with PCB.

b.Surfaces

NIOSH recommends that occupational exposures to carcinogens be reduced to the lowest feasible level. Results of several investigations of PCB surface contamination in office buildings indicate that there is a "background" level of surface contamination in the range of 50 to 100 micrograms per square meter (ug/m^2).[58-61] Therefore, for surfaces in the occupational environment that may be routinely contacted by the unprotected skin, NIOSH investigators have recommended that PCB contamination not exceed 100 ug/m^2 (the lowest feasible level considering background contamination).

The risk posed by this level of contamination was assessed by the Environmental Protection Agency (EPA) in its PCB spill cleanup policy.[62] In the "Development" section of the policy (Risks Posed by Leaks and Spills of PCBs), the EPA states that the estimated level of oncogenic risk associated with dermal exposures to 50 ug/m^2 of PCBs on hard, indoor, high-contact surfaces is between 1×10^{-5} and 1×10^{-6} (between 1 in 100,000 and 1 in 1,000,000 excess deaths, usually stated in terms of workers with a 30-year work history). Although the EPA document did not provide a risk estimate for the cleanup criterion it established for high-contact indoor surfaces (1000 ug/m^2), it did state, "EPA also believes that the surface standards of 1000 ug/m^2 for indoor low-contact surfaces (and vaults) and high-contact surfaces in a restricted access industrial facility would not present significant risks to workers or the the general population." However, since there is a considerable degree of uncertainty associated with such a risk assessment calculation, EPA also stated that, "...the results of these [EPA] studies indicate that high-contact surfaces such as manually operated machinery may require surface standards more stringent than the 1000 to 10,000 ug/m^2 standards."

3. PCDD and PCDF

NIOSH recommends that 2,3,7,8-TCDD be regarded as a potential occupational carcinogen, that occupational exposure to 2,3,7,8-TCDD be controlled to the lowest feasible level, and that decontamination measures be used for 2,3,7,8-TCDD-contaminated work environments. This recommendation is based on a number of reliable studies demonstrating carcinogenicity in rats and mice.[44]

In July 1985, an advisory panel was convened to develop air and surface cleanup guidelines for PCB, PCDD, and PCDF for the New Mexico State Highway Department Building in Sante Fe. Both NIOSH and EPA were represented on this panel, which considered the potential risk of developing cancer as a result of exposure to PCDF and PCDD. The panel's exposure guidelines for PCDF and PCDD were intended to maintain this risk below one in one million for a person spending his/her working lifetime (30 years) in the building.

The air and surface guidelines recommended by the advisory panel were 2 picograms per cubic meter (pg/m^3) and 1 nanogram per square meter (ng/m^2), respectively, expressed as 2,3,7,8-TCDD equivalents.[63] 2,3,7,8-TCDD equivalents are defined as the concentration of 2,3,7,8-TCDD which, by itself, would exhibit the same biological potency as the mixture of structurally-related compounds, PCDDs and PCDFs, actually present in a sample. The structually-related PCDDs and PCDFs that are considered in the calculation of 2,3,7,8-TCDD equivalents include the tetra- through octachloro homologs and 2,3,7,8-substituted isomers.

This procedure, initially developed by the New York State Department of Health, estimates the amount of 2,3,7,8-TCDD that would have to be present to exhibit a similar toxicity as the measured amounts of all of the other PCDDs and PCDFs. The procedure assumes certain weighting factors (ratios of toxicities) between 2,3,7,8-TCDD and the other PCDDs and PCDFs.[64] The weighting factors (called toxicity equivalency factors by EPA) are those currently proposed by EPA [Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Dibenzo-p-Dioxins and Dibenzofurans (CDDs and CDFs), Risk Assessment Forum, EPA 625/3-87/012, 1987].

PCDFs	Factor	PCDDs	Factor
2,3,7,8-TCDFs	0.1	2,3,7,8-TCDD	1.0
other TCDFs	0.001	other TCDDs	0.01
2,3,7,8-PeCDFs	0.1	2,3,7,8-PeCDDs	0.5
other PeCDFs	0.001	other PeCDDs	0.005
2,3,7,8-HxCDFs	0.01	2,3,7,8-HxCDDs	0.04
other HxCDFs	0.0001	other HxCDDs	0.0004
2,3,7,8-HpCDFs	0.001	2,3,7,8-HpCDDs	0.001
other HpCDFs	0.00001	other HpCDDs	0.00001
OCDFs	0.0	OCDDs	0.0

The concentrations of the PCDD and PCDF compounds are converted to TCDD equivalents by multiplying measured values by the appropriate factor. The TCDD equivalents are then summed and compared to the guideline value.

VI. RESULTS

A. Environmental Evaluation

1. Personal Inhalation Exposures to PCBs and TCE

The personal exposures to PCBs and TCE for all three evaluations are summarized in Tables 1 and 2. The results for the two follow-up evaluations are combined in the summary tables since they were collected under similar conditions, following engineering control changes at the plant. Separating initial and follow-up results allows for a comparative evaluation of the control measures. The results of personal exposure monitoring for the individual evaluations are in Tables 3-5.

Average exposures to TCE ranged from 5.3 to 11.8 ppm during the initial evaluation and from 20.8 to 29.2 ppm during the follow-up evaluations (Table 1). The decontamination technicians had the higher average exposures (11.8 and 29.2 ppm) to TCE. However, the higher individual personal TCE exposure concentrations measured (34.2 and 35.5 ppm) were collected from the breathing zones of the stripper technicians during the first follow-up survey (Table 4). NIOSH recognizes TCE as being a potential occupational carcinogen and recommends that exposure be controlled to the fullest extent possible.

Average personal exposures to PCBs for the three technician job categories ranged from 14.5 to 20.8 ug/m^3 during the initial survey and from 9.9 to 25.9 ug/m^3 during the follow-ups. The higher average exposures were experienced by the decontamination technician during the initial, and by the stripper technicians during the follow-ups. While the highest individual exposures to PCBs occurred to the decontamination technician (23.4 ug/m^3) during the initial and (22.6 ug/m^3) final evaluations, and to the stripper technicians (45.2 and 57.5 ug/m^3) during the second evaluation, all of the personal exposures measured far exceeded the NIOSH criterion of <1.0 ug/m^3, suggested as the lowest feasible limit.

During primary decontamination the transformer cores are saturated with liquid TCE solvent, which does not completely evaporate while in the controlled environment of the degreaser. When the transformer is removed from the degreaser to the uncontrolled (unventilated) teardown area, the TCE and solvated PCB evaporate. This continues throughout the disassembly. This vapor is the primary exposure to the degreaser operator and the teardown techs. Similarly, when the parts are removed from secondary decontaminaion, they are placed in the open environment, instead of in a ventilated area. These parts, however, tend to be drier.

When the induction coils are brought to the stripper room, the insulation material covering the wire can still be saturated with solvated PCB and the TCE solvent. The vapor, due to evaporation, as well as the particulate dispersed by the stripper, contribute to the high exposures to the stripper operators.

2. General Area Air Concentrations of TCE and PCBs

General area air concentrations of the TCE and PCBs are summarized for the three evaluations in Table 6 and 7. Individual survey results are in Tables 8-10.

Average general area air concentrations of TCE ranged from 4.2 to 30.5 ppm during the first evaluation (Table 6). The highest area air TCE concentration was collected at the primary degreaser. Interestingly, during the initial survey, the average TCE concentration in the stripper area (4.2 ppm) was lower than both the breakroom (10.0 ppm) and the business office (5.5 ppm). During the follow-ups the average general area air concentrations ranged from 0.3 to 28.3 ppm. The greatest potential for exposure to TCE appeared to be in the teardown area, with the stripper area next (17.1 ppm). Ventilation changes to positively pressurize the office and break areas with respect to the production areas appeared to be effective. These two areas had the lowest general area air concentrations of TCE during the follow-ups.

The average general area air concentrations for PCBs are summarized in Table 7. Average concentrations throughout the production areas were higher during the initial evaluation, ranging from 14.3 to 25.8 ug/m^3. Concentrations near 30 ug/m^3 were measured in the primary decontamination and teardown areas. In the breakroom and the business office, the average values were 6.4 and 2.2 ug/m^3, respectively, indicating that there was nowhere in this plant that a worker could not be exposed to PCBs above the NIOSH REL. The situation was dramatically better during the follow-up evaluations. With the exception of the stripper area, where the average concentration of PCBs was 20.3 ug/m^3, the range of area concentrations was 1.0 to 3.3 ug/m^3 in production areas, and 0.2 and 0.9 in the business office and breakroom. This provided strong evidence that the stripping operation was a major contributor to overall PCB exposure during the initial survey. Although the operation has been isolated, PCB exposure to the workers in the stripper room are still not well controlled.

3. Surface Concentrations of PCBs

Results of the surface concentration samples for PCBs are presented in Table 11. Except where indicated, all sampled areas were 0.25 m^2. Surface samples were collected in the process containment area, where Tyvek suits, double-layered rubber gloves, and rubber boots are worn, as well as in areas outside the containment where these protective equipment measures are not taken and skin contact with surfaces is common.

During the initial evaluation, seven samples were collected from "high-contact" surfaces (surfaces which can be repeatedly touched with unprotected skin) outside the containment area. PCB contamination levels measured ranged from 10 to 800 ug/m^2. Two of the results were below 100 ug/m^2. All others were near, or greater than, this recommended evaluation criterion. Cleanup efforts made between the initial and first follow-up surveys did not appear to lower contamination outside the containment area, except for the sample collected on the business office floor. PCB concentrations on the supervisor's desk top and the breakroom lunch table were greater when sampled during the follow-up evaluations.

Nineteen surface samples for PCBs were collected in work areas inside the containment, over all three evaluations. The surface concentrations ranged from 1,000 to 72,000 ug/m^2, with all of the samples meeting or exceeding the established EPA surface standard of 1,000 ug/m^2 for high- and low-contact surfaces in a restricted access industrial facility. Since it was common for workers to remove their outer glove when using the controller to the overhead crane to transfer material to and from the degreasers, the concentrations on these high-contact surfaces are the most remarkable. The crane controller sample results ranged from 11,000 to 16,000 ug/m^2. A concentration of 20,000 ug/m^2 was measured on the top surface of the primary degreaser. The PC 4500 surface applied over the concrete in the containment area is designed to have a low permeation rate for PCBs. This appears to be of little consequence, since the floors throughout the areas were highly contaminated anyway. The floor area sampled near the teardown pan was as contaminated as the floor of the pan itself (33000 vs. 34000 ug/m^2).

4. Surface PCDDs and PCDFs

Surface concentrations of PCDDs and PCDFs are reported in Table 12 as 2,3,7,8-TCDD equivalents. All of these results are from samples of one square meter of surface area. A sample collected from the painted concrete floor outside the containment area, during the initial survey, measured a concentration of 3.0 nanograms per square meter (ng/m^2). Cleanup of the area between the surveys had a positive effect. The concentrations found during the two follow-ups were 0.2 and 0.3 ng/m^2. These are below the recommended criterion of 1 ng/m^2.

Within the containment area, concentrations of 2,3,7,8-TCDD equivalents were 16.0 and 19.0 ng/m^2 during the initial survey. The higher result was measured in the area of the stripper where the inductor cores were placed while waiting for the wire to be removed and stripped. The other was collected next to the transformer drain pan. The concentrations measured on the stripper room floor, coated with PC 4500, during the follow-up evaluations were 12.6 and 13.5 ng/m^2. On the floor near the teardown pan on the follow-ups the concentrations were 4.7 and 11.3 ng/m^2. Concentrations in both of these areas increased from the second to the third survey.

5. General Area Air Concentrations of 2,3,7,8-TCDD Equivalents

Four general area air samples were collected to measure PCDD/PCDF. The results are reported in Table 13, as 2,3,7,8-TCDD equivalents. In the production areas the concentrations ranged from ND to 4.2 picograms per cubic meter (pg/m^3). The highest value was measured in the stripper room and exceeds the evaluation criterion of 2.0 pg/m^3. This result gives credence to the idea that control measures tried in this area were not effective. A concentration of 0.01 pg/m^3 was measured in the business office.

B. Medical Evaluation

One of the seven G & L employees reported prior occupational exposure to PCB. His PCB blood level in 1981, measured as part of a NIOSH Health Hazard Evaluation,[65] was 127 ppb.

The G & L employees can be divided into groups on the basis of work history and job. Four worked for G & L since operations began in September 1985. The remaining 3 were hired 60 - 90 days prior to the initial evaluation. Of the 4 long-term employees, 3 worked primarily on the processing floor and 1 worked primarily in the office area. Of the 3 short-term employees, 2 worked primarily on the processing floor and 1 worked primarily in the office area.

None of the participants had head and neck skin lesions suggestive of chloracne. The serum PCB values (reported as Aroclor 1260) for the seven participants were 12, 12, 13, 13, 17, 26, and 211 ppb. Persons without occupational exposure generally have levels less than 20 ppb, usually less than 10 ppb. The three long-term processing area workers had a mean serum PCB level of 19 ppb. The two short-term processing area workers had a mean serum PCB level of 12.

VII. DISCUSSION

The environmental evaluation results show that, although general area air concentrations of PCBs were reduced, in most instances, in the follow-up evaluations, personal inhalation exposures still exceeded the NIOSH REL (LFL, <1.0 ug/m^3). Of particular concern are the general area air concentrations of PCDDs/PCDFs measured. Also, personal exposures to TCE exceeded the NIOSH REL (LFL) of <25 ppm, which was thought to be achievable with control technologies available in 1978. The stripper and decontamination techs receive the greater exposures to both PCBs and TCE, although the teardown workers are also exposed to high concentrations. The decontamination technician often would wear a respirator and the stripper room is a respiratory protection area, although there is no sign indicating this. Respirators are not worn constantly throughout the workday, and therefore must be handled with contaminated hands whenever put in place or removed while in the work area. Improper use was observed by workers in the stripper room, where they would sometimes use only one set of straps to hold the respirator in place, instead of the two sets provided, thus compromising the effectiveness of the respirator. Since the workers at G&L are exposed to suspected human carcinogens, the half-mask respirators in use do not meet the NIOSH recommended level of protection.[66] When respiratory protection is required to achieve the lowest exposure concentration, then only the most effective respirators should be used. Supplied-air respiratory protection is recommended in such situations.

Regardless, respirators should not be used as a substitute for proper control measures. The best engineering controls and work practices should be instituted throughout the production area. The greatest inhalation exposures to TCE and PCBs, and the greatest general area air concentration of dioxin, were found in the stripper room. There is no way to control this operation without the extensive use of modern exhaust and replacement-air ventilation systems. Continued use of recirculation systems in this area is unacceptable. Likewise, in the other areas of the production plant, the use of recirculation air-cleaning systems should be discontinued and replaced with conventional, state of the art ventilation systems. Combinations of local exhaust and general area dilution systems would be optimal. Emphasis should also be put on controlling exposures in the teardown and primary decontamination areas. Enclosure of these areas, such as was done with the stripper operation, would be good, but may not be possible.

Surface contamination with PCBs inside the containment area is much greater than the existing EPA cleanup standard (1,000 ug/m^2). Surface concentrations of 2,3,7,8-TCDD equivalents inside the containment area were also high. Surface contamination with PCBs outside the containment area is not being controlled to near background concentrations (100 ug/m^2 or less). This indicates that policies and procedures in place for containing the PCBs inside the controlled area are not effective. The physical separation of the protection and non-protection areas is too easily compromised.

Although 6 of 7 of the G & L participants had serum PCB levels close to the range expected in groups without occupational PCB exposure, the duration of exposure was relatively short. The association between duration of employment in the processing area and elevation of serum PCB level suggests that G & L employees are currently absorbing PCB from the plant environment. The finding of significant plant contamination with 2,3,7,8-TCDD equivalents, combined with evidence of PCB absorption, suggests that workers may be absorbing these compounds as well.

VIII. RECOMMENDATIONS

NIOSH data suggest that current work practices and environmental controls are not sufficient to adequately prevent worker exposures to TCE, PCBs, and PCDD/PCDF. Based upon these findings the following recommendations are made:

1. The following ventilation changes should be made to lower air contaminant concentrations in the plant.

    a. The practice of recirculating exhaust air in the stripper room and other areas of the plant should be discontinued.

    b. In the stripper room, the stripper machine should be controlled by local ventilation which exhausts to the outside (with appropriate air cleaning systems). This system should be designed to control both particulate and vapor contaminants. In addition, the stripper room should have a dilution ventilation system. This room should be kept negatively pressurized with respect to the rest of the plant. Replacement air for these ventilation systems should come from the outside, giving proper regard to reentrainment of exhausted air, unless concentrations of suspected carcinogens in the general plant air are maintained at the lowest feasible limit.

    c. Local ventilation should be installed at the teardown work station. A downdraft bench system, for instance, may be practical for this situation. The cores to be disassembled should be set on the bench over the ventilation. Similarly, the disassembled parts, as well as the baskets for secondary decontamination, should be placed in locally ventilated areas. Enclosure of the process would be best, but may not be possible.

    d. Air concentrations of contaminants in the general production area of the plant should be controlled by dilution ventilation using outside replacement air. Specific processes, not mentioned above, may be optimally controlled by local exhaust ventilation.

2. Until ventialtion engineering controls have been installed and proven effective in controlling personal airborne exposures to TCE, PCBs, and PCDD/PCDF to their lowest feasible limits, anyone entering the production (restricted) areas of the plant should wear a combination Type C supplied-air respirator, with full facepiece, operated in pressure-demand mode and equipped with an auxiliary positive pressure, self-contained air supply.[66] This is in addition to currently worn personal protective equipment.

3. The "clean" areas of the plant should be isolated, using physical barriers, a three phase decontamination system, and ventilation systems, from the production (restricted) areas. The administrative and supervisor offices, and the break/lunch area should be designated as clean areas.

4. Access between the contaminated and clean areas of the plant should be on a restricted and controlled basis. The employer should ensure that employees enter and exit the restricted area through the decontamination facility. The decontamination facility should consist of a contaminated equipment room, a shower area, and a clean room in series. These type of hygiene facilities and practices are standard, and required, in other decontamination industries where the contaminant is a carcinogen (e.g., asbestos), and are necessary to prevent PCBs, PCDDs, and PCDFs from being transferred to clean areas of the plant and to areas outside the plant.

5. At a minimum, high-contact surfaces, as defined by the EPA,[62] in the restricted access area should be cleaned, using EPA described methods, to below the EPA Standard of 1,000 ug/m^2 (10 ug/100 cm^2).

6. All office areas and break/lunch areas should have ventilation systems designed so that they are kept under positive air pressure with respect to the production areas.

7. Continued employee monitoring for exposure and absorption of TCE, PCBs, and PCDD/PCDF should be conducted to assure the effectiveness of control measures employed.

IX. REFERENCES

1. National Institute for Occupational Safety and Health. NIOSH manual of analytical methods. 3rd Ed. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1984. (DHHS (NIOSH) publication no. 84-100).

2. Burse, V. W., Needham, L. L. et. al., Evaluation of Potential Analytical Approach for Determination of Polychlorinated Biphenyls in Serum: Interlaboratory Study

3. National Institute for Occupational Safety and Health. Current intelligence bulletin no. 2 - trichloroethylene (TCE). Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1975; DHEW (NIOSH) publication no. 78-127.

4. National Institute for Occupational Safety and Health. Special occupational hazard review with control recommendations - trichloroethylene (TCE). Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1978; DHEW (NIOSH) publication no. 78-130.

5. Lloyd JW, Moore RM, Woolf BS, Stein HP. Polychlorinated biphenyls. J Occup Med 1976;18:109.

6. Hutzinger O, Safe S, Zitko V. The chemistry of PCBs. Cleveland: The Chemical Rubber Company Press, 1974.

7. Landrigan PJ. General population exposure to halogenated biphenyls. In: Kimbrough RD, ed. Halogenated biphenyls, terphenyls, naphthalenes, dibenzodioxins, and related products. Amsterdam: Elservier/North Holland Biomedical Press, 1980:267.

8. Smith AB, Schloemer J, Lowry LK, et al. Metabolic and health consequences of occupational exposure to polychlorinated biphenyls (PCBs). Br J Ind Med 1982;39:361.

9. Vos JG, Koeman JG. Comparative toxicologic study with polychlorinated biphenyls in chickens, with special reference to prophyris, edema formation, liver necrosis, and tissue residues. Tox App Pharm 1970;17:656.

10. Vos JG, Koeman JH, van der Mass HL, ten Noever de Brauw MC, de Vos RH. Identification and toxicological evaluation of chlorinated dibenzofuran and chlorinated naphthalene in two commercial polychlorinated biphenyls. Fd Cosmet Toxicol 1970;8:625.

11. Bowes GW, Mulvihill MJ, Simoneti BRT, Burlingame AL, Risebrough RW. Identification of chlorinated dibenzofurans in American polychlorinated biphenyls. Nature 1975;94:125.

12. Buser HR, Bosshardt HP, Rappe C. Formation of polychlorinated dibenzofurans (PCDFs) from the pyrolysis of PCBs. Chemosphere 1978;7:109

13. Buser HR, Rappe C. Formation of polychlorinated dibenzofurans (PCDFs) from the pyrolysis of individual PCB isomers. Chemosphere 1977;8:157.

14. Vos JG. Toxicology of PCBs for mammals and for birds. Env. Health Perspect 1969;21:29.

15. Kuratsune M, Yoshimura T, Matsuzaka J, Yamaguchi A. Epidemiologic study on Yusho, a poisoning caused by ingestion of rice oil contaminated with commercial brand of polychlorinated biphenyl. Environ Health Perspect 1972;1:119.

16. Wong CK. PCB poisoning special issue. Clinical Medicine (Taipei). Volume 7, no. 1, 1981.

17. Masuda Y, Duroki H. Polychlorinated dibenzofurans and related compounds in patients with "Yusho." In: Hutzinger O, Frei R W, Merian E, Pocchiari F, eds. Chlorinated dioxins and related compounds. Oxford: Pergamon Press, 1982:561.

18. Maroni M, Colombi A. Arbosti G, Cantoni S, Foa V. Occupational exposure to polychlorinated biphenyls in electrical workers, II. Health effects. Br J Ind Med 1981;38:55.

19. Ouw KH, Simpson GR, Siyali DS. The use an health effects of Aroclor 1242, a polychlorinated biphenyl in the electrical industry. Arch Environ Health 1976;31:189.

20. Karppanen E, Kolho L. The concentration of PCB in human blood and adipose tissue in three different research groups. In: PCB Conference II, Stockholm, 1972. National Swedish Environmental Protection Board, 1973: 124.

21. Fischbein A, Woolf MS, Lilis R, Thornton J, Selikoff IJ. Clinical findings among PCB-exposed capacitor manufacturing workers. Ann NY Acad Sci 1979;320:703.

22. Chase KH, Wong O, Thomas D, Berney BW, Simon RK. Clinical and metabolic abnormalities associated with occupational exposure to polychlorinated biphenyls (PCBs). J Occup Med 1982;24:109.

23. National Institute for Occupational Safety and Health. Health hazard evaluation report no. HETA 80-007-1520. Cincinnati: National Institute for Occupational Safety and Health, 1984.

24. Lawton RW, Sack BT, Ross MR, Feingold J. Studies of employees occupationally exposed to PCBs. General Electric Research and Development Center, Schenectady, 1981.

25. Crow KD. Chloracne: a critical review including a comparison of two series of cases of acne from chloronaphthalene and pitch fumes. Trans St John's Hosp. Dermatol Soc 1970;56:79.

26. Baker EL Jr, Landrigan PJ, Glueck CJ. Metabolic consequences of exposure to polychlorinated biphenyls in sewage sludge. Am J Epid 1980;112:553.

27. Kreiss K, Zack MM, Kimbrough RD, Needhan LL, Smrek AL, Jones BT. Association of blood pressure and polychlorinated biphenyl levels. JAMA 1981;245:2505.

28. International Agency for Research on Cancer. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans. Chemicals, Industrial Process, and Industries Associated with Cancer in Humans. IARC Monographs, Volumes 1 to 29. Supplement 4, Lyon, France, 1982: 218.

29. Brown DP, Jones M. Mortality and industrial hygiene study of workers exposed to polychlorinated biphenyls. Arch Environ Health 1981;36:120.

30. Brown DP. Mortality of workers exposed to PCBs. Arch Environ Health 1987 (in press).

31. Bertazzi PA, Zocchetti C, Guercilena S, Foglia MD, Pesatori A, Riboldi L. Mortality study of male and female workers exposed to PCBs. Presented at the International Symposium on Prevention of Occupational Cancer, April, 1981, Helsinki, Finland.

32. Bertazzi PA, Riboldi L, Pesatori A, Radice L, Zocchetti C. Cancer mortality of capacitor manufacturing workers. Am J Industr Med 1987;11:165-76.

33. Goldstein JA. The structure-activity relationships of halogenated biphenyls as enzme inducers. Ann NY Acad Sci 1979;320:164-78.

34. Youshimura H, Youshihara S, Ozawa N, Miki M. Possible correlation between induction modes of hepatic enzymes by PCBs and their toxicity in rats. Ann NY Acad Sci 1979;320:179-92.

35. Poland A, Greenlee W, Kende AS. Studies on the mechanism of action of the chlorinated dibenzo-p-dioxins and related compounds. Ann NY Acad Sci 1979;320:214-30.

36. McConnell EE, Moore JA, Haseman JK, Harris MW. The comparative toxicity of chlorinated dibenzo-p-dioxins in mice and guinea pigs. Toxicity Appl Pharmacol 1978;44:335-56.

37. Nagayama J, Kuroki H, Masuda Y, Kuratsune M. A comparative study of polychlorinated dibenzofurans, polychlorinated biphenyls and 2,3,7,8-tetrachlorodibenzo-p-dioxin on aryl hydrocarbon hydroxylase inducing potency in rats. Arch Toxicol 1983;53:177-84.

38. Yoshihara S, Nagata K, Youshimura H, Kuroki H, Masuda Y. Inductive effect on hepatic enzymes and acute toxicity of individual polychlorinated dibenzofuran congeners in rats. Toxicol Appl Pharmacol 1981;59:580-8.

39. Moore JA, McConnell EE, Dalgard DW, Harris MW. Comparative toxicity of three halogenated dibenzofurans in guinea pigs, mice, and rhesus monkeys. Ann NY Acad Sci 1979;320151-63.

40. Schwetz BA, Norris JM, Sparschu GL, et al. Toxicology of chlorinated dibenzo-p-dioxins. Environ Health Perspect 1973;5:87-99.

41. McConnell EE, Moore JA, Dalgard DW. Toxicity of 2,3,7,8-tetrachloro-dibenzo-p-dioxin in rhesu monkeys (masaca mulatta) following a single oral dose. Toxicol Appl Pharmacol 1978;43:175-87.

42. Garthoff LH, Cerra FE, Marks EM. Blood chemistry alterations in rats after single multiple gavage administration of polychlorinated biphenyl. Toxicol appl Pharmacol 1981;60:33-44.

43. Moore JA, Gupta BN, Vos JG. Toxicity of 2,3,7,8-tetrachlorodibenzo-furan - preliminary results. In: Proceedings of the National Conference on Polychlorinated Biphenyls, held 1975 November 19-21 in Chicago, EPA-560/6-75-004. Environmental Protection Agency, Office of Toxic Substances, 1976:77-80.

44. National Institute for Occupational Safety and Health. Current intelligence bulletin 40 - 2,3,7,8-tetrachlorodibenzo-p-dioxin. Cincinnati, Ohio: National Institute for Occupational Safety and Health [DHHS (NIOSH) publication no. 84-104], 1984.

45. Hassoun E, d'Argy R. Deneker L, Teratogenicity of 2,3,7,8-tetrachloro-dibenzofuran in the mouse. J Toxicol Environ Health 1984;14:337-51.

46. Kociba RJ, Keyes DG, Beyer JE, et al. Results of a two-year chronic toxicity and oncogenicity study of 2,3,7,8-tetrachlorodibenzo-p-dioxin in rats. Toxicol Appl Pharmacol. 1978;46:279-303.

47. National Toxicology Program. Bioassay of 2,3,7,8-tetrachlorodibenzo-p-dioxin for possible carcinogenicity (gavage study). Bethesda, MD and Research Triangle Park, North Carolina: National Toxicology Program [DHHS (NIH) publication no. 82-1765], 1982.

48. National Toxicology Program. Bioassay of 1,2,3,6,7,8-and 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin for possible carcinogencity (gavage study). Bethesda, MD and Research Triangle Park, North Carolina: National Toxicology Program [DHHS (NIH) publication no. 80-1758], 1980.

49. Ideo G, Bellati G, Bellobuono A, Bissanti L. Urinary D-glucaric acid excretion in the Seveso area, polluted by tetrachlorodibienzo-p-dioxin (TCDD): five years of experience. Environ Health Perspect 1985;60:151-7.

50. Urabe H, Koda H, Asahi M. Present State of Yusho patients. Ann NY Acad Sci 1979;320:273-6.

51. Kuratsune M. epidemiologic studies on Yusho. In: Higuchi K, ed. PCB poisoning and pollution. Tokyo: Kodansha Ltd., 1976:9-23.

52. Hardell L, Sandstrom A. Case-control study: soft tissue sarcomas and exposure to phenoxyactic acids or chorophenols. Br J Cancer 1979;39:711-7.

53. Hardell L. Malignant lymphoma of histiocytic type and exposure to phenoyacetic acids or chlorophenols. Lancet 1979;55-6.

54. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to trichloroethylene. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. (DHEW publication no. HSM 73-11025.

55. National Institute for Occupational Safety and Health. Current intelligence bulletin 45 – polychlorinated biphenyls (PCB's): potential health hazards from electrical fires or failures. Cincinnati, Ohio: National Institute for Occupational Safety and Health [DHHS (NIOSH) publication no. 86-111], 1986.

56. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to polychlorinated biphenyls. Cincinnati, Ohio: National Institute for Occupational Safety and Health [DHEW publication no. (NIOSH) 77-225], 1977.

57. American Conference of Governmental Industrial Hygienists. Documentation of the threshold limit values and biological exposure indices. 5th ed. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists, 1986.

58. National Institute for Occupational Safety and Health. PCB exposures following fluorescent light ballast burnout. Applied Industrial Hygiene 1987; 3:R-24.

59. National Institute for Occupational Safety and Health. Health hazard evaluation report no. HETA 86-112-1819. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1987.

60. National Institute for Occupational Safety and Health. Health hazard evaluation report no. HETA 86-472-1832. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1987.

61. National Institute for Occupational Safety and Health. Health hazard evaluation report no. HETA 87-166-1835. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1987.

62. U. S. Environmental Protection Agency. Polychlorinated biphenyls spill cleanup policy. 40 CFR 761.120. Federal Register 52(63):10688, April 2, 1987.

63. National Institute for Occupational Safety and Health. Health hazard evaluation report no. HETA 85-414-1805. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1987.

64. Eadon G, K. Aldouos, G. Frenkel, et al. 1982. Comparisons of Chemical and Biological Data on Soot Samples from the Binghamton State Office building. Albany, NY: Center for Laboratories and Research, New York State Department of Health, 1982.

65. National Institute for Occupational Safety and Health. Health hazard evaluation report no. HETA 81-415-1385, Cincinnati, Ohio: National Institute for Occupational Safety and Health.

66. National Institute for Occupational Safety and Health. NIOSH respirator decision logic. Cincinnati, Ohio: National Institute for Occupational Safety and Health [DHHS (NIOSH) Publication no. 87-108], 1987.

IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by:	Michael S. Crandall, M.S, CIH Industrial Hygiene Engineer Industrial Hygiene Section
Other Investigators:	Steven Galson, M.D. Medical Officer Medical Section
	Richard W. Hartle, M.S., CIH Industrial Hygienist Industrial Hygiene Section
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies
Report Typed By:	Sharon Jenkins Clerk (Typing) Industrial Hygiene

XI. DISTRIBUTION AND AVAILABILITY OF REPORT

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1. U.S. Environmental Protection Agency, Region 5
2. G&L Recovery Systems, Incorporated
3. NIOSH, Cincinnati Region
4. OSHA, Region 5

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Trichloroethylene
Personal Airborne Exposure Summary
G&L Recovery Systems, Incorporated
Ashtabula, Ohio

HETA 87-095

	--------------- Concentration, ppm -----------------					
	Initial Survey			Follow-up Surveys		
Job Title	n	Range	Mean	n	Range	Mean
Decontamination Tech	2	9.4-14.2	11.8	2	25.1-33.4	29.2
Stripper Technician	4	4.9-6.0	5.3	6	8.8-35.5	20.8
Teardown Technician	-	---	--	7	13.7-33.7	22.4
Supervisor	2	8.6-11.7	10.2	-	---	--
Criteria	NIOSH REL			LFL		

LFL - Lowest feasible limit

Table 2

Polychlorinated Biphenyls
Personal Airborne Exposure Summary
G&L Recovery Systems, Incorporated
Ashtabula, Ohio

HETA 87-095

	------------- Concentration, ug/m^3 ----------------					
	Initial Survey			Follow-up Surveys		
Job Title	n	Range	Mean	n	Range	Mean
Decontamination Tech	2	18.1-23.4	20.8	2	7.2-22.6	14.9
Stripper Technician	4	11.8-17.5	14.5	6	11.1-57.5	25.9
Teardown Technician	-	---	--	7	4.6-16.8	9.9
Supervisor	2	12.6-16.8	14.7	-	---	--
Criterion		NIOSH REL			LFL (1.0 ug/m^3)	

ug - micrograms (10^{-6} gram)
LFL - Lowest feasible limit

Table 3

Personal Exposures to
Trichloroethylene and Polychlorinated Biphenyls
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
June 23-24, 1987
HETA 87-095

Job Title	Sample	Volume	Concentration	
	TCE (l)	PCBs (m^3)	TCE (ppm)	PCB (ug/m^3)
<u>June 23, 1987</u>				
Decontamination tech	22.4	0.431	14.2	18.1
Stripper technician	21.3	0.415	5.0	12.8
Stripper technician	22.1	0.406	5.2	11.8
Supervisor	22.3	0.422	11.7	16.8
<u>June 24, 1987</u>				
Decontamination tech	21.9	0.406	9.4	23.4
Stripper technician	22.5	0.432	4.9	17.5
Stripper technician	23.1	0.458	6.0	15.8
Supervisor	19.3	0.434	8.6	12.6
Criteria	NIOSH REL	LFL	LFL (<1.0)	
Limit of detection (LOD) per sample		0.01 mg	0.08-0.12 ug	
Limit of quantitation (LOQ) per sample		0.03 mg	0.26-0.41 ug	

LFL - Lowest feasible limit
ug - microgram (10^{-6} gram)

Table 4

Personal Exposures to
Trichloroethylene and Polychlorinated Biphenyls
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
October 28, 1987
HETA 87-095

Job Title	Sample	Volume	Concentration	
	TCE (l)	PCBs (m^3)	TCE (ppm)	PCBs (ug/m^3)
Teardown technician	25.9	0.490	13.7	6.9
Teardown technician	24.4	0.488	13.8	6.1
Teardown technician	24.5	0.487	16.8	4.6
Stripper technician	22.9	0.449	34.2	57.5
Stripper technician	22.6	0.445	35.5	45.2
Criteria		NIOSH REL	LFL	LFL (<1.0)
Limit of Detection (LOD)			0.08	0.06
Limit of Quantitation (LOQ)			0.23	0.25

LFL- Lowest feasible limit
ug - micrograms (10^{-6} gram)

Table 5

Personal Exposures to
Trichloroethylene and Polychlorinated Biphenyls
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
November 11-12, 1987
HETA 87-095

Job Title	Sample	Volume	Concentration	
	TCE (l)	PCBs (m^3)	TCE (ppm)	PCBs (ug/m^3)
<u>November 11, 1987</u>				
Teardown technician	26.2	0.494	28.5	16.8
Teardown technician	26.0	0.509	33.7	15.9
Stripper technician	26.7	0.505	18.9	14.1
Stripper technician	26.4	0.502	17.7	15.7
Decontamination tech	25.7	0.553	33.4	22.6
<u>November 12, 1987</u>				
Teardown technician	26.7	0.505	26.6	14.1
Teardown technician	27.4	0.494	23.8	4.7
Stripper technician	27.6	0.470	8.8	11.1
Stripper technician	25.1	0.477	9.7	11.5
Decontamination tech	26.8	0.501	25.1	7.2
Criteria	NIOSH REL	LFL	LFL (<1.0)	
Limit of detection (LOD) per sample		0.01 mg	0.009-0.03 ug	
Limit of quantitation (LOQ) per sample		0.03 mg	0.03-0.1 ug	

LFL - Lowest feasible limit
ug - micrograms (10^{-6} gram)

Table 6

Trichloroethylene
General Area Air Concentration Summary
G&L Recovery Systems, Incorporated
Ashtabula, Ohio

HETA 87-095

	Concentration, ppm					
	Initial Survey			Follow-up Surveys		
Area	n	Range	Mean	n	Range	Mean
Teardown	2	13.5-16.9	15.2	3	15.8-38.0	28.3
Stripper	2	4.1-4.4	4.2	3	9.7-27.7	17.1
Primary Decontamination	2	18.7-42.3	30.5	1	9.9	9.9
Secondary Decontamination	2	8.8-10.9	9.8	1	13.1	13.1
Breakroom	2	9.8-10.2	10.0	2	0.4-0.5	0.4
Business Office	2	5.5-5.6	5.5	3	0.1-0.4	0.3

Table 7

Polychlorinated Biphenyls
General Area Air Concentration Summary
G&L Recovery Systems, Incorporated
Ashtabula, Ohio

HETA 87-095

	------------- Concentration, ug/m^3 ----------------					
	Initial Survey			Follow-up Surveys		
Area	n	Range	Mean	n	Range	Mean
Teardown	2	22.6-29.1	25.8	3	1.0-7.1	3.3
Stripper	2	10.8-24.7	17.8	3	12.5-34.1	20.3
Primary Decontamination	2	19.8-30.5	25.2	1	1.0	1.0
Secondary Decontamination	2	11.8-16.8	14.3	1	1.0	1.0
Breakroom	2	5.9-6.8	6.4	2	0.7-1.1	0.9
Business Office	2	1.8-2.6	2.2	3	0.1-0.3	0.2

Table 8

General Area Air Concentrations of Trichloroethylene and Polychlorinated Biphenyls

G&L Recovery Systems, Incorporated
Ashtabula, Ohio
June 23-24, 1987
HETA 87-095

Location	Sample Volume TCE (l)	Sample Volume PCBs (m^3)	Concentration TCE (ppm)	Concentration PCBs (ug/m^3)
<u>June 23, 1987</u>				
Front Office	21.2	0.467	5.5	1.8
Supervisor's Office	22.1	0.452	5.1	5.1
Break room	22.9	0.424	9.8	5.9
Stripping Machine	23.3	0.390	4.1	10.8
Primary Decontamination	20.3	0.408	42.3	19.8
Teardown	22.1	0.410	16.9	22.6
Secondary Decontamination	24.0	0.388	10.9	11.8
Primary Thermal Separator	81.4	---	16.5	---
Secondary Thermal Separator	85.5	---	18.1	---
<u>June 24, 1987</u>				
Front Office	22.4	0.470	5.6	2.6
Supervisor's Office	---	0.467	---	6.0
Break Room	23.8	0.465	10.2	6.8
Stripping Machine	24.6	0.466	4.4	24.7
Primary Decontamination	24.0	0.442	18.7	30.5
Teardown	24.8	0.433	13.5	29.1
Secondary Decontamination	21.3	0.445	8.8	16.8
Primary Thermal Separator	86.4	---	10.1	---
Analytical LOD per sample			0.01 mg	0.08-0.12 ug
Analytical LOQ per sample			0.03 mg	0.26-0.41 ug

ug - microgram (10^{-6} gram)

Table 9

General Area Air Concentrations of Trichloroethylene and Polychlorinated Biphenyls
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
October 28, 1987
HETA 87-095

Location	Sample TCE (l)	Volume PCBs (m^3)	Concentration TCE (ppm)	PCBs (ug/m^3)
Business office	26.6	0.502	0.4	(0.1)*
Teardown area	22.4	0.459	15.8	1.9
Stripper room	23.6	0.472	27.7	34.1
Primary Decontamination	20.7	0.460	9.9	1.0
Secondary Decontamination	24.2	0.465	13.1	1.0
Limit of Detection (LOD)			0.08	0.06
Limit of Quantitation (LOQ)			0.23	0.25

* - values in parentheses are between the analytical LOD and LOQ, and are considered to be semi-quantitative.
ug - micrograms (10^{-6} gram)

Table 10

Surface Concentrations of Polychlorinated Biphenyls
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
June 23-24, 1987
HETA 87-095

Sample Location	Sampled Area m^2	Concentration ug/m^2
Front Office		
-Formica desk top	0.25	90
-painted metal filing cabinet top	0.25	10
-tile floor in hallway to work area	0.25	1400
Supervisor's Office		
-rubberized surface desk top	0.25	100
Break Area		
-Formica lunch-table top	0.25	160
-break area door, including doorknobs	0.25	70
-painted concrete floor, near door	0.25	1050
Locker Room		
-locker room door, including doorknobs	0.25	120
-recently painted concrete floor	0.25	430
-painted metal doors, lockers #1-4	0.25	20
-rim of smooth plastic hand-wash basin	0.125	800
Work Area Outside Containment		
-concrete floor 15 feet from break area	0.25	2880
-decontaminated transformer casing surface	0.25	250
Work Area Inside Containment		
-painted concrete floor in stripper area	0.25	71760
-painted concrete floor next to drain pan	0.25	13960
-painted metal crane control unit	0.10	13960
-painted metal hand-railing, sec decontam	0.25	960
-painted metal top surface, pri degreaser	0.25	8360
-painted metal top surface, sec degreaser	0.25	40400

ug - micrograms (10^6 gram)

Table 11

Polychlorinated Biphenyls
Surface Concentration Summary
G&L Recovery Systems, Incorporated
Ashtabula, Ohio

HETA 87-095

Surface Description*	—— Concentration, ug/m^2 ----- Initial Survey	Follow-up #1	Follow-up #2
Business Office			
Formica desk top	90	---	---
Painted metal filing cabinet top	10	---	---
Tile floor, hallway to work area	1400	520	---
Supervisor's Office			
Rubberized, non-porous desk top	100	---	308
Break Room			
Wood-grained Formica table top	160	1080	640
Door, including doorknobs	70	---	---
Painted concrete floor, near door	1050	---	---
Locker Room			
Door, including doorknobs	120	---	---
Painted conrete floor	430	400	---
Painted metal doors, lockers #1-4	20	---	---
Rim of smooth plastic wash basin (0.12 m^2)	800	---	---
Work Area, Outside Containment			
Concrete floor, 15 feet from break area	2880	---	---
Painted concrete floor, near entry/exit to containment area	---	1080	1064
Wooden bench used for containment area entry/exit	---	---	680
decontaminated transformer casing	250	---	---

(continued)

Table 11
(continued)
Polychlorinated Biphenyls
Surface Concentration Summary
G&L Recovery Systems, Incorporated
Ashtabula, Ohio

HETA 87-095

Surface Description*	---- Concentration, ug/m^2 ----- Initial Survey	Follow-up #1	Follow-up #2
Work Area Inside Containment			
Painted concrete floor near drain pan	13960	---	---
Painted metal overhead-crane control unit (0.1 m^2)	13960	11000	16000
Painted metal hand-railing, secondary decontamination	960	---	---
Painted metal top surface, primary degreaser	8360	3080	20280
Painted metal top surface, secondary degreaser	40400	2320	4720
Painted concrete floor in stripper area	71760	---	---
PR 4500 coated floor in stripper room	---	14000	29000
PR 4500 coated floor at entry/exit area	---	6800	12800
PR 4500 coated floor near teardown pan	---	33200	---
Floor of steel teardown pan	---	---	34800
Steel plate part from transformer core, teardown area (0.1 m^2)	---	---	16000

Criteria - NIOSH - 50-100 ug/m^2 for high contact surfaces, no protection
- EPA - 10,000 ug/m^2, high-contact surfaces, restricted access industrial facility, with protection

* - all surfaces sampled measured 0.25 m^2, unless otherwise noted

Table 12

2,3,7,8-Tetrachlorodibenzo-p-dioxin Equivalents
Surface Concentration Summary
G&L Recovery Systems, Incorporated
Ashtabula, Ohio

HETA 87-095

	—— Concentration, ng/m^2 -----		
Surface Description*	Initial Survey	Follow-up #1	Follow-up #2
Work Area Outside Containment			
Painted concrete floor near work area entry	3.0	0.2	0.3
Work Area Inside Containment			
Painted concrete floor in stripper area	19.0	---	---
PR 4500 coated floor in stripper room	---	12.6	13.5
Painted concrete floor near drain pan	16.0	---	---
PR 4500 coated floor near teardown pan	---	4.7	11.3
Criterion		NIOSH	LFL (1 ng/m^2)

* - All surfaces sampled measured 1 m^2
LFL - Lowest feasible limit
ng - nanogram (10^{-9} gram)

Table 13

General Area Air Concentrations of 2,3,7,8-Tetrachlorodibenzo-p-dioxin Equivalents
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
November 11-12, 1987
HETA 87-095

Area	Sample Volume (m^3)	Concentration (pg/m^3)
Stripper room	21.8	4.2
Teardown area	21.6	0.3
Entry/Exit station to controlled area	21.6	ND
Business office	46.9	0.01
Criterion	NIOSH	LFL (2.0 $pg/m^3$0)

pg - picogram (10^{-12} gram)
ND - None detected
LFL - Lowest feasible limit

Table 14

Surface Concentrations of Polychlorinated Biphenyls
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
October 28, 1987
HETA 87-095

Sample Location	Sampled Area m^2	Concentration ug/m^2
Business office		
Tile floor in hallway to work area	0.25	520
Break Room		
Wood-grained formica lunch-table top	0.25	1080
Locker Room		
Painted concrete floor	0.25	400
Work Area Outside Containment		
Painted concrete floor 5 feet from work area entry	0.25	1080
Work Area Inside Containment		
PR 4500 coated concrete floor at work area entry/exit	0.25	6800
PR 4500 coated concrete floor in stripper room	0.25	14000
PR 4500 coated concrete floor 3 feet from teardown pan	0.25	33200
Painted metal crane control unit	0.10	11000
Painted metal top surface, pri. degreaser	0.25	3080
Painted metal top surface, sec. degreaser	0.25	2320

ug - micrograms (10^{-6} gram)

Table 15

Surface Concentrations of
2,3,7,8-Tetrachlorodibenzo-p-dioxin Equivalents
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
October 28, 1987
HETA 87-095

Sample Location	Sampled Area m^2	Concentration ng/m^2
Work Area Outside Containment		
Painted concrete floor 4 feet from work area entry	1.0	0.2
Work Area Inside Containment		
PR 4500 coated concrete floor in stripper room	1.0	12.6
PR 4500 coated concrete floor 3 feet from teardown pan	1.0	4.7
Criteria	NIOSH	1.0

ng - nanograms (10^{-9} gram)

Table 16

Surface Concentrations of
2,3,7,8-Tetrachlorodibenzo-p-dioxin Equivalents
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
June 23-24, 1987
HETA 87-095

Sample Location	Sampled Area m^2	Concentration ng/m^2
Work Area Outside Containment		
Painted concrete floor near work area entry/exit	1.0	3
Work Area Inside Containment		
Painted Concrete floor in stripper area	1.0	19
Painted concrete floor near drain pan	1.0	16
Criteria	NIOSH	1.0

ng - nanograms (10^{-9} gram)

Table 17□

General Area Air Concentrations of Trichloroethylene and Polychlorinated Biphenyls
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
November 11-12, 1987
HETA 87-095

Location	Sample	Volume	Concentration	
	TCE (l)	PCBs (m^3)	TCE (ppm)	PCBs (ug/m^3)
<u>November 11, 1987</u>				
Teardown area	23.1	0.522	38.0	1.0
Stripper area	24.2	0.483	13.9	14.3
Entry/Exit station	26.0	0.506	30.9	2.2
Breakroom	22.2	0.437	0.4	1.1
Business office	26.1	0.502	(0.1)*	0.2
<u>November 12, 1987</u>				
Teardown area	25.2	0.504	31.1	7.1
Stripper area	24.9	0.432	9.7	12.5
Entry/Exit station	26.1	0.513	20.7	2.0
Breakroom	25.1	0.487	0.5	0.7
Business office	27l1	0.500	0.3	0.3
Limit of detection (LOD) per sample			0.01 mg	0.009-0.03 ug
Limit of quantitation (LOQ) per sample			0.03 mg	0.03-0.1 ug

* - values in parentheses are between the analytical LOD and LOQ, and are considered to be semi-quantitative.
ug - micrograms (10^{-6} gram)

Table 18

Surface Concentrations of Polychlorinated Biphenyls
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
November 11-12, 1987
HETA 87-095

Sample Location	Sampled Area m^2	Concentration ug/m^2
Supervisor's office		
Non-porous desktop	0.25	308
Break Room		
Wood-grained formica lunch-table top	0.25	640
Work Area Outside Containment		
Painted concrete floor 3 feet from work area entry	0.25	1064
Wooden bench used for work area entry and exit	0.25	680
Work Area Inside Containment		
PR 4500 coated concrete floor at work area entry/exit	0.25	12800
PR 4500 coated concrete floor in stripper room	0.25	29000
Floor of steel teardown pan	0.25	34800
Painted metal crane control unit	0.10	16000
Painted metal top surface, pri. degreaser	0.25	20280
Painted metal top surface, sec. degreaser	0.25	4720
Steel plate from transformer core in teardown area	0.10	16000

ug - micrograms (10^{-6} gram)

Table 19

Surface Concentrations of
2,3,7,8-Tetrachlorodibenzo-p-dioxin Equivalents
G&L Recovery Systems, Incorporated
Ashtabula, Ohio
November 11-12, 1987
HETA 87-095

Sample Location	Sampled Area m^2	Concentration ng/m^2
Work Area Outside Containment		
Painted concrete floor near the work area entry	1.0	0.3
Work Area Inside Containment		
PR 4500 coated concrete floor at work area entry/exit	1.0	3.0
PR 4500 coated concrete floor in stripper room	1.0	13.5
PR 4500 coated concrete floor 3 feet from teardown pan	1.0	11.3
Criteria	NIOSH	1.0

ng - nanograms (10^{-9} grams)