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Draft Protocol

A Study of Cancer Incidence and Mortality Among Workers Exposed to Polychlorinated Biphenyls (PCBs) in Electrical Capacitor Manufacturing Plants

Karen E. Davis-King[1]
Elizabeth Ward[1]
Martha Waters[1]
David P. Brown[2]
Philip Taylor[3]

[1]National Institute for Occupational Safety and Health
Industrywide Studies Branch
Cincinnati, Ohio 45226

[2]National Institute for Environmental Health Sciences
Office of Disease Prevention and Exposure Research
Research Triangle Park, North Carolina 27709

[3]National Cancer Institute
Cancer Prevention Studies Branch
Rockville, Maryland 20892

July 27, 1992

SDMS DOC ID 274586

I. PURPOSE

The primary purpose of this study is to investigate further the increased risk for rectal and liver cancers previously observed among a group of workers with occupational exposures to polychlorinated biphenyls (PCBs) (Brown and Jones, 1981; Brown, 1987). In addition, we will examine the effects of PCBs on mortality for all neoplasms, brain cancer and malignant melanoma, conditions for which other cohort studies demonstrated increased risks (Bertazzi, et al, 1986; Liss, 1989; Sinks, et al, 1990). Due to the recent report published by Falck et al (1992) which suggest a relationship between PCBs and breast cancer, we also will examine increased risk for breast cancer among women in the New York portion of the cohort. These objectives will be accomplished by: 1) updating the mortality experience of the Brown cohort, a group of workers in New York and Massachusetts with potentially high exposure to PCBs; 2) expanding the cohort to include all workers at plants in both states (currently only the potentially highly exposed workers are in the Brown cohort); 3) examining the mortality experience of this expanded cohort; 4) examining cancer incidence in the New York state portion of the cohort; and 5) if feasible, constructing an exposure matrix and performing a multivariate analysis to examine in greater detail the components of exposure to PCBs which increases the risk for site-specific cancer(s).

II. BACKGROUND

PCBs are a synthetic group of polycyclic hydrocarbons which were produced commercially from 1929 to 1977. They were used widely in the electrical industry due to their high stability, dielectric properties and resistance to

oxidation. PCBs have long half-lives as a result of these properties and were documented to remain in humans and in the environment. The exact length of retention is related to the PCB isomer (and degree of chlorination) with more highly chlorinated isomers persisting longer. With increasing concern about the persistence of PCBs in the environment and potential health risks, PCBs were banned from production and distribution in 1977. PCBs remain a potential occupational exposure, especially to persons who repair capacitors and transformers.

A. Morbidity Studies

Morbidity studies of workers occupationally exposed to PCBs indicate several organs may adversely be affected by exposure. Many nonmalignant conditions were documented on the skin, including chloracne, hyperpigmentation, and rashes (Fishbein et al, 1982; Maroni et al, 1981). A few studies indicated higher rates of adverse reproductive outcomes, in particular low birthweight and neonatal behavioral anomalies, among the children of women exposed to PCBs during pregnancy (Taylor, 1988a; Jacobson, 1990); in addition, changes in liver enzymes were noted among workers (Smith, et al, 1987; Maroni et al, 1981). The relation of these findings to the onset of more chronic illnesses, if any, is unclear.

Recently, Falck et al (1992) published an article which suggested a link between PCBs and breast cancer. In this study, levels of PCBs and DDE were measured in the mammary adipose tissue of twenty women with breast cancer and in twenty women with benign disease. The mean concentrations of PCBs and DDE in women with malignancies was 50-60% higher than in women with benign

disease. These differences were statistically significant. This difference remained when multivariate models were run to control for potential confounders (age, Quetelet's index, and smoking status). A previous study, however, did not demonstrate a relationship between elevated PCB levels in mammary adipose tissue and breast cancer (Unger et al, 1982).

B. Mortality Studies

Human mortality studies present inconsistent findings (Appendix I: Tables 1, 2 & 3). Seven studies among five cohorts of electrical capacitor and transformer manufacturers are reported in the literature or in unpublished documents.

1. Bertazzi et al, 1981, 1987

Bertazzi, et al (1981) examined workers in the production department (high exposure) at a northern Italian electrical capacitor manufacturing plant who worked a minimum of six months. They found an excess in deaths for all neoplasms among males (SMR=241; 95% CL:104-475) and females (SMR=194; 95% CL:109-320); for cancer of the GI tract among males (SMR=340, not statistically significant); and for cancer of the lymphatic and hematopoietic tissue among males (SMR=435, not statistically significant) and females (SMR=444, not statistically significant).

In an update, the cohort was expanded to include all who had worked a minimum of one week (Bertazzi, et al 1987). The findings were unchanged. In comparison to the national population, cancer deaths remained elevated for both males (SMR=253; 95% CL:144-415) and females (SMR=156), although not

statistically significant among females. Cancer of the GI tract was elevated for males (346; 95% CL:141-721) and hematologic neoplasms had nonsignificant elevations (males 375 & females 266). No consistent pattern was noted when deaths were examined by latency, duration of employment, or year of first employment. The authors state the interpretation of these findings is limited because of the few number of deaths in this cohort.

2. Gustavsson et al, 1986

Gustavsson (1986) examined mortality among 142 Swedish workers and found no excess of cancer deaths (7 observed, 5.39 expected), site-specific cancer deaths, or cancer incidence (7 observed, 7.58 expected). Due to the small number of deaths (21) and cases of cancer (7) as well as the short follow-up period, the findings are not very meaningful.

3. Liss, 1989

A cohort study of workers who manufactured and repaired transformers was performed in St. Catharine's, Ontario (Liss, 1989). PCB exposure was determined by a union/management committee which examined detailed work histories. Jobs with any frequency (intermittent, frequent) or intensity (some or high) of exposure to PCBs were categorized as ever exposed; a separate category of high intensity, frequent exposure was defined. Although the company had been using PCBs since the 1930s, exposure was assessed after 1951 when detailed job histories were available for all positions.

Overall mortality was lower (SMR=94) and all cancer mortality was increased (SMR=121) for males. Those with no direct exposure, however, had a

nonsignificant lower rate of cancer mortality (SMR=82) while those with any exposure had an elevated rate (SMR=141; 95% CL:95-199). All cause and all cancer mortality rates for females were similar to those for males. Site-specific and exposure-specific cancer mortality rates for females were not analyzed due to the small number of female deaths (3).

Excess mortality from prostate and brain cancers were noted among males in the ever exposed group (SMRs=418; 95% CL:135-974 and 481; 95% CL:131-1231, respectively). Those with high intensity and frequent exposure were noted only to have a nonsignificant excess of lymphatic and hematopoietic tissue cancer (SMR=308; 95% CL 37-1112). Among those identified with no occupational exposure, an excess of cancer of the gall bladder and bile ducts was noted (SMR=1854; 95% CL:224-6693); this increase was based on two deaths.

4. Sinks et al, 1990

The most recently presented study was performed among workers in a capacitor manufacturing plant located in Bloomington, Indiana. The mortality experience was studied for a cohort who had worked at the plant for a minimum of one day (Sinks et al, 1990). A reduction in overall (SMR=80, 95% CL:60-80) and cancer mortality (SMR=80; 95% CL:60-110) was noted, but a significantly elevated risk for malignant melanoma (SMR=410,95% CL:180-800) and a nonsignificant elevation for tumors of the brain and nervous system (SMR=180;95% CL:60-420) also were observed.

In the proportional hazards model used in this study, the risk for brain cancer increased as duration of employment increased and average estimated

cumulative dose of PCBs increased; risk for brain cancer did not vary by latency. These increases, however, were not statistically significant. Risk for malignant melanoma did not vary by duration of employment, latency or estimated cumulative exposure to PCBs. These findings should be viewed with caution due to the small number of deaths for brain (5) and malignant melanoma (8).

5. Bahn et al, 1976

Bahn (1976), using a case study design presents the only other report of increases in melanoma among workers exposed to PCBs. Three cases of malignant melanoma were identified in a petrochemical plant. Two cases occurred among thirty-one people identified as highly exposed to PCBs, and one case occurred among forty-one workers identified as having had less exposure. These findings should be viewed with caution since data on other potentially confounding exposures were not reported and information characterizing exposure to PCBs was limited.

6. Brown & Jones, 1981; Brown, 1987

A NIOSH retrospective cohort study originally performed by Brown and Jones (1981) and updated by Brown (1987) examined a cohort of workers in plants in New York state (designated as Plant 1 but consists of two plants operated by the same company) and Massachusetts (Plant 2) which produced electrical capacitors and where the workers had potentially high exposures to PCBs (approximately 10% of the overall work force). Criteria for entry into the study were a minimum of three months of employment in areas of the plant which were deemed to represent those workers with the heaviest exposure to PCBs.

Estimates of exposures were based on job classifications. The assignments into exposure categories were designated by the company and verified by the unions in the New York plants. Moreover, a cross-sectional industrial hygiene survey of area and personal air samples (for PCBs) confirmed the exposure classification (Brown and Smith, 1981).

The initial study found mortality from all causes (163 obs. vs 182.4 exp.) and from neoplasms (39 obs. vs 43.8 exp.) to be lower than expected compared with the U.S. population. A statistically non-significant elevation in mortality was noted for both rectal cancer (4 vs 1.19) and liver cancer (3 vs 1.07). Females in plant two, however, did have a statistically significant increase in cancer of the rectum (3 vs 0.5, $p < 0.05$). Moreover, an excess mortality from cirrhosis of the liver (3 vs. 1.92) was noted among females in this same plant. This was not statistically significant.

The relationship between latency and mortality from all neoplasms, cancer of the liver, cancer of the rectum, and cirrhosis of the liver was examined. The only association noted was a slight increase for cancer of the rectum with increasing latency. No associations were noted between these cancers and duration of employment in a PCB exposed job.

Due to the small number of deaths (n=163) and short observation period, a follow-up study through 1983 was performed, adding an additional seven years of observation and 132 deaths. Similar results were found with lower than expected deaths from all causes (295 vs 318) and from all neoplasms (62 vs 80). A statistically significant excess in mortality from cancer of the

liver, gall bladder and biliary tract (5 vs 1.9) was noted. This excess largely occurred among women who worked in one plant. No association was noted between latency or length of employment and cancer of the liver, gall bladder and biliary tract.

Even with the additional seven years worth of follow-up data, the findings were inconclusive, in part because of the relative rareness of the diseases studied.

7. Taylor, 1988b

Using only the New York plants which previously were studied by Brown and Jones (1981), Taylor (1988b) examined mortality among workers employed for a minimum of three months between 1946 and 1975. Vital status was ascertained through 1980. Unlike Brown and Jones, Taylor did not restrict the cohort to the most highly exposed. Thus, the Taylor cohort of 6,292 individuals included 2,588 individuals at the New York plants who also were studied by Brown and Jones. (Taylor did not include the workers from the Massachusetts plant in his study). Total deaths were significantly lower than expected, but cancer deaths were as expected. Several site-specific cancers were elevated, including cancer of the esophagus (SMR=159, 95% CL:32-463), rectum (SMR=173; 95% CL:47-444), and kidney (SMR=184; 95% CL:49-470) among males and cancer of the large intestine (SMR=165; 95% CL:75-313), rectum (SMR=235; 95% CL:47-686), pancreas (SMR=182; 95% CL:49-466), and respiratory system (SMR=167; 95% CL:86-292) among females; none reached statistical significance.

8. Nicholson, 1987

Nicholson (1987) also studied workers from the New York plants (originally studied by Brown and Jones (1981)). The mortality experience of workers at the New York plants who were employed for a minimum of five years and whose date of initial hire was prior to 1954 were eligible for the study. Person years at risk were accumulated after initial employment or initial use of PCBs at the facility (Nicholson, 1987). First, analyses were run for all workers which met the Nicholson cohort definition. Second, Nicholson excluded all workers who were included in both the Nicholson cohort and the Brown and Jones cohort and the mortality analyses were re-run. Neither of these analyses indicated an overall excess or site-specific excess of cancer mortality. This study had limited power due to the small size of the cohort. The full Nicholson cohort had a total of 769 workers and the sub-analyses excluding workers from the Brown and Jones cohort only had 521 workers.

Nicholson (1987) subsequently performed a meta-analysis of five of these studies (for details, see Appendix I: Tables 1, 2 & 3). His work provides the most powerful assessment of the risks associated with PCBs; however, these findings should be interpreted with caution due to the inherent problems associated with any meta-analysis: combining populations which may not have similar exposures and inability to control for variations in quality of the studies. With these caveats, the results indicate an increased risk of cancer of the rectum; liver, biliary tract and gall bladder; urinary bladder and kidney; as well as for lymphomas. Despite pooling results from many studies, the findings are tenuous due to small numbers of deaths for many of the sites.

In summary, site-specific SMRs do vary between the studies; increases in

deaths were noted for cancers of the liver (Brown and Jones, 1981; Nicholson, 1987b), rectum (Brown and Jones, 1981; Taylor, 1988b), brain (Liss, 1989; Sinks et al, 1990), and possibly malignant melanoma (Bahn, 1976; Sinks et al, 1990).

Three studies provide little information (Bahn et al, 1976; Gustavsson et al, 1986; Liss 1989) because of small sample size and potential differences in exposures and problems in study design, respectively. Moreover, differences in the remaining studies may be a result of limited number of deaths and therefore low power; poor exposure characterization; or variation in study entry criteria. Alternatively, this variation may indicate that PCBs are not carcinogenic or only are weakly carcinogenic.

According to the rating scheme of the International Agency for Research on Cancer (IARC), PCBs are probable human carcinogens (IARC, 1987); the evidence for experimental animal studies was sufficient to classify PCBs as carcinogenic, but the evidence from human studies was limited. The Environmental Protection Agency (EPA) also reported PCBs to be probable human carcinogens; as with IARC, EPA reported the animal carcinogenicity data to be sufficient but the human carcinogenicity data to be inadequate (IRIS). The National Toxicology Program (NTP) reported they considered there to be sufficient evidence to consider several of the PCB mixtures to be carcinogens in animals. There was, however, insufficient evidence to conclude that PCBs were carcinogenic in humans (NTP Sixth Annual Report on Carcinogens, 1991).

C. History of the Study Plants and Data on Historical Exposure

Workers studied by Brown and Jones were employed in plants located in two eastern states: New York and Massachusetts. A total of three plants were studied. Two of these plants were located in New York and Massachusetts and were operated by the General Electric Company. They were combined for analyses and designated as Plant 1 by Brown and Jones (1981). In this protocol, we will use the terms "New York plants" or "Plant1" to describe the two New York plants, consistent with the terminology used by Brown and Jones (1981). The term "Plant 2" will be use to describe the plant located in Massachusetts and operated by Aerovox.

1. New York facilities

The General Electric Corporation had two facilities in New York (Fort Edward and Hudson Falls), located approximately one mile from each other, which produced PCB containing capacitors. The Fort Edward plant began operations using PCBs in 1946 for the manufacture of small capacitors while the Hudson Falls plant began using PCBs in 1951 for the manufacture of power capacitors (Jones, 1978). The type of PCB mixture used varied over the years and included Aroclor 1254, 1242, and 1016. These Aroclor products contained 54%, 42% and 41% chlorine, respectively (Brown & Jones, 1981). Use of PCBs was discontinued June 30, 1977 (R. Lawton, 1985).

In 1976, when Brown and Jones completed a walk through survey, both plants combined employed approximately 1600 employees. There were 564 hourly employees at Fort Edwards and 233 hourly employees at Hudson Falls. An estimated 7000 employees ever worked at both sites (Brown, 1976a). The work force was predominantly white and equally distributed between males and

females (Jones, 1978). A majority of workers were employed in areas where there was no direct exposure to PCBs. According to General Electric, 137 employees were exposed to PCBs at both plants at the time of the survey.

An industrial hygiene survey was performed by NIOSH investigators in June of 1976. Due to problems in the sampling procedure and analytic method, a follow-up survey was conducted in April 1977 (Jones, 1978). Air samples were collected by NIOSH in each plant during this follow-up for the purpose of determining exposure to PCBs, trichloroethylene, toluene, methyl isobutyl ketone, lead, zinc, tin, aluminum, and iron. Personal air samples also were taken in the treatment area and adjacent operations (i.e. areas of greatest potential exposure to PCBs) (Jones, 1978). The time-weighted average (TWA) of the area air samples ranged from a low of 3 $\mu g/m^3$ in the winding area (an area of low exposure) of the power capacitor facility to a high of 476 $\mu g/m^3$ in the soldering area (an area of high exposure) in the small capacitor manufacturing facility. Although there is a large difference in potential exposure between workers in low and high exposure areas, all of these reported levels are well above background level. Background urban air levels average 0.1 $\mu g/m^3$ (Kutz & Yang as cited in Taylor et al, 1988).

Additional IH surveys have been performed by General Electric and OSHA. A limited amount of these data are available in published and unpublished documents (R. Lawton & R. Lawton as cited in P. Taylor). At the present time, we have not approached General Electric to determine the number of surveys performed or to request these documents. We plan to do this.

2. Massachusetts facility

Capacitors have been manufactured by Aerovox at the New Bedford, Massachusetts site since 1938. Prior to 1972, mica, electrotube, oil and tubular capacitors were manufactured. Since 1972 only oil-filled capacitors were manufactured (Jones, 1976).

At the time of the NIOSH survey in March 1977, approximately 380 employees worked at the facility; the total number of individuals who ever had been employed at the factory was estimated at 3000-4000 (Brown, 1976b). Of the 380 active employees, 300 were involved in the production process; approximately two-thirds of these workers were female and the racial make-up of the workforce reflected that of the general population in the area which was largely Cape Verdean and Portuguese (Brown & Jones, 1981). NIOSH estimated that approximately 104 of the 380 current employees potentially had exposure to PCBs (Aerovox estimated only 40 to be exposed) (Jones, 1977). Again, several types of PCB containing products also were used at this facility over the years, including Aroclor 1254, 1242 and 1016 (Brown & Jones, 1981). The exact date that use of PCBs was discontinued is not known at the present time, but will be requested from the company; most likely use was discontinued in 1977.

In the NIOSH exposure survey, 56 air samples were collected to evaluate exposures to PCBs, trichloroethylene, toluene, lead, tin, and zinc. Personal air samples also were collected throughout the facility to determine exposures to PCBs (Jones, 1977). Due to differences in the production processes between the two New York plants owned by General Electric and the Massachusetts plant

owned by Aerovox, exposure measures reported by jobs or work areas for the New York plants are not directly comparable to those reported for the Massachusetts plant (Brown & Jones, 1981). The time-weighted average (TWA) area air samples ranged from a low of 60 $\mu g/m^3$ in the cover manufacturing (an area of low exposure) to a high of 810 $\mu g/m^3$ in the impregnation area (an area of high exposure). Again, even those with potentially low exposure to PCBs have levels well above ambient measures.

The NIOSH survey is the only source of industrial hygiene data for this plant that we have available. The NIOSH industrial hygiene report, however, indicated that prior to their survey both the Kemper Insurance Company and the State of Massachusetts collected air samples for the evaluation of PCBs (Jones, 1977). We will request these data from the company.

D. Public Health Impact

Although PCBs currently are not produced in the United States, the issue of human carcinogenicity of PCBs remains an important topic for several reasons. First, some U.S. workers continue to be exposed to PCBs. Reliable estimates of the number of workers exposed to PCBs do not appear to be available from the National Occupational Hazard Survey (NOHS) or the National Occupational Exposure Survey (NOES). The groups with the highest potential for current exposure are those who repair and maintain capacitors and transformers containing PCBs and those in the reclamation industry who are responsible for the disassembly of PCB containing capacitors and transformers. Second, a large number of workers were exposed to PCBs in the past. And third, if certain cancers which are amenable to screening, such as malignant melanoma,

are found in excess, a worker notification program can be put in place to alert workers to their risks.

III. STUDY DESIGN

The first step will be to expand the cohort to include workers with low or moderate exposure to PCBs who were not included in cohort studied by Brown and Jones. The original Brown and Jones cohort is defined as 'Brown1' and Brown2' in Appendix I: Table 4; these constitute those workers with potentially high exposure to PCBs from the New York and Massachusetts plants, respectively. We propose to include workers with low or moderate exposure to PCBs in the New York and Massachusetts plants and these subcohorts are defined as 'Other1' and 'Other2', respectively, in the present study. The expanded cohort, therefore, is defined as 'Total1' and 'Total2' in Appendix I: Table 4, and includes the entire workforce in New York and Massachusetts, respectively. Demographic information as well as detailed work history information will be coded for those not currently in the Brown cohort. The records of all employees at the New York and Massachusetts plants were microfilmed in 1976 and 1977 when Brown & Jones initiated the study. Microfilmed records of all workers in the New York plants (defined as 'Total1' in Appendix I: Table 4) were provided to the state Department of Health who computerized these records for the Taylor, et al study. The microfilmed records from the Massachusetts portion of the cohort constitute 'Total2'. Only the records from the most highly exposed group in Massachusetts (i.e. 'Brown2') have been coded. Therefore, the records of those workers with low or moderate exposure to PCBs in the Massachusetts plant, i.e. 'Other2', will be coded by NIOSH staff. These data will be merged with the existing masterfile (defined as 'Brown1' and

'Brown2'). The new masterfile, therefore, will include 'Brown1', 'Brown2', 'Other1', and 'Other2' and is defined as 'Total1' and 'Total2'.

From this updated dataset, several analyses will be performed; these also are outlined in Appendix I: Table 4. First, the mortality experience of the original cohort--workers with potentially high exposure to PCBs ('Brown1' and 'Brown2')--will be determined. Mortality analyses of the original 'Brown1' and 'Brown2' "high" exposure cohort will be performed, since nine additional years of follow-up will increase the number of deaths in the group. Mortality analyses also will be conducted on the entire updated cohort (i.e. all workers in the New York and Massachusetts plants; 'Total1' and 'Total2'). For the New York portion of the cohort ('Total1'), this constitutes an update of the Taylor study, where an additional ten years of observation will be added, while for the Massachusetts portion of the cohort this constitutes an original study of the low and moderately exposed workers. Second, a cancer incidence study among the original and the entire cohort at the New York plant will be performed; these are 'Brown1' and 'Total1', respectively. And third, the feasibility of developing an exposure matrix will be determined; if feasible, these classifications of exposure will be used to run multivariate models to calculate standardized mortality ratios (SMR) and standardized incidence ratios (SIR) to identify the contribution of PCBs to increased risk for cancer.

A. Expanding the Cohort

The original NIOSH study of the General Electric and Aerovox plants, located in New York and Massachusetts, respectively, (Brown and Jones, 1981) examined

workers with direct and potentially high exposure to PCBs. The purpose of the NIOSH industrial hygiene surveys for that study was to provide data to show that the workers in the job classifications chosen for inclusion in the study in fact had potentially high PCB exposure. These surveys also indicated that all workers had exposure to PCBs above background levels. More recently, some epidemiologic studies suggested that low levels of exposure to PCBs may increase the risk of developing cancer (Liss, 1989; Sinks, et al, 1990). Expanding the original Brown and Jones cohort to include all workers at the plants (i.e. update the vital status of the workers in New York studied by Taylor as well as study the workers in Massachusetts with low or moderate exposure who have not been studied to date) would provide an opportunity to crudely examine the issue of dose-response in this cohort. Moreover, the additional workers will increase the statistical power of the study.

It appears that all personnel records at each plant in the current study were microfilmed by NIOSH. Detailed work history information was coded by NIOSH for the Brown and Jones study only for those individuals with potentially high exposure to PCBs. In addition, only those jobs which potentially high PCB exposure were coded.

Demographic and detailed work history data on all of the records of individuals employed for at least three months between 1946 and 1975 in the New York state plants were coded by the New York state Department of Health; completeness of this cohort was verified by New York state by obtaining copies of the Social Security premium payment records for 1945 to 1965 (Taylor, et al, 1988b). They provided these records to NIOSH in computerized form. A

sample of the data coded by New York state will be re-coded by NIOSH to validate the completeness and accuracy of the data computerized by New York state. NIOSH will code all demographic and detailed work history information for employees at the Massachusetts site who worked for a minimum of three months.

B. Exposure Assessment

Exposure potential to PCBs at the capacitor manufacturing facilities under study largely is determined by the department and job tasks as well as the duration of employment in specific jobs. Since personal exposure measurements were limited, several proxy measures will be constructed to determine the association between PCB exposure and cancer incidence and mortality. Some proxy measures that may be used are:

1. Job Description and Duration of Employment

The method of exposure assessment used in the original SMR study performed by Brown and Jones (1981) was based on duration of employment in specific jobs which were judged to include direct exposure to PCBs. These jobs included impregnation, final assembly of capacitors, laboratory work, and rebuilding of rejected capacitors. The classification of these jobs as high exposure was supported by air sampling, described in Section IIC of the protocol.

2. Duration of Employment

In this scheme, duration of employment in any area of the plant is the proxy for exposure. As indicated in the section describing the facilities under

study (Section IIC) PCB air concentrations in areas where there was no direct contact with the chemical were higher than ambient levels. Vaporized PCBs may settle on surfaces of the facility, providing exposure opportunity to workers in the plant who do not necessarily have direct contact with liquid PCBs.

3. Job-Exposure Matrix

To determine the feasibility of developing a job-exposure matrix, the extent and usefulness of industrial hygiene data mentioned in Section IIC will be evaluated. Additionally, the feasibility of using serum PCB concentration data from a select number of workers at the New York facilities to assign exposure will be examined. Taylor et al (1991) recently developed an empirical model to estimate exposures to PCBs based on surrogate measures which included serum PCB levels. The empirical model developed by Taylor, et al and any additional exposure data available from the companies will be reviewed. Based on this review, the feasibility of constructing a job-exposure matrix will be determined. Factors which could be incorporated into estimation of exposure dose include opportunity for direct exposure with liquid PCBs, air sampling measurements for specific job titles, and degree of chlorination of PCB (which is known by era). Exposure estimated for specific job titles by era would be combined with individual work histories and serum concentrations, where available, to estimate individual exposures.

The exposure assessment method will be determined after review of the feasibility of constructing a job-exposure matrix. If the plan is relatively straight forward, i.e. to use duration of exposure, it will be described in an analysis plan. If it is feasible to construct a job-exposure matrix, the

methodology for constructing the matrix will be described in a separate protocol.

C. Identifying Mortality and Cancer Incidence Status

1. Identifying Mortality Status

Vital status was ascertained by Brown (1987) through December 31, 1982. For this update, we will determine vital status through December 31, 1990 by submitting names of the 2,194 high PCB exposure cohort members, those alive at the last follow-up, to the National Death Index (NDI).

For workers in the low or moderate PCB exposure cohort, those not included in Brown's and Jones' study, we will identify vital status in several ways. Members first will be computer matched with the in-house Social Security Administration tapes of deaths for all available years (through 12-91). Names of those known alive as of 1979 subsequently will be sent to the National Death Index, which began a centralized United States death system in 1979, as well as to the Internal Revenue Service to determine the current/last address of cohort members.

Death certificates will be obtained from state vital statistics departments for all newly identified deaths. These will be reviewed by a nosologist to determine the cause of death and all relevant data will be used to update the data file.

2. Identifying Cancer Incidence Status

We will examine cancer incidence by matching the New York state occupational

cohort against that state's cancer registry for years 1973 to 1991. The Massachusetts cohort will not be included in this analysis because that state only recently began to report on a statewide basis. We will prepare an "Application for Research Use of Personal Identifiable Information" for access to New York State Cancer Registry data. When the application has been approved, we will supply the New York state cancer registry with a computer tape of cohort member names and other vital status information necessary for matching and request that the registry provide a list of all matches which includes the following: name, each primary cancer diagnosed, ICD-9 code, and date of diagnosis. If possible, we also will request whether the diagnosis was histologically confirmed, ICD-O morphology code, stage of diagnosis, size at diagnosis, type(s) of treatment, date and cause of death. We will request permission to write to the hospital where each patient was diagnosed to ask for further information, if necessary (registry application information and sample letter to hospital are located in Appendix II).

D. Analyses

1. Updating Mortality

a. Updating the Original Cohort Studied: High Exposure

Only the potentially highly exposed group ("Brown1" & "Brown2") (Brown & Jones, 1981) will be included in this analysis with vital status follow-up from the original study end date of 12-31-82 to 12-31-90. In order for direct comparability, the same analyses performed in both the original study and the first update will be re-run. Standardized mortality ratios (SMRs) will be computed with the U.S. population as a reference employing the modified life-table analysis system developed by NIOSH to calculate person years at risk and

expected numbers of deaths (Steenland et al, 1990).

The criteria for calculating person years will remain the same as in the previous NIOSH study (Brown & Jones, 1981); after three months of employment in a potentially highly exposed job is completed, each person will contribute one person day for each day of the study or until the date of death whichever occurs first. Each day is categorized by age, race, gender, calendar time, and duration of exposure and time since first exposure and each person day is allocated to the correct stratum based on these variables (Steenland et al, 1990). Persons lost to follow-up will be censored at the date that they were last known to be alive, usually this date is the date of termination of employment.

Gender- and five year age-specific SMRs will be calculated as well as SMRs by length of employment and by latency periods. Under the assumption of a Poisson distribution test, statistics and confidence intervals will be calculated according to the methods of Rothman and Boice (1979).

This mortality study has 80% power to detect a SMR of 123 for all neoplasms in the New York and Massachusetts plants when analyses are run on the individuals with potentially high exposure to PCBs (i.e. "Brown1" and "Brown2"). There also is 80% power to detect SMRs of 137 and 130 for plants 1 and 2, respectively. The power to detect differences by specific types of cancer, however, is variable. This study would have 80% power to detect SMRs for both plants combined at the following levels or greater: 305 for rectal cancer; 290 for liver, gall bladder, and biliary tract cancers; 320 for skin cancers

(melanomas account for approximately 75% of all skin cancer deaths); and 265 for brain and other nervous system cancers. Complete power calculations are located in Appendix I: Table 5.

b. Analyzing Mortality of the Entire Workforce

The mortality experience of the entire workforce will be analyzed and it will be assumed that everyone had some exposure to PCBs. Again, standardized mortality ratios (SMRs) will be computed with the U.S. population as a reference employing the modified life-table analysis system developed by NIOSH to calculate person years at risk and expected numbers of deaths.

Gender- and five year age-specific SMRs will be calculated. SMRs will be calculated by duration and latency where duration and latency are defined as number of days employed and time since first employment, respectively. In order to compare the results of this analysis to the other mortality analyses described in this section, the criteria for calculating person years will be similar to that described in the mortality update (section a above). After three months of employment, each person will contribute one person day for each day of the study or until the date of death.

Taylor, et al used these criteria when they performed their SMR study; as a result, we have an approximation of the number of workers at the New York plant who meet these criteria. A crude power calculation can be made for the New York portion of the cohort if we assume that all important parameters are the same in the entire population as in the highly exposed group. If the assumption holds true, then a simple proportion can be used to calculate a new

expected rate. One example is provided to show the increase in power. The study of the entire workforce would have approximately 80% power to detect a SMR of 210 for rectal cancer (compared with 450 in the highly exposed cohort).

c. Analyzing Mortality of the Original Brown and Jones Cohort Using County Cancer Rates

We also will re-calculate SMRs using the county cancer rates as a reference to determine if risks associated with PCBs are sensitive to the reference group chosen. These analyses will be re-run using the cohort originally studied by Brown and Jones, 1981 (i.e. 'Brown1' and 'Brown2'). For example, there is marked geographic variation in the mortality rate for some of the cancers which we are studying, e.g. malignant melanoma. Comparing mortality rates at the county level will control for this variation. All workers do not live in the county where the plants are located. Therefore, we propose to use the counties of residence of most of the workers as the reference.

d. Analyzing Mortality Using the Job-Exposure Matrix

An exposure dose file to run with the life table will be created. The exposure dose file assigns an exposure for each person-day for each worker when that worker is in an exposed department or operation. This exposure dose is accumulated over time and a measure of cumulative exposure dose is assigned to each person-day by the life table analysis system. SMRs for the site-specific cancer(s) under study will be calculated by cumulative exposure dose by the life table analysis system.

Regression models also will be run to further analyze a possible dose-response relationship between the measures of PCB exposure and site-specific cancer

mortality. The exact types of cancers chosen for the regression analysis will depend on the results of the SMR analysis. In the regression modelling, different measures of dose will be used, e.g. cumulative, average, and peak. Interactions between dose and covariates, such as age and time since first hire also will be analyzed. A detailed analysis plan will be written once the parameters of the job-exposure matrix are known.

2. Determining Cancer Incidence

At least one of the site-specific cancers, malignant melanoma, is associated with relatively high survival rates; using mortality as the end-point, may not accurately reflect the risks for some site-specific cancers as a result of exposure to PCBs. The degree to which mortality may underestimate risks is likely to vary by the site of the cancer. Based on SEER data, there are approximately 3.5 times as many incident malignant melanoma cases as deaths from malignant melanoma. In addition, the incidence:mortality ratio was approximately 4.0 for rectal cancer; 1.2 for brain and other nervous system; and 1.1 for liver, biliary tract, and gall bladder. These ratios varied slightly by gender; complete calculations are provided in Appendix I: Table 6.

Two previous studies examined cancer incidence among workers occupationally exposed to PCBs in the manufacture of capacitors or transformers. No excess in cancer incidence was noted in the Swedish study (Gustavsson, et al 1986) or for females in the Canadian study (Liss 1989). An excess of brain cancer was noted among manufacturers of transformers in the latter study. Both studies had few subjects, making it difficult to assess the carcinogenicity of PCBs.

a. Analysis of Incidence Rates for the Potentially Highly Exposed and for all Workers at the New York Facilities

For incidence analyses, the New York employees from both the potentially highly exposed group ("Brown1") and the entire group ("Total1") will be studied. The masterfile will be subsetted to include workers at the New York plants ("Total1"); the file of primary tumors, received from the New York State Cancer Registry, will be linked to the subsetted masterfile and serve as the basis for incidence analysis. Separate analyses will be run to determine incidence rates in the New York portion of the Brown cohort (i.e. "Brown1") as well as the entire New York cohort (i.e. "Total1").

We will calculate an age, gender, and calendar-year specific SIR for all cancers and for site-specific cancers. The observed cases will include all confirmed cancers reported as of December 1990. The expected number of cases will be calculated based on the New York state incidence rates for 1973 to 1990. Gender-specific and site-specific New York state cancer incidence rates for the period of interest will be requested from the New York State Cancer Registry.

The NIOSH modified life-table analysis system (Waxweiler et al, 1983; Steenland et al, 1990) will be used to calculate person days at risk and the expected number of cases. The methods for producing these estimates are the same as those used for the mortality analyses. Prior to 1973, the New York state cancer registry did not code social security number. Without this piece of data, it is difficult to identify cases through computer matching. Person days at risk will accumulate beginning on January 1, 1973 or on the date of

first employment, whichever is later.

For former workers residing out of state (and not identifiable by the registry) as of December 30, 1991, or who died out of state, we need to determine (or estimate) when an individual moved out of state, and therefore, ceased to be at risk for cancer diagnosis in New York state. The criteria for calculating person days at risk, therefore, are somewhat different from the criteria for the mortality analyses. Using the IRS data and post office checking, we will know which individuals no longer have an current "in-state" address. For this group, we will examine the personnel records to determine if there is a date indicated when a person left the state. If a date is given, we will stop counting person-days at risk at that point. If no date is listed, we will censor an individual who currently is alive at the midpoint between the date of last known employment and the earliest date that we have an out of state address. For individuals who died out of state, we will censor individuals at the midpoint between termination of employment and date of death.

In the incidence analysis among workers with high exposure to PCBs, after three months of employment in a potentially high exposure job, each person contributes one person day for each day of the study or until the date of diagnosis of cancer or death from a disease other than cancer; for the analyses which includes all workers, after three months of employment, each person contributes one person date for each day of the study or until the date of diagnosis of cancer or death from a disease other than cancer.

If several assumptions are made, a crude measure of power can be calculated. The three main assumptions are: 1) complete reporting of all cancers in the cohort to the NY state registry; 2) members of the population are ages 40-75 for the entire study period; and 3) the experience of the SEER population is the same as the cohort under study. This study then would have 80% power to detect a standard incidence ratio of the following or greater: 175 for rectal cancer, 270 for liver, gall bladder and biliary tract cancers, 230 for malignant melanoma, and 245 brain and other nervous system.

b. Analysis of Incidence Rates Using the Job Exposure Matrix

This analyses performed will be similar to those to be used to calculate SMRs using the job-exposure matrix. The exposure dose file created for the SMR analysis will be used in this analysis. SIRs for the site-specific cancer(s) under study will be calculated by cumulative exposure dose.

Again, regression models will be run to further analyze the a possible exposure dose-response relationship between the measures of PCB exposure and site-specific cancer incidence. The exact cancers chosen for the regression modelling will depend on the results of the SIR analysis. These models will examine the impact of using different measures of exposure dose, e.g. cumulative, average, and peak as well as examining interactions between covariates.

IV. CONFIDENTIALITY

The individual data files supplied by the New York State Department of Health,

New York State Cancer Registry and the National Death Index as well as the combined masterfile will be maintained as confidential information in accordance with the Federal Privacy Act. Data will be stored on a secure computer at the Parklawn Computer Center. Printouts which contain confidential individual data will be kept in locked cabinets in a locked office of the Data Support Section, Industrywide Studies Branch, Ridge Avenue, Cincinnati, Ohio. The facility is guarded 24 hours per day. Visitors to the building (non-NIOSH personnel) must sign in and out, wear a visitor's badge, and be escorted during their visits by someone from NIOSH. All NIOSH personnel sign a memorandum obligating maintenance of confidentiality of all data.

V. WORKER NOTIFICATION

This cohort will be notified of the study results according to the procedures contained in the Industrywide Studies Branch's Procedures for Worker Notification.

VI. References

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TABLE 1: Study Design of PCB Mortality Studies among Electrical Capacitor and Transformer Manufacturers

First Author	Brown1	Brown2	Nicholson1	Taylor	Bertazzi1
Type of Plant	Lg & Small capacitor production	Lg & Small capacitor production	Lg & Small capacitor production	capacitor production	capacitor production
No. Subjects Male Female	2,567 1,258 1,309	2,588 1,270 1,318	779 449 332	6,292 3,601 2,691	1,310 290 1,020
No. Deaths Male Female	163 83 80	295 141 154	188 137 51	510 355 155	466 235 231
Person Years Male Female	39,018 17,054 21,964	55,543 25,053 30,492		122,783 68,505 54,278	20,646 4,558 16,088
Min. Period Employment	3 months	3 months	5 years	3 months	6 months
Employment Period	1940 to ?	1940 to ?	1946/1951 to 1954	1946 to 1975	1946 to 1970
Study Period	1940 to 1-1-76	1940 to 1-1-83	1956 to 1983	1946 to 1980	1954 to 1978
Tracing Completeness	97.9%	96.2%	98.6%	99.9%	98.0%
Type of PCB Exposure	High Exposure	High Exposure	All ranges (None-high)	All ranges	High Exposure (Prodn only)

TABLE 1: Study Design of PCB Mortality Studies among Electrical Capacitor and Transformer Manufacturers

First Author	Bertazzi2	Gustavsson	Liss	Sinks**	Nicholson
Type of Plant	Small capacitor production	Capacitor production	Prod & repair electrical equipment & transformers	Capacitor production	Capacitor production
No. Subjects Male Female	2,100 544 1,556	142 142 not included	1,073 800 273	3,588 2,742 846	
No. Deaths Male Female	64 30 34	21 21 n/a	146 136 10	192 ? ?	466 235 231
Person Years Male Female	41,010 10,307 10,703			72,010 n/a	
Min. Period Employment	1 week	6 months		1 day	variable
Employment Period	1946 to ?	1960 to ?	1960 to 1977	1957 to 4-1-77	variable
Study Period	1946 to 1983	1960 to 1979	1960 to 1986	1957 to 7-1-86	variable
Tracing Completeness	99.9%	99.8%	96.1%		variable
Type of PCB Exposure	all ranges (none-high)	direct exposure*	all ranges	all ranges	all ranges

*Direct expos identified by job classification: filling, painting, testing, packaging, transport & repair
**Known non-whites excluded from study; 139 cases with unknown vital status were assumed to be alive

TABLE 2: SMRs and Relative Risks of PCB Mortality Studies among Electrical Capacitor and Transformer Manufacturers

Cause of Death	Brown1	Brown2	Nich1	Taylor Male	Taylor Female	Nich2	Bert1	Bert2 Male	Bert2 Female	Gust RR	Liss	Liss	Sinks
All Cause	89 76-104	93	95	83 74-92	84 71-98			108	132	0.95 0.58-1.45	100	91	70 60-80
All Cancers	89 63-122	76	97	83 64-105	110 85-140	95		253 144-415	158	1.36 0.52-2.67	82	141 96-199	80 60-110
Rectum	336 92-860	211	167	173 47-444	235 47-666	159 p=0.17		346			130	114	80 0-450
Liver, Biliary Tract, Gall Bladder	280 58-820	263	0	133 15-480	90 1-500	275 p=0.015					0++ 1854 224- 6693	0 0	110 0-640
Skin			0	98 11-355	100	88							410 180-800
Brain			0	30 0-165	0	48						481 135-974	180 60-420
Lymphomas	46	68	103	0	0	161	375				89	147	100 40-200
Urinary Bladder, Kidney		143	91 128	0 184	--- ---	136 152							
Prostate			87	110 30-281		97					0	418 131-1231	

TABLE 3: Number of Deaths in the PCB Mortality Studies among Electrical Capacitor and Transformer Manufacturers

Cause of Death	Brown1	Brown2	Nich1	Taylor Male	Taylor Female	Nich2	Bert1	Bert2 Male	Bert2 Female	Gust	Liss Never	Liss Ever	Sinks
All Cause	163	295	43	355	155	466		30	34	21	52	84	192
All Cancers	39	62	18	69	67	132		14	12	7	10	32	54
Rectum	4	4	1	4	3	6		0	0		5	8	1
Liver, Biliary Tract, Gall Bladder	3	5	0	2	1	7		2	0		0 2	0 0	1
Skin			1	2	1	2		0	0				8
Brain			0	1	0	2		1	1		0	4	5
Lymphomas	2	5	1	0	0	13		1	4		1	3	7
Urinary Bladder		4	1	0	1	4		0	0				
Kidney			0	4	1	4		0	0				2
Prostate	0	1	2	4		5		1			0	5	

TABLE 4: Cohort Composition and Proposed Analyses for the Current Study

PROJECT OUTLINE	
Cohort Make-up	
PLANT 1 (New York) Brown1: High Exposure Other1: Low/Moderate Expos.	PLANT 2 (Massachusetts) Brown2: High Exposure Other2: Low/Moderate Expos.
Study Type	**Cohort Studied**
Cancer Mortality Study	-Brown1 and Brown2 -Total1 and Total2 -Site-specific cancers: Brown1, Brown2, Other1 &/or Other2*
Cancer Incidence Study	-Brown1 -Total1 -Site-specific cancers: Brown1, &/or Other1

*The sites to be studied will depend on the number of cases identified; this analysis will use the job exposure matrix.

TABLE 5: Power Calculations for Detection of Elevated SMRs for all Neoplasms and for Selected Cancers by Plant and Gender

ALL NEOPLASMS							
	PLANT 1			PLANT 2			
SMR	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	OVERALL
Expected	30.6749	22.6886	53.3630	25.3368	56.1250	81.4610	134.8253
1.5	80%	69%	95%	73%	96%	99%	100
2.0	100	99	100	99	100	100	
3.0		100		100			

LIVER, GALL BLADDER AND BILIARY TRACT							
	PLANT 1			PLANT 2			
SMR	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	OVERALL
Expected	0.6734	0.5267	1.2001	0.5380	1.3567	1.8947	3.0948
1.5	10%	9%	12%	9%	13%	15%	20%
2.0	17	15	23	15	25	31	43
3.0	33	28	48	28	52	64	82
4.0	50	42	71	43	75	87	97
5.0	65	56	86	57	89	96	100
6.0	77	68	94	68	96	99	
7.0	85	77	98	78	99	100	
8.0	91	84	99	85	100		
9.0	95	90	100	90			
10.0	97	93		94			

TABLE 5: Power Calculations for Detection of Elevated SMRs for all Neoplasms and for Selected Cancers by Plant and Gender

BRAIN AND OTHER NERVOUS SYSTEM							
	PLANT 1			PLANT 2			
SMR	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	OVERALL
Expected	0.9819	0.6050	1.5869	0.9106	1.4891	2.3997	3.9866
1.5	12%	10%	14%	11%	14%	17%	23%
2.0	20	16	27	20	26	36	50
3.0	42	31	58	40	56	73	90
4.0	63	46	81	60	79	93	99
5.0	79	61	93	76	91	99	100
6.0	89	73	98	87	97	100	
7.0	95	82	99	93	99		
8.0	98	88	100	97	100		
9.0	99	93		99			
10.0	100	96		99			

RECTAL CANCER							
	PLANT 1			PLANT 2			
SMR	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	OVERALL
Expected	0.6997	0.4379	1.1376	0.5373	1.1441	1.6814	2.8190
1.5	10%	9%	12%	9%	12%	14%	19%
2.0	17	14	22	15	22	28	40
3.0	34	25	47	28	47	60	79
4.0	51	37	69	43	69	83	96
5.0	66	50	84	57	84	94	99
6.0	78	61	93	68	93	98	100
7.0	87	70	97	78	97	100	
8.0	92	78	99	85	99		
9.0	96	84	100	90	100		
10.0	98	89		94			

TABLE 5: Power Calculations for Detection of Elevated SMRs for all Neoplasms and for Selected Cancers by Plant and Gender

SKIN (MELANOMA AND NON-MELANOMA)							
	PLANT 1			PLANT 2			
SMR	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	OVERALL
Expected	0.7008	0.3171	1.0179	0.6618	0.8035	1.4653	2.4832
1.5	10%	8%	12%	10%	11%	14%	17%
2.0	17	12	21	17	18	26	37
3.0	34	21	43	32	37	55	75
4.0	51	30	65	49	56	78	93
5.0	66	40	80	64	72	91	99
6.0	78	49	90	76	83	97	100
7.0	87	58	95	85	90	99	
8.0	92	66	98	91	95	100	
9.0	96	73	99	95	97		
10.0	98	79	100	97	99		

TABLE 6: Number of Incident Cases and Deaths for Selected Cancers, Whites, 1973-77, by Gender*

MALIGNANT MELANOMA			
	BOTH GENDERS	MALES	FEMALES
INCIDENCE	3605	1913	1692
MORTALITY	1027	603	424
RATIO	3.5	3.2	4.0
BRAIN AND OTHER NERVOUS SYSTEM			
	BOTH GENDERS	MALES	FEMALES
INCIDENCE	3116	1787	1329
MORTALITY	2635	1521	1114
RATIO	1.2	1.2	1.2
RECTAL			
	BOTH GENDERS	MALES	FEMALES
INCIDENCE	9679	5272	4123
MORTALITY	2196	1294	902
RATIO	4.4	4.3	4.6
LIVER, GALL BLADDER AND BILIARY TRACT			
	BOTH GENDERS	MALES	FEMALES
INCIDENCE	2442	1338	1104
MORALITY	2155	1123	1032
RATIO	1.1	1.2	1.1

*Source: Surveillance, Epidemiology and End Results

REGISTRY APPLICATION INFORMATION

New York State Cancer Registry, New York State Department of Health. Tower Building, Empire State Plaza, Albany, NY 12237.
Registry Director: Dr. William Burnett (518) 474-2255.

The Application for Research Use of Personal Identifiable Information asks for study title; sponsor; source of funds; evidence of review and approval by an IRB for the protection of human subjects; a copy of an informed consent form from subjects or next of kin seeking permission to obtain data from their records or the reason(s) no consent is being sought; a summary of the study proposal, including primary focus, objectives, analyses to be performed, linkage with other data files, release of results, potential benefits to study subjects or the population, and source of identifying information for study subjects; the data needed for the study,; storage and security measures taken to insure confidentiality; additional information, if any, which will be sought from subjects, next of kin, physicians, or institutions as a basis for legal, administrative, or other actions, or for any other research project.

Matching can be done if 1) diagnosed after 1973 and 2) both SSN and date of birth are in the records. A computer program, developed at the registry, uses some or all of the following data for matching: name, gender, date of birth, residence (address), social security number, and race for matching purposes. All matching variables are available for our study cohort.

SAMPLE LETTER TO HOSPITAL OF DIAGNOSIS

Date

Dear :

RE:

SOCIAL SECURITY NUMBER:
DATE OF BIRTH:
DATE OF DEATH:

MEDICAL CERTIFIER:

The National Institute for Occupational Safety and Health (NIOSH) is authorized under Section 20 of the Occupational Safety and Health Act of 1970 to conduct special research, industrywide and other studies related to the epidemiological evaluation of cancer case incidence and mortality among workers exposed to polychlorinated biphenyls.

Included in the study is an individual who is known to have been a patient and/or died at your hospital. (See name listed above). We would appreciate your sending us the following medical records that your hospital has on the patient: All (1) admission histories, (2) pathological reports, (3) discharge summaries, and (4) autopsy report. Release of this information is authorized by Section 8 (specifically 8b) of the Occupational Health and Safety Act. A copy of Sections 8 and 20 of the Act is enclosed for your records.

If there is a cost involved, please enclose an invoice with the medical records. If you do not have the information requested, please provide us with the name(s) and address(es) of the physician and/or hospital who may have it. If there are any questions, please contact Ms. Bettie Walpole, Lead Statistical Assistant, by writing to the above address or by calling (513) 841-4235. A preaddressed mailing label is enclosed for your convenience. Thank you in advance for your assistance with our research study.

Sincerely yours,

Karen E. Davis-King
Epidemiologist
Epidemiology 2 Section
Industrywide Studies Branch
Division of Surveillance, Hazard
Evaluations and Field Studies