RESPIRATORY CANCER MORTALITY AMONG ALUMINUM PLANT WORKERS

by

Hekmat K. Aly
M.B.B.ch., Cairo University, 1967
D.P.H., Cairo University, 1970

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II. DESCRIPTION OF PROCESSES[1-4]

Aluminum metal is produced by electrolytic reduction of purified alumina (aluminum oxide)*.

The basic industrial process was developed by Hall and Heroult in 1886. Figure 2 presents a schematic flow sheet of the aluminum reduction process.

Alumina is shipped to the primary reduction plant where it is electrically reduced to aluminum and oxygen. This reduction process is carried out in large rectangular cells (pots) made of carbon lined steel with consumable carbon blocks which are suspended above and extend down into the pots (Figure 3). The pots and carbon blocks are connected electrically to serve as cathode and anode, respectively. Several pots are electrically connected in series forming a "potline" and are located in the "potroom".

Cryolite, fluorspare, and aluminum fluoride serve as both an electrolyte and a solvent for alumina. Aluminia is added to and dissolves in the molten cryolite. The cells are heated and operated between 950c and 1000c with heat generated by the electric resistance between the electrodes.

During the reduction process the heavier aluminum formed at cathode sinks to the bottom of the pot to the cathode and oxygen is liberated at the anode forming carbon dioxide and carbon monoxide.

Alumina and cryolite are periodically added to the pot to replace material which is removed or consumed during normal operation. The

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*Figure 1 contains a list of raw materials for aluminum reduction.

aluminum is tapped or siphoned from beneath the cryolite bath at intervals and generally cast into pigs or taken to holding furnaces for further treatment.

Two basic types of processes exist for the preparation of anodes for the pots. In one the anode is prebaked and this is usually called a "prebake" pot or cell. Since the anode is consumed during the reduction operation, old anode remnants are replaced periodically with new anodes. The old remnants are removed from the cell, cleaned, ground, mixed with new coke, and blended together with coal tar pitch in a carbon plant. The mixture is weighed, then solidified by slowly baking it in well enclosed fire pit furnaces.

It is assumed that essentially all of the pitch volatiles are driven off into a collection system.

On the other hand a "soderberg" pot or cell permits the consumable anode to be baked in situ. A mixture of ground coke and coal tar pitch is periodically added to the top of the electrode. Heat from the process drives off the lower boiling organic and fuses the new material to the old electrode.

Steel "pins" or "spikes" are embedded in the anode and conduct the electric current. These pins may be oriented in the anode either vertically (vertical pin soderberg) or horizontally (horizontal pin soderberg) as shown in Figure 3.

III. DESCRIPTION OF TYPES OF WORK

ALCOA uses the following classification of types of work:

A. Types of Work in the Potroom

1. Pot tending includes:

Adding alumina and process materials to pots, maintaining pot feeder operation, supressing anode effects, adjusting anode clamp arms, adjusting individual anodes as necessary, checking pots for proper operation and taking remedial action as required, and baking and starting new pots.

2. Tapping includes:

Preparing tapping equipment and pots for tapping including handling pot enclosures, assembling the siphon, removing anodes, breaking crusts, and adjusting voltage as required during tapping by adjusting the anode assembly.

3. Carbon changing (prebake only) includes:

Replacing used carbon anodes, removing burned off carbons from pots, removing both from carbon butts and removing butts from stubs.

4. Tapping and carbon changing (prebake only) includes:

Preparing tapping equipment and pots for tapping including handling pot enclosures, assembling the siphon, removing anodes, and breaking crusts, adjusting voltage as required during tapping by adjusting the anode assembly, replacing used carbon anodes, removing

burned off carbons from pots, removing both from carbon butts and removing butts from stubs.

5. Electrode tending (soderberg only) includes:

Adding paste to anodes, preparing the anode casing, and setting and resetting spikes.

6. Potroom Craning is:

Operating the crane in the potroom area.

7. Potroom service and other includes:

Receiving, transporting, stocking, and distributing materials, supplies and equipment used in the potroom and operating, crushing, blending, and handling equipment for potroom materials.

B. Types of Work in the Carbon Plant

1. Green carbon or paste work includes:

Producing green carbon for prebaked anodes and paste for soderberg pots and potlining, and processing mix ingredients such as coal, coke, pitch, scrap anode, etc.

2. Potlining and repairing includes:

Removing old linings, preparing lining materials, installing new linings, and performing repair work as required while pots are in operation.

3. Baked carbon work includes:

Operating ring furnaces to bake carbon anodes, placing green carbon in pits, packing with carbon dust, and removing baked carbon from pits.

4. Anode assembling and rodding includes:

Performing manual work or operating equipment to remove and clean butts, both, and cast iron from rod assemblies coming from the potrooms, and operating cranes and other material handling equipment in the anode assembly or rodding area.

5. Other is:

Other work not identified in 1, 2, 3 or 4 above which is performed in the carbon paste area.

C. Types of Work in Ingot (Casting)

1. Melting is operating furnaces to melt aluminum.
2. Casting is pouring molten aluminum into molds.
3. Craning is operating cranes in the ingot area.
4. Other is other work not identified in 1, 2, 3 or 4 above which is performed in the ingot area.

D. Other

The following areas of work were classified as "other" in this study:

1. Maintenance
2. Electrical
3. Cryolite
4. Laboratory
5. Other

IV. LITERATURE REVIEW

It has long been recognized that some agents produced during the combustion or distillation of bituminous coal are carcinogenic for the skin of man, and since the turn of the century a variety of industrial populations exposed to coal tar products have shown an increased risk of cancer of the skin.[5] More recent studies[6,7] indicate that exposure to coal tar products and coke oven emissions also may result in an increased risk of cancer to other organ systems.

The first report of excessive lung cancer in men engaged in coal carbonization concerned Japanese producer gas workers.[8] Producer gas is a fuel generated to meet the power needs of the plant in which it is produced. Eighty percent (12 out of 15 cases) of the malignant neoplasms observed in men working at these gas generators occurred in the lung. A recent report on men transferred from this facility, when it was closed in 1953, shows that lung cancer for the period 1954 to 1960 was 33 times the rate observed for other steel workers.[9]

In the same year that the Japanese reported on lung cancer in gas generator workers, Kennaway and Kennaway noted an excess of lung cancer in British gas producer male workers.[10] Furthermore their survey of death certificates for England and Wales, 1921 to 1932, showed that other coal carbonization and byproduct workers might have experienced higher than expected lung cancer mortality. In this and a subsequent report for 1921 to 1938 the Kennaways reported excess lung cancer mortality in gas producer workers, chimney sweeps, and several other

categories of gas workers.[6] The excess risk indicated for "as stokers" and "coke-oven changers" was approximately three-fold.

In 1971, Lloyd[11] reported that men employed as coke oven workers in Allegheny County had a lung cancer mortality rate two and one half times that predicted by the experience of all steel workers (31 deaths observed vs. 12.3 expected).

In a similar study Redmond et al.[7] confirmed these findings, reporting relative risk for lung cancer in coke oven workers almost identical to those observed in the Lloyd study. Lloyd and Redmond et al. have shown that the risk for coke oven workers is related to length of exposure and level of exposure to coal tar pitch volatiles.

Animal toxicity studies (Horton,[12] Tye[13] and Laskin[14]) demonstrate the carcinogenicity of coal tar and some of its components for a variety of animal species. For example, Laskin et al.,[14] reported that rats inhaling benz(a)pyrene and sulfur dioxide in combination, but not either alone, developed bronchial mucosal changes and tumors of bronchogenic origin which may closely simulate lung cancer in man.

As a result of these studies it seems that coal tar and some of its constituents are human carcinogens.

Exposure to coal tar pitch volatiles in the aluminum industry has been studied by environmental studies and epidemiological studies. During the electrolysis reduction of alumina to aluminum, coal tar pitch volatiles are some of the toxic substances which may contaminate the workroom air. Other substances released during aluminum processing are hydrogen fluoride, particulate fluoride, dust, and carbon monoxide.

The National Institute of Occupational Safety and Health (NIOSH) conducted environmental surveys in four aluminum reduction plants in Eastern and Northwestern states.[3] The object of these studies was to determine the extent to which workers are exposed to potential carcinogenic compounds found in CTPV and a variety of other potentially hazardous substances. Production areas in plants using prebaked anodes, the vertical pin soderberg and the horizontal pin soderberg processes were surveyed.

The findings indicate that the concentration of CTPV as measured by the benzene soluble matter (BSM) was elevated in certain work areas above the current OSHA standard of 0.2 mg/m^3 CTPV for an 8 hour time weighted average.

The levels were highest in soderberg potrooms, since the pitch is heated and baked in these potrooms. Lower levels of CTPV in the carbon plant facilities were probably due to the lower processing temperature in the mixing area. The lowest concentrations were measured in the prebaked potrooms. Theoretically all the volatiles present in the carbon anode should be removed at the curing furnaces in the carbon plant before the anode is used in the potrooms. Table 1 is a summary of these studies.

It must be noted that the OSHA standard of 0.2 mg/m^3 benzene solubles for workers exposed to CTPV was adapted based on information from animal exposure and the coke oven industry. The benzene soluble fraction only gives the concentration of organic material present that is soluble in benzene. The polynuclear aromatic compounds which are potentially carcinogenic are not measured by using the benzene soluble

fraction they may or may not be present near aluminum reduction operations.

Litnivov et al.[15] made an attempt in the USSR to relate lung cancer mortality in a polluted neighborhood of an aluminum plant to a control area. They reported a standardized mortality index for lung cancer of 4.8 per 100,000 for the study area and 3.6 per 100,000 for the control area.

Kostantinov et al.[16] in the USSR studied the mortality from respiratory cancer among electrolysis shop workers in three aluminum plants. The plants using the self-baking anode process had a benz(a)pyrene concentration above 0.15 mg/m^3, the USSR standard, while the plant using the prebaked process had a benz(a)pyrene concentration below 0.15 mg/m^3. The respiratory cancer mortality among the workers in the self-baking anode plants was 1.7-2.6 times the respiratory cancer mortality rate in the male population of the cities where the plants are located.

Neither of these Russian studies[15,16] is considered to be sufficiently well documented to permit firm conclusions.[17,18]

Milham[19] analyzed Washington State death records for white males for the period 1950-1971. He reported a proportionate mortality ratio from respiratory cancer of 128 (not significant) among aluminum workers (40 observed vs. 31 expected deaths). Significant increases in mortality from all cancers, cancer of the pancreas, and malignant lymphoma were found among aluminum workers.

In Canada Gibbs and Harovtz[20] conducted a study to determine the lung cancer mortality of men employed in three aluminum plants

during the period 1950-1973. Jobs were grouped by intensity of tar exposure. An index of exposure was developed by multiplying intensity by duration of exposure (in years) and the results expressed as "tar years". The authors came to the conclusion that the mortality from lung cancer of men ever exposed to tars was similar to that of workers never exposed to tars. Among the 15% of persons exposed more than 21 tar years the standardized mortality ratio was 2.3 times that of persons not exposed to tars (see Table 2).

Environmental and epidemiological studies were conducted in four vertical pin soderberg smelters in Scotland.(21) The benzene soluble matter concentrations were above the current standard of 0.2 mg/m^3. Comparisons were made between those employed in the aluminum company, others of working age living in the same area, and others of working age living in another area in western Scotland. The combined lung cancer rate for the aluminum workers and others living in the same area was 4.4 compared to 1.84 per thousand in western Scotland but these rates are based on small numbers and the difference is not statistically significant.

In a study of chronic respiratory disease among aluminum reduction workers, sputum cytology was utilized to determine the degree of abnormal cells in the respiratory tract as an early indicated of cancer.(18) The authors detected one positive cancer in 390 members of the study group and none in 193 members of a matched control group. The difference is not statistically significant. The members of the study group had significantly more atypical smears ($p < .01$) than the control group but this may have been due to exposure to inflammatory agents rather than carcinogens.

OBJECTIVES

1. To determine whether workers in two departments, the potroom and the carbon plant in aluminum smelters have an excess risk of respiratory cancer.
2. To determine whether respiratory cancer risk among the workers in these two departments increases with years of exposure and years since first exposure.
3. To determine whether workers in specific types of work in the potroom and the carbon plant have an excess risk of respiratory cancer.

VI. MATERIALS AND METHODS

A. Study Populations

The original study population as defined by E.E.H. consisted of all men who worked in 15 plants from January 1, 1946 through December 31, 1973, and who worked in aluminum production for at least 5 years.

Our study group was selected from this population using a sample design suggested by Dr. Enterline:

1. For each of the four oldest ALCOA smelters, Massena, Tennessee, Badin, and Vancouver, a table was prepared from the E.E.H. tapes showing the number of men by date of birth and date of hire (see Tables 3-6).

2. Tables similar to those described in step 1 were prepared for the sub-group of men who died from respiratory cancer (codes 160-164 in the seventh revision of the International Classification of Diseases).

3. For every age and year of hire group which contained a respiratory cancer death, three men were chosen randomly from this age and year of hire group.

For example, the Tennessee table has 2 respiratory cancer deaths and 68 employees in the 1900-1904 year of birth and 1940-1944 year of hire group. Six men were chosen at random from the 68 employees in this cell. The six men may include none, one, or both of the respiratory cancer cases in that cell. The reason for including cases in the control group was that it provides an estimate of relative risk which is similar to the relative risk of a prospective study (see page 21).

ALCOA provided Tables 3 to 6 and the microfilmed personnel records for all men who died from respiratory cancer and the employees selected

in step 3.

B. Occupational Histories

The work history for each employee included in the study was obtained from the personnel records of ALCOA. Each job in each man's work history was categorized and coded by process, department, and job title according to the job coding system prepared by ALCOA.

The only reduction process ever used in the Massena, Badin, and Vancouver plants was the prebake process.

The Tennessee plant used:

1. The prebake process up to 1928,
2. The prebake and horizontal pin soderberg processes from 1929 to 1949, and
3. The prebake and vertical pin soderberg processes from 1950 to 1974.

The departments were grouped into 4 categories:

1. Potroom
2. Carbon or paste
3. Casting (ingot)
4. Other

Only those occupations in potrooms, carbon plants, and casting were coded by job title. Employment in other departments was given the job title of other. The length of time at a particular job within the plant was calculated.

Any change in work history for less than one month was neglected but a change for more than one month was coded, and if the employee left

the company for more than one month this time was not counted as part of the time at a certain job.

VII. METHODS OF ANALYSIS

Since respiratory cancer has a long latent period, recent exposure to carcinogenic agents is probably not the cause of respiratory cancer.[22] We calculated exposure for cases and controls up to December 31, 1959 or to the date of death of the index case, whichever occurred first. This probably includes any exposure that might have caused cancer in this population.

The results were compared to those obtained using exposure up to 10 years before the death of the case given that at least two controls are living at the date of death of the case (a similar method was suggested by Miettinen[23] and used by Liddell et al.[24]

The data was analyzed as follows:

Method 1

1. Ever and never exposed

a. The total number of respiratory cancer cases who were ever and never exposed to the potroom and/or carbon plant, to the potroom, and to the carbon plant from the beginning of exposure up to December 31, 1959 or to the date of death of the index case, whichever occurred first, was determined. The number ever and never exposed among the control group was also determined and relative risks of exposure and tests of significance were calculated.

b. The total number of respiratory cancer cases who were ever and never exposed to different types of work specified in the potroom and in the carbon plant from the beginning of exposure up to December 31, 1959 or to the date of death of the index case whichever occured first was determined. The number ever and never exposed among the control

group was also determined and relative risks of exposure and tests of significance were calculated.

2. Years of exposure

For each respiratory cancer case the number of years of exposure to the potroom and/or the carbon plant, to the potroom, and to the carbon plant from the beginning of exposure to December 31, 1959 or to the date of death of the case, whichever occurred first, was determined. The length of exposure for the controls was also obtained.

Men were classified as having had less than 10 vs. 10 or more, less than 20 vs. 20 or more and less than 30 vs. 30 or more years of exposure. Relative risks of exposure and significance levels were calculated.

3. Years since first exposure

For each case and control the number of years from the first exposure to the potroom and/or carbon plant, to the potroom, and to the carbon plant to December 31, 1959 or to the date of death of the case whichever occurred first was determined.

Men were classified by interval since first exposure, 10 years vs. 10 or more years, less than 20 years vs. 20 or more years and less than 30 vs. 30 or more years. Relative risks and significance levels were calculated.

Method 2

The Miettinen[23] method as used by Liddell et al.[24] was based on selection of controls born in the same year as the case and known

to have survived at least into the year following that in which the case died. Exposure levels were determined up to seven years before the death of the case. We used a similar method where exposure was determined up to ten years before the death of the case. Some controls died before the cases so in order to have two controls for each case (the same number of controls should be available for each case so as not to bias the results) we selected the cases and controls as follows:

1. If the three controls were living at the date of death of the case-we chose two of them at random. If one of the controls chosen was the case it was kept as a control.

2. If only two controls were living at the date of death of the case the two living controls were used. If the case is also a control it was kept as a control.

3. If one or none of the controls were living at the date of death of the case we dropped that case and its controls.

As a result only 121 respiratory cancer cases were analyzed as follows:

1. Ever and never exposed

a. The number of cases and controls ever and never exposed to the potroom and/or carbon plant, to the potroom, and to the carbon plant, up to ten years before the date of death of the case was determined. Relative risks of exposure and significance levels were calculated.

b. The number of cases and controls who were ever and never exposed to the specified types of work in the potroom and in the carbon plant from the beginning of exposure up to ten years before the date

of death of the index case was determined. Relative risks of exposure and significance levels were calculated.

2. Years of exposure

The number of years of exposure to the potroom and/or carbon plant, to the potroom, and to the carbon plant from the beginning of exposure up to ten years before the date of death of the case was calculated.

Men were classified as having had less than 10 vs. 10 or more, less than 20 vs. 20 or more and less than 30 or 30 or more years. Relative risks and significance levels were calculated.

3. Years since first exposure

The number of years since first exposure to the potroom and/or carbon plant, to the potroom and to the carbon plant from the beginning of exposure up to ten years before the date of death of the case was determined. Men were classified by interval since first exposure, less than 10 years vs. 10 or more years, less than 20 vs. 20 or more years and less than 30 vs. 30 or more years. Relative risks and significance levels were calculated.

Estimation of relative risk and test of significance

For each of the four plants the relative risks were estimated using 2 x 2 contingency tables of the form shown in figure 4.

Figure 4

Structure of a 2 x 2 contingency table
for the ith plant

	Respiratory Cancer	Controls	Total
Exposure to CTPV-1	Ai	Ci	M1i
Exposure to CTPV-2	Bi	Di	M2i
Total	N1i	N2i	Ti

Exposure to CTPV-1 and 2 may be ever and never exposed, first exposed 30 or more years ago and first exposed less than 30 years ago, exposed for 10 or more years and exposed for less than 10 years, etc.

Relative Risk = (Ai Di)/(Bi Ci)

This is an estimate of the relative risk where controls are chosen at random from the total population in an age-date of hire group. This can be seen as an estimate of the relative risk that would be obtained in a prospective study. In a prospective study the relative risk would equal

$$\frac{\text{Proportion of exposure group 1 developing disease}}{\text{Proportion of exposure group 2 developing disease}}$$

$$= \frac{\frac{A_i}{A_i + E_i}}{\frac{B_i}{B_i + F_i}}$$

where E_i is the number of disease-free workers in exposure group 1 and F_i is the number of disease-free workers in exposure group 2. This is approximately equal to

$$\frac{\frac{A_i}{A_j + E_i}}{\frac{B_i}{B_j + F_i}} = \frac{\frac{A_i}{C_i}}{\frac{B_i}{D_i}} = \frac{A_i D_i}{C_i B_i}$$

where A_j is the number of cases in exposure group 1 randomly selected as part of the control group, E_i is the number of non cases in exposure group 1 randomly selected, B_j is the number of cases in exposure group 2 randomly selected as part of the control group, and F_i is the number of non-cases in exposure group 2 randomly selected as part of the control group. Therefore, the estimate of relative risk is approximately the relative risk of a prospective study.

The test of significance is:

$$\chi^2 = \frac{(|Ai\ Di - Bi\ Ci| - \frac{1}{2}\ Ti)^2\ Ti}{N1i\ N2i\ M1i\ M2i}$$

Mantel and Haenszel[25,26] have presented a summary formula which was used to estimate the relative risk of exposure for all four plants combined. This estimate of relative risk is given by:

$$\text{Relative Risk} = \sum_{1=1}^{4} (Ai\ Di/Ti) / \sum_{1=1}^{4} (Bi\ Ci/Ti)$$

The test of significance for this statistic which is described by Mantel and Haenszel[24,25] is based on a one degree of freedom corrected

chi-square statistic. This chi square value is given by:

$$X^2 = \frac{(\Sigma Ai - \Sigma E(Ai) \quad --\tfrac{1}{2})^2}{V(Ai)}$$

where the expected number of deaths, E(Ai), and the variance, V(Ai), are computed based on the separate contingency table marginal totals and are given by:

$$E(Ai) = N1i\ M1i/Ti$$

$$V(Ai) = N1i\ N2i\ M1i\ M2i/Ti^2\ (Ti--1).$$

VIII. RESULTS

There were 134 respiratory cancer deaths among male workers at the four plants whose vital status was known as of December 31, 1973. There were 68 cases at the Massena plant, 34 at the Tennessee plant, 22 at the Badin plant and 10 at the Vancouver plant.

Three controls were chosen as described earlier for each of the cases. As of December 31, 1973, 219 of the controls were known to be living, 183 were deceased, and of these the cause of death was known for 172.

The results of the analysis of respiratory cancer mortality in the four aluminum plants are shown in Table 7 to 44. Tables 7 through 25 show results based on method 1 (i.e. exposure of 134 cases was calculated to December 31, 1959 or to the date of death of the case, whichever was first). Tables 26 through 44 show results based on method 2 (i.e. exposure of 121 cases was calculated to ten years before the death of the case and there are two controls for each case).

The relationship between respiratory cancer mortality and years of exposure to the potroom and/or the carbon plant, to the potroom, and to the carbon plant, are shown in Tables 10 through 12. In Tables 10 and 11 the computed relative risks do not increase with increased years of exposure and are sometimes less than one except for the Tennessee* plant where the relative risks are greater than 1 and increase with increased years of exposure to the potroom and/or the carbon plant.

In Table 12 the computed relative risks for the Badin and Tennessee plants are greater than 1 and increase with increased years of exposure

*The only soderburg operation

to the carbon plant. In the same table the computed relative risks for the combined group are greater than 1 and increase with increased years of exposure to the carbon plant. None of the above results in Tables 10 through 12 are significant at the 5% level.

The relationship between respiratory cancer mortality and years since first exposure to the potroom and/or the carbon plant, to the potroom, and to the carbon plant are shown in Tables 13 through 15. Again the computed relative risks are inconsistent and sometimes less than one. Table 15 shows relative risks greater than 1 which increase with increased years since first exposure in the Badin plant. None of the results in Tables 13 through 15 are significant at the 5% level.

Tables 16 through 20 show the computed relative risks for those ever and never exposed to the different types of work in the potroom. The combined relative risks for the types of work, pot tending, tapping, and potroom craning are greater than one. None of the results in Tables 16 through 20 are significant at the 5% level.

Tables 21 through 25 show the computed relative risks for those ever and never exposed to the different types of work in the carbon plant. In Table 23 the estimated relative risk for the type of work "baked carbon" for the Tennessee plant is significant at the 1% level. In the same table the combined relative risk for the four plants is 2.2 and is significant at the 5% level.

In Table 25 the estimated relative risk for "other" jobs in the carbon plant in the Tennessee plant is 13.5 and is significant at the 5% level.. Also the combined relative risk for exposure to "other"jobs in the carbon plant is 2.3 and is significant at the 5% level.

The results of analysis using the second method are shown in Tables 26 to 44. The second method analysis is based on 121 cases and 2 controls for each case (i.e. exposure was calculated to 1).

The computed relative risks using the second method are more or less similar to the computed relative risks using the first method.

In Table 26, the Badin plant has the highest relative risk for exposure to the potroom and/or carbon plant. In Table 27, 3 of the 4 plants show a relative risk greater than 1 for exposure to the potroom. The combined relative risk for exposure to the potroom is 1.2. In Table 28, 3 of the 4 plants show a relative risk greater than 1 for exposure to the carbon plant. The combined relative risk is 1.3.

Table 29 shows relative risks for years of exposure to the potroom and/or the carbon plant. Many of the relative risks are less than 1. Table 30 shows years of exposure to the potroom. Many of the relative risks are also less than 1. Table 31 shows years of exposure to the carbon plant. The combined relative risk increases with increased years of exposure. Those exposed 30 years or more have a risk of respiratory cancer that is 4.2 times those exposed less than 30 years.

Table 32 through 34 show the number of years since first exposure to the potroom and/or carbon plant, to the potroom, and to the carbon plant. Many of the relative risks are less than 1. However the combined relative risk for the carbon plant for 20 or more years since first exposure gives a risk 1.6 times the risk for the group first exposed less than 20 years before 10 years before the death of the cases. None of the results in Tables 26 through 34 are significant at the 5% level.

Tables 35 through 39 show the relative risks for workers ever exposed to different types of work in the potroom. None of the results are significant at the 5% level.

Tables 40 through 44 show the number ever and never exposed to the different types of work in the carbon plant. The only significant relative risk in Tables 40 through 44 is for baked carbon jobs in the Tennessee plant (see Table 42).

Significant results were found in two specific types of work in the carbon plant under method 1. A significant result was found under method 2 only for the baked carbon type of work in the carbon plant. The combined relative risk increases with increased years of exposure in the carbon plant under both methods but this result is not significant at the 5% level.

IX. COMPARISON OF RESULTS WITH THE RESULTS OF THE E.E.H. STUDY

Since the data used in this study is part of the E.E.H. data, it would be interesting to compare our results with the E.E.H. results.

In the E.E.H. study the standardized mortality ratio (SMR) was estimated in the following way:

The number of deaths observed in the study population was compared with the number of deaths which would have been expected in a comparable sample of U.S. males. This was done by a modified life table method. The observed deaths were then expressed as a percentage of the expected deaths to obtain the SMR.

The SMR is the observed deaths divided by the expected deaths times 100. In this study the observed number of deaths is the number of cases in the higher exposed group. The expected number of deaths is the number of deaths (cases) in the lower exposure group divided by the controls in the lower exposure group times the number of controls in the higher exposure group.

The only table from the E.E.H. study that we can compare with this study is the prebake potroom table. Table 45 shows the calculated SMR for both studies.

Table 45

SMR's for the E.E.H. study and the present study

	> 10 years	> 20 years	> 30 years
E.E.H. study	109	133	70
Present study	114	120	74

The calculated SMR is similar in both studies. This result was unexpected since the expected number of deaths in the E.E.H. study was calculated using the general population. In this study the expected number of deaths was calculated using the lower risk group. Also the E.E.H. results were based on analysis for seven prebake plants and in this study we used data from four plants.

X. DISCUSSION

A review of the present findings in the light of other studies of comparable populations shows that the respiratory cancer experience noted for aluminum workers is generally consistent with prior observations. An excess level of respiratory cancer mortality has been noted in previous studies of aluminum workers but the results were usually not significant.

In the present study the respiratory cancer mortality of male aluminum workers ever exposed to tars was similar to that of workers who had never been exposed to tars. The combined relative risk is 1.2 (by method 1 and method 2) comparing workers ever exposed to those never exposed but the result is not significant. This result agrees with the Alcan[20] study where no difference was detected between those ever exposed to tars and persons who had never been exposed to tars.

When years of exposure and years since first exposure to the potroom and/or the carbon plant were considered in this analysis the relative risks were sometimes greater than one. For the carbon plants in Badin and Tennessee, the years of exposure table under method 1 shows that the realtive risk is highest for the comparison of over 30 years of exposure to under 30 years of exposure. The combined risk for 30 or more years of exposure to the carbon plant is 3.1 (by method 1) and 4.2 (by method 2) times risk for under 30 years of exposure. None of these results are significant. However the results for years of exposure and years since first exposure for the carbon plant show a greater risk of respiratory cancer than do the results for potroom exposure. This

is consistent with the NIOSH study[3] showing a higher CTPV level in the carbon plants than in the potroom under the prebake process.

The analysis by type of work using method 1 shows that workers exposed to baked carbon jobs in the carbon plant in Tennessee have a significant relative risk of 6.4 of developing respiratory cancer compared to workers in Tennessee who never had these types of jobs. The combined significant relative risk of respiratory cancer is 2.2 for all plants. The "other" jobs in the carbon plant in Tennessee have a significant relative risk of 13.5 under method 1. The combined relative risk for the "other" jobs in the carbon plant is 2.3 and is significant at the 5% level. The relative risks for all other types of work analyzed are not statistically significant at the 5% level.

Using method 2 the only significant result in the analysis by type of job (see Table 42) is for baked carbon jobs in the Tennessee plant. The relative risk is 7.2.

The significant result for employees involved in carbon baking work may not be surprising since workers in these types of jobs could possibly be exposed to coal tar pitch volatile bakes driven off during processes at temperatures up to 1100°C. Workers in other types of work in the carbon plant are not exposed to such high temperatures,[3] with the possible exception of workers in the "other" (i.e. undefined) type of work in the carbon plant. There is a significant result under method 1 for workers in the "other" type of work in the carbon plant.

Doll et al.[27] and recently[11] reported a positive relationship between temperatures attained during carbonization and the lung cancer rates for men employed in several industries. As shown in

Table 46 workers exposed to 900°C to 1100°C had an 83% excess risk of lung cancer.

In this study, method 2 is based on fewer controls and fewer cases than method 1 and the results are frequently similar for the two methods. Although method 2 is more logical because exposure of cases and controls was computed up to 10 years before date of death of case, since recent exposure is not important, the loss of information (i.e. cases and controls) probably makes method 2 less reliable for use in this analysis.

Few of the results are significant in this study and there are only two significant results from previous studies. In the Alcan[20] study the 20 years and more exposure to mainly the soderberg process was compared to 0 years exposure and found significant. The NIOSH[3] study showed greater exposure levels under the soderberg process than under the prebake process. The Russian[17] study was not clear as to the method used to find significance and therefore cannot be evaluated. In addition the difference was only significant for the soderberg process.

The primary result from this study, therefore, is that there may be an increased risk of respiratory cancer among some aluminum workers in the carbon plant of the prebake process.

XI. CONCLUSION

A case-control study of respiratory cancer in male workers in four ALCOA plants using primarily the prebake process for making aluminum shows few significant results. Workers who were ever exposed to two types of jobs in the carbon plant are significantly more likely to develop respiratory cancer than those never exposed. This may be due to exposure to volatiles driven off in the process of carbonization.

The results from the analysis of duration of exposure do show an increasing relative risk with increased years of exposure to the carbon plant in all plants combined but these results are not significant.

This study is limited by lack of information on smoking which is related to respiratory cancer and on levels of exposure to coal tar pitch volatiles for these aluminum workers. The number of cases and controls may be too small to produce significant results.

There is also the possibility that some of the workers in non-exposed job classifications in these plants may have been exposed to CTPV or other possible carcinogenic agents while working in these plants.

The results suggest, however, that long term exposure to CTPV in the carbon plant of the prebake process may be associated with respiratory cancer. In particular workers in certain jobs in the carbon plant may be at higher risk of developing respiratory cancer than all other aluminum workers.

Figure 1. LIST OF RAW MATERIALS FOR ALUMINUM REDUCTION PROCESS

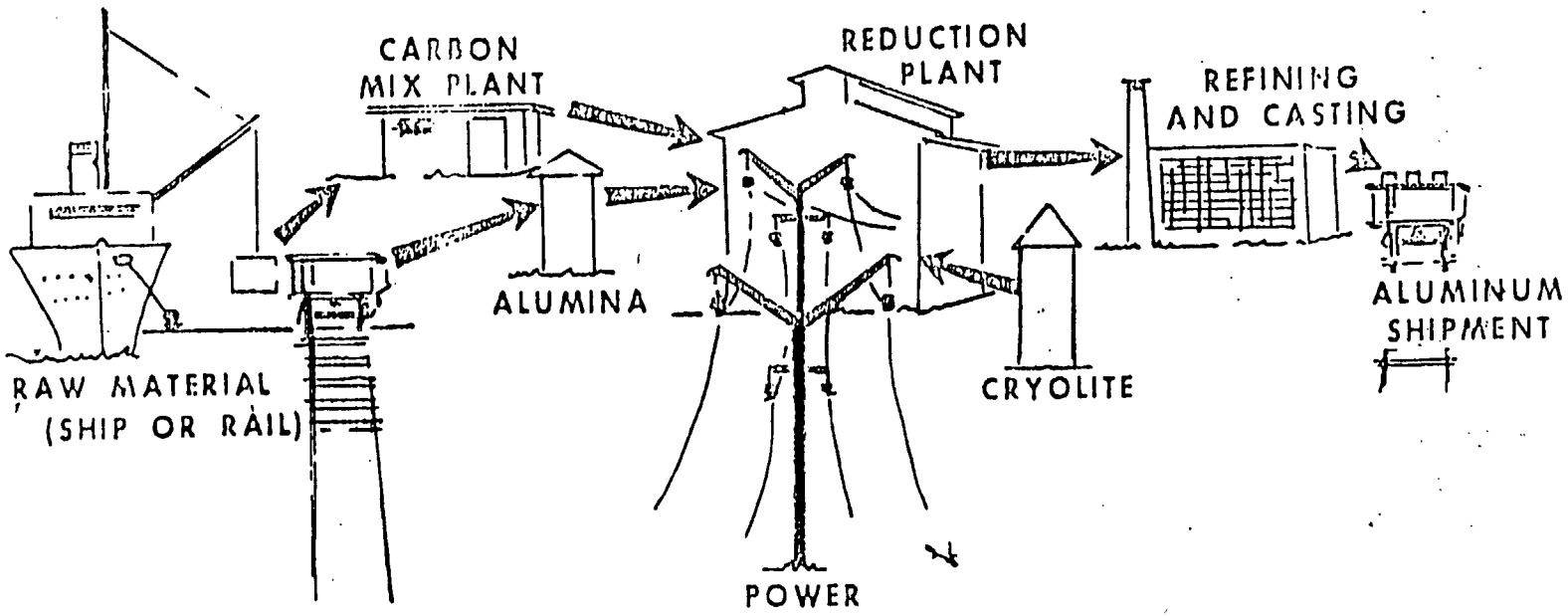
Aluminum Production

1. Alumina
2. Cryolite
3. Aluminum Fluoride
4. Fluorspar

Carbon Products

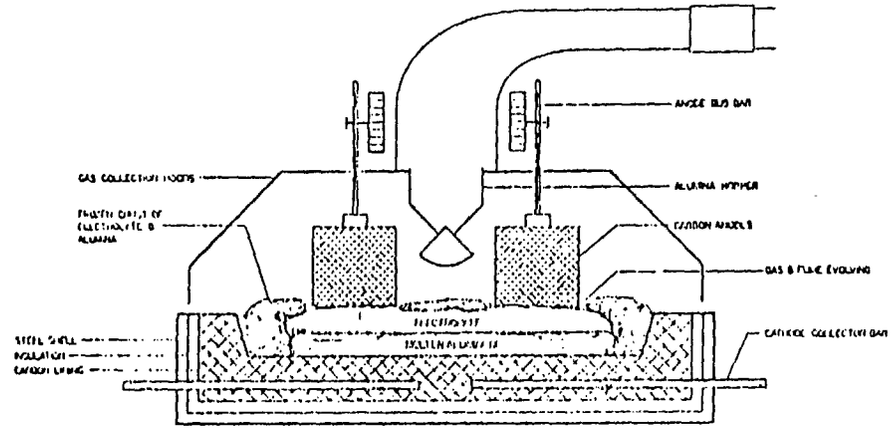
1. Petroleum Coke
2. Petroleum or Coal Tar Pitch
3. Anthracite Coal
4. Coke

FIGURE 2

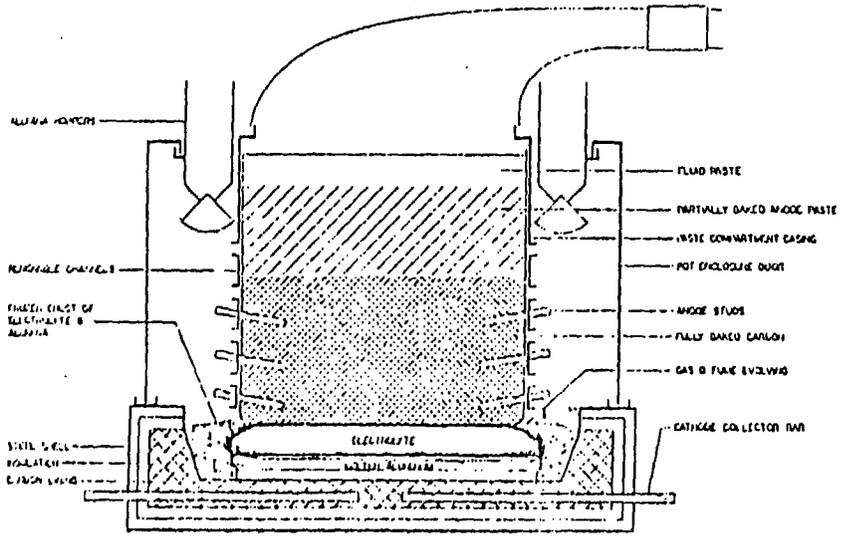


Aluminum reduction process.

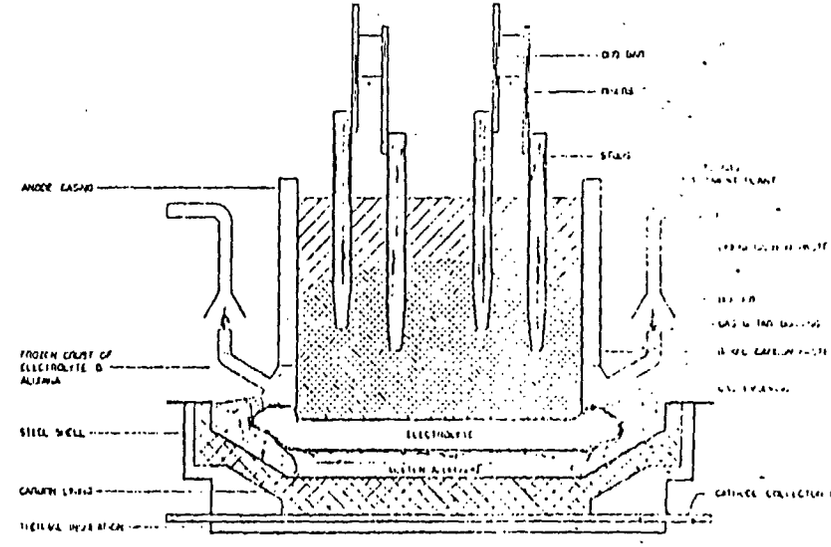
Figure 3. ALUMINIUM REDUCTION POTS



PREBAKE



HORIZONTAL SODERBERG



VERTICAL SODERBERG

TABLE 1

Comparison of Time Weighted Average (TWA) Pitch Volatile Results in Aluminum Reduction Facilities in the Eastern United States Versus Those in the Northwestern United States

of Plant Job Type	Eastern Facilities Number of Samples	Eastern Facilities Concentration, mg/m^3	Northwestern Facilities Number of Samples	Northwestern Facilities Concentration, mg/m^3
Baked				
trooms				
tman	3	0.2	13	0.2
ppers/anode setters	3	0.5	34	0.1-0.5
t reliner	1	0.3	29	0.4
on Plant				
l mill opr.	1	2.4	3	0.2
ss opr.	1	2.9	6	0.1
er opr.	1	0.6	3	0.3
ical Pin erberg				
rooms				
otman	10	2.2	5	0.3
pper	5	12.0	10	0.3
n Setter	5	2.5-7.5	40	1.1
on Plant				
er Operator	1	2.6	2	< 0.1
zontal Soderberg				
rooms				
otman	4	4.5	42	0.5
lex raisers	1	18.5	10	0.3
in pullers	2	1.5	4	0.4
hannel hangers	1	3.5	4	0.5
appers	4	2.0-3.4	5	0.3
ot reliners	1	8.3	5	0.1

er: Shaler, P.J. and Bierbaum, P.J.: 1974 Environmental Surveys of Aluminum Reduction Plants. U. S. Department of Health, Education and Welfare, Public Health Service, National Institute for Occupational Safety and Health, HEW Publication Number (NIOSH) 74-101, page 26

Table 2

LUNG CANCER MORTALITY IN RELATION TO TAR EXPOSURE
ARVIDA-ISLE MALIGNE AND ARVIDA-ISLE MALIGNE
AND SHAWINIGAN PLANTS COMBINED

ARVIDA-ISLE MALIGNE

	Tar Years			
	0 Years	<1-10 Years	11-20 Years	21+ Years
SMR	118.8	84.2	166.7	279.7
E	20.2	29.7	10.8	6.1
O	24	25	18	17

"Combined"
ARVIDA-ISLE MALIGNE-SHAWINIGAN

	Tar Years			
SMR	128.3	91.3	170.2	285.6
E	21	31.7	11.7	6.6
O	27	29	20	19

After: Gibbs GW and Horowitz I.: Lung cancer mortality in aluminum plant workers. A final report to Alcan Smelters and Chemicals. Department of Epidemiology and Health, McGill University, Montreal, Quebec.

HASSENA OPERATIONS

Table 3

YEAR BORN

	1865-69	1870-74	1875-79	1880-84	1885-89	1890-94	1895-99	1900-04	1905-09	1910-14	1915-19	1920-24	1925-29	1930-34	1935-39	1940-44	1945-49	Total
1900-04	1			4	4 1													9 1
1905-09				5	6	7	2											[illegible]
1910-14			2	12	21	23 1	15 1											73 2
1915-19		1	6 2	19	48 4	61 3	64 1	27										226 10
1920-24		2	9	13 1	30	40	78	152 2	62 3									384 6
1925-29		1	1	12	24 2	38 1	42 3	89 6	175 2	73								455 14
1930-34					5	4	4	2	8	9								[illegible]
1935-39		1	3	2	8	23	26 1	25 2	48 1	119 1	156 1	26						457 6
1940-44				9	43 2	62 1	81 1	117 4	136 4	185 4	219 1	324 1	90					[illegible] 18
1945-49					3	1	3	9	12 2	17	51 1	102	156	30				[illegible] 3
1950-54							2	14 1	30 1	29	52 3	78 2	121 1	102	7			455 8
1955-59										3	1	4	2	15	5			30
1960-64									1	1	6	6	4	6	21	24	4	73
1965-70										1	2	5	14	23	51	142	75	311
Total	1	5	21 2	76 1	192 9	259 6	317 7	435 15	472 13	437 5	487 6	545 3	387 1	176	84	166	79	3139 68

Upper Figure is Total Study Population
Lower Figure is Respiratory Cancer Deaths

Table 4

YEAR HIRED

YEAR BORN

	1875-79	1880-84	1885-89	1890-94	1895-99	1900-04	1905-09	1910-14	1915-19	1920-24	1925-29	1930-34	1935-39	1940-44	1945-49	Total
1910-14			2	2												4
	2	1	6	10	12	8										39
			1													1
1915-19	2	7	14	21	28	29	11									112
				1	1	2										4
1920-24		8	8	11	21	26	70	14								166
				1	1	1	1									4
1925-29		3		6	8	1	7	4								29
					1											1
1930-34		3	4	12	33	59	102	173	114	1						501
						1	4		1							6
1935-39		3	4	15	34	68	113	177	222	156	10					805
						2	1	4	3	1	1					12
1940-44				1	6	8	34	52	97	142	133	2				475
						1	1	1	2		1					6
1945-49						5	6	15	30	46	44	24				170
1950-54							1		1	5	5	6	3			21
1955-59								1			2			1		4
1960-64									1	1		1	35	75	8	121
1965-69																
Total	4	25	38	78	142	204	344	436	465	351	194	33	38	76	8	2436
			1	2	3	7	7	5	6	1	2					34

Upper Figure is Total Study Population
Lower Figure is Respiratory Cancer Deaths

BADIN WORKS

Table 5

YEAR BORN

YEAR HIRED	1870-74	1875-79	1880-84	1885-89	1890-94	1895-99	1900-04	1905-09	1910-14	1915-19	1920-24	1925-29	1930-34	1935-39	1940-44	1945-49	Total
1910-14	1		2	1	2	1											7
1915-19	3	3	5 1	22 2	31	33 1	12 2										109 6
1920-24			2	7	7	24	30 1	15 1	1								86 2
1925-29		1	1	5	2	5 1	20	34 2	12	0							80 3
1930-34		1			3	1	1	9	11	4							33
1935-39			1	2	7 1	12	14	41 2	86 3	75	7						245 6
1940-44						3	5	19	33 1	56 2	70	2					188 3
1945-49						1	2	2	10 1	15	45	77	10				162 1
1950-54									1	11	30 1	30	26				98 1
1955-59												3	12	3			18
1960-64											1	1		5	4		11
1965-69										2	3	5	14	25	49	10	108
Total	4	5	11 1	37 2	52 1	80 2	84 3	120 5	154 5	163 2	156 1	118	62	33	53	10	1146 22

511971 0243

Upper Figure is Total Study Population
Lower Figure is Respiratory Cancer Deaths

Table 6

VANCOUVER OPERATIONS

YEAR HIRED	YEAR BORN 1890-84	1895-99	1890-94	1895-99	1900-04	1905-09	1910-14	1915-19	1920-24	1925-29	1930-34	1935-39	1940-45	1945-49	Total
1910-14			1												1
1915-19			1	1											2
1920-24			1												1
1925-29					3	1									4
1930-34						1									1
1935-39						2	2	2							6
1940-44	7	19 1	32 1	44	42 1	35 1	81	69 1	22	6					357 5
1945-49		5	9 1	11	25 1	26	43	52 1	68	46	5				290 3
1950-54				6	9 2	16	35	43	40	67	26	1			243 2
1955-59							1	3	4	3	13	11	1		37
1960-64							2	3	7	6	8	15	26	3	70
1965-69							5	5	13	14	14	21	50	23	145
Total	7	24 1	44 2	62	79 4	81 1	169	177 2	154	142	67	48	77	26	1157 10

Upper figure is Total Study Population
Lower Figure is Respiratory Cancer Deaths

Table 7

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to December 31, 1959 or to Date of Death of the Index Case Whichever Occurred First

number ever and never exposed to potroom and/or carbon plant

Badin

	Cases	Controls
ever exposed	20	48
never exposed	2	18

RR = 3.8

Vancouver

	Cases	Controls
ever exposed	7	20
never exposed	3	10

RR = 1.2

Massena

	Cases	Controls
ever exposed	35	97
never exposed	33	107

RR = 1.2

Tennessee

	Cases	Controls
ever exposed	27	89
never exposed	7	13

RR = 0.6

Combined RR of exposure for the four plants = 1.2

Table 8

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
December 31, 1959 or to Date
of Death of the Index Case
Whichever Occurred First

number ever and never exposed to the potroom

Badin

	Cases	Controls
ever exposed	17	42
never exposed	5	24

RR = 1.9

Vancouver

	Cases	Controls
ever exposed	6	18
never exposed	4	12

RR = 1.0

Massena

	Cases	Controls
ever exposed	31	77
never exposed	37	127

RR = 1.4

Tennessee

	Cases	Controls
ever exposed	21	74
never exposed	13	28

RR = 0.6

Combined RR of exposure for the four plants = 1.2

Table 9

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to December 31, 1959 or to Date of death of the Index Case Whichever Occurred First

number ever and never exposed to the carbon plant

Badin

	Cases	Controls
ever exposed	10	20
never exposed	12	46

RR = 1.9

Vancouver

	Cases	Controls
ever exposed	3	6
never exposed	7	24

RR = 1.7

Massena

	Cases	Controls
ever exposed	15	41
never exposed	53	163

RR = 1.1

Tennessee

	Cases	Controls
ever exposed	11	31
never exposed	23	71

RR = 1.1

Combined RR of exposure for the four plants = 1.3

Table 10

Respiratory Cancer Mortality in Relation
to Years of Exposure to the Potroom
and/or the Carbon Plant from
Beginning of Exposure up to December 31, 1959
or to Death of the Index Case Whichever Occurred First

Badin

	Cases	Controls
≥ 10	14	34
< 10	8	32

R.R. = 1.6

	Cases	Controls
≥ 20	11	21
< 20	11	45

R.R. = 2.1

	Cases	Controls
≥ 30	5	9
< 30	17	57

R.R. = 1.9

Vancouver

	Cases	Controls
≥ 10	2	9
< 10	8	21

R.R. = 0.6

	Cases	Controls
≥ 20	0	0
< 20	10	30

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	10	30

R.R. =

Massena

	Cases	Controls
≥ 10	15	50
< 10	53	154

R.R. = 0.8

	Cases	Controls
≥ 20	10	30
< 20	58	174

R.R. = 1.0

	Cases	Controls
≥ 30	2	12
< 30	66	192

R.R. = 0.5

Tennessee

511971 0248

	Cases	Controls
≥ 10	23	63
< 10	11	39

R.R. = 1.3

	Cases	Controls
≥ 20	10	21
< 20	24	81

R.R. = 1.6

	Cases	Controls
≥ 30	4	6
< 30	30	96

R.R. = 2.1

Combined R.R. of exposure for the four plants. (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)
1.1 1.4 1.2

Table 11

Respiratory Cancer Mortality in Relation to Years of Exposure to the Potroom from the Beginning of Exposure up to December 31, 1959 or to Date of Death of the Index Case Whichever Occurred First

Badin

	Cases	Controls
≥ 10	10	27
< 10	12	39

R.R. = 1.2

	Cases	Controls
≥ 20	8	16
< 20	14	50

R.R. = 1.8

	Cases	Controls
≥ 30	2	8
< 30	20	58

R.R. = 0.7

Vancouver

	Cases	Controls
≥ 10	1	8
< 10	9	22

R.R. = 0.3

	Cases	Controls
≥ 20	0	0
< 20	10	30

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	10	30

R.R. =

Massena

	Cases	Controls
≥ 10	13	34
< 10	55	170

R.R. = 1.2

	Cases	Controls
≥ 20	7	19
< 20	61	185

R.R. = 1.1

	Cases	Controls
≥ 30	1	7
< 30	67	197

R.R. = 0.4

Tennessee

511971 0249

	Cases	Controls
≥ 10	18	46
< 10	16	56

R.R. = 1.4

	Cases	Controls
≥ 20	5	18
< 20	29	84

R.R. = 0.8

	Cases	Controls
≥ 30	2	5
< 30	32	97

R.R. = 1.2

Combined R.R. of exposure for the four plants.	(<10 vs ≥10)	(<20 vs ≥20)	(<30 vs ≥30)
	1.2	1.2	0.7

Table 12

Respiratory Cancer Mortality in Relation to
Years of Exposure to the Carbon Plant from
the Beginning of Exposure up to December 31, 1959
or to Date of Death of the Index Case,
Whichever Occurred First

Badin

	Cases	Controls
≥ 10	4	6
< 10	18	60

R.R. = 2.2

	Cases	Controls
≥ 20	3	4
< 20	19	62

R.R. = 2.4

	Cases	Controls
≥ 30	3	1
< 30	19	65

R.R. = 10.3

Vancouver

	Cases	Controls
≥ 10	1	1
< 10	9	29

R.R. = 3.2

	Cases	Controls
≥ 20	0	0
< 20	10	30

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	10	30

R.R. =

Massena

	Cases	Controls
≥ 10	3	17
< 10	65	187

R.R. = 0.5

	Cases	Controls
≥ 20	2	9
< 20	66	195

R.R. = 2.1

	Cases	Controls
≥ 30	0	3
< 30	68	201

R.R. = 6.3

Tennessee

	Cases	Controls
≥ 10	6	16
< 10	28	86

R.R. = 1.2

	Cases	Controls
≥ 20	2	3
< 20	32	99

R.R. = 2.1

	Cases	Controls
≥ 30	2	1
< 30	32	101

R.R. = 6.3

511971 0250

Combined R.R. of exposure for the four plants: (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)
1.1 1.3 3.1

Table 13

Respiratory Cancer Mortality in Relation to Years Since First Exposed to the Potroom and/or the Carbon Plant up to December 31, 1959 or to Date of Death of the Index Case Whichever Occurred First

Badin

	Cases	Controls
≥ 10	18	43
< 10	4	23

R.R. = 2.4

	Cases	Controls
≥ 20	14	33
< 20	8	33

R.R. = 1.8

	Cases	Controls
≥ 30	8	21
< 30	14	45

R.R. = 1.2

Vancouver

	Cases	Controls
≥ 10	6	17
< 10	4	13

R.R. = 1.1

	Cases	Controls
≥ 20	0	0
< 20	10	30

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	10	30

R.R. =

Massena

	Cases	Controls
≥ 10	29	82
< 10	39	122

R.R. = 1.1

	Cases	Controls
≥ 20	22	61
< 20	46	143

R.R. = 1.1

	Cases	Controls
≥ 30	15	49
< 30	53	155

R.R. = 0.9

Tennessee

511971 0251

	Cases	Controls
≥ 10	26	87
< 10	8	15

R.R. = 0.6

	Cases	Controls
≥ 20	11	37
< 20	23	65

R.R. = 0.8

	Cases	Controls
≥ 30	6	20
< 30	28	82

R.R. = 0.9

Combined R.R. of exposure for the four plants: (<10 vs ≥10) 1.1 (<20 vs ≥20) 1.1 (<30 vs ≥30) 1.0

Table 14

Respiratory Cancer Mortality in Relation to Years Since First Exposed to the Potroom up to December 31, 1959 or to Date of Death of the Index Case Whichever Occurred First

Badin

	Cases	Controls
≥ 10	15	36
< 10	7	30

R.R. = 1.8

	Cases	Controls
≥ 20	12	29
< 20	10	37

R.R. = 1.5

	Cases	Controls
≥ 30	5	18
< 30	17	48

R.R. = 0.8

Vancouver

	Cases	Controls
≥ 10	6	16
< 10	4	14

R.R. = 1.3

	Cases	Controls
≥ 20	0	0
< 20	10	30

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	10	30

R.R. =

Massena

	Cases	Controls
≥ 10	26	65
< 10	42	139

R.R. = 1.3

	Cases	Controls
≥ 20	19	48
< 20	49	156

R.R. = 1.3

	Cases	Controls
≥ 30	13	39
< 30	51	165

R.R. = 1.1

Tennessee

511971 0252

	Cases	Controls
≥ 10	19	72
< 10	15	30

R.R. = 0.5

	Cases	Controls
≥ 20	7	32
< 20	27	70

R.R. = 0.6

	Cases	Controls
≥ 30	4	17
< 30	30	85

R.R. = 0.7

Combined R.R. of exposure for the four plants. (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)
1.1 1.1 0.9

Table 15

Respiratory Cancer Mortality in Relation to
Years Since First Exposed to the Carbon Plant
up to December 31, 1959 or to
Date of Death of the Index Case Whichever
Occurred First

Badin

	Cases	Controls
≥ 10	7	14
< 10	15	52

R.R. = 1.7

	Cases	Controls
≥ 20	5	7
< 20	17	59

R.R. = 2.5

	Cases	Controls
≥ 30	4	4
< 30	18	62

R.R. = 3.4

Vancouver

	Cases	Controls
≥ 10	2	2
< 10	8	28

R.R. = 3.5

	Cases	Controls
≥ 20	0	0
< 20	10	30

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	10	30

R.R. =

Massena

	Cases	Controls
≥ 10	13	36
< 10	55	168

R.R. = 1.1

	Cases	Controls
≥ 20	9	26
< 20	59	178

R.R. = 1.0

	Cases	Controls
≥ 30	3	16
< 30	65	188

R.R. = 0.5

Tennessee

511971 0253

	Cases	Controls
≥ 10	11	31
< 10	23	71

R.R. = 1.1

	Cases	Controls
≥ 20	5	12
< 20	29	90

R.R. = 1.3

	Cases	Controls
≥ 30	2	5
< 30	32	97

R.R. = 1.2

Combined R.R. of exposure for the four plants. (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)
1.3 1.3 1.1

Table 16

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to December 31, 1959 or to Date of Death of the Index Case Whichever Occurred First

number ever and never exposed to pot tending

Badin

	Cases	Controls
ever exposed	15	36
never exposed	7	30

RR = 1.8

Vancouver

	Cases	Controls
ever exposed	4	11
never exposed	6	19

RR = 1.2

Massena

	Cases	Controls
ever exposed	25	66
never exposed	43	138

RR = 1.2

Tennessee

	Cases	Controls
ever exposed	18	65
never exposed	16	37

RR = 0.6

Combined RR of exposure for the four plants = 1.1

Table 17

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
December 31, 1959 or to Date of Death
of the Index Case
Whichever Occurred First

number ever and never exposed to tapping

Badin

	Cases	Controls
ever exposed	0	0
never exposed	22	66

RR =

Vancouver

	Cases	Controls
ever exposed	1	0
never exposed	9	30

RR =

Massena

	Cases	Controls
ever exposed	4	14
never exposed	64	190

RR = 0.8

Tennessee

	Cases	Controls
ever exposed	8	16
never exposed	26	86

RR = 1.6

Combined RR of exposure for the four plants = 1.4

Table 18

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to December 31, 1959 or to Date of Death of the Index Case Whichever Occurred First

number ever and never exposed to tapping and carbon changing

Badin

	Cases	Controls
ever exposed	7	20
never exposed	15	46

RR = 1.1

Vancouver

	Cases	Controls
ever exposed	2	4
never exposed	8	26

RR = 1.6

Massena

	Cases	Controls
ever exposed	7	24
never exposed	61	180

RR = 0.9

Tennessee

	Cases	Controls
ever exposed	7	19
never exposed	27	83

RR = 1.1

Combined RR of exposure for the four plants = 1.0

Table 19

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
December 31, 1959 or to Date of Death
of the Index Case
Whichever Occurred First

number ever and never exposed
to potroom craning

Badin

	Cases	Controls
ever exposed	2	5
never exposed	20	61

RR = 1.2

Vancouver

	Cases	Controls
ever exposed	0	0
never exposed	10	30

RR =

Massena

	Cases	Controls
ever exposed	2	4
never exposed	66	200

RR = 1.5

Tennessee

	Cases	Controls
ever exposed	3	7
never exposed	31	95

RR = 1.3

Combined RR of exposure for the four plants = 1.3

Table 20

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
December 31, 1959 or to Date of Death
of the Index Case
Whichever Occurred First

number ever and never exposed
to potroom service and other

Badin

	Cases	Controls
ever exposed	14	36
never exposed	8	30

RR = 1.5

Vancouver

	Cases	Controls
ever exposed	3	12
never exposed	7	18

RR = 0.6

Massena

	Cases	Controls
ever exposed	17	39
never exposed	51	165

RR = 1.4

Tennessee

	Cases	Controls
ever exposed	14	53
never exposed	20	49

RR = 0.6

Combined RR of exposure for the four plants = 1.0

Table 21

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
December 31, 1959 or to Date of Death
of the Index Case
Whichever Occurred First

number ever and never exposed to green carbon

Badin

	Cases	Controls
ever exposed	3	8
never exposed	19	58

RR = 1.1

Vancouver

	Cases	Controls
ever exposed	0	0
never exposed	10	30

RR =

Massena

	Cases	Controls
ever exposed	2	11
never exposed	66	193

RR = 0.5

Tennessee

	Cases	Controls
ever exposed	2	4
never exposed	32	98

RR = 1.5

Combined RR of exposure for the four plants = 0.9

Table 22

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
December 31, 1959 or to Date of Death
of the Index Case
Whichever Occurred First

number ever and never exposed
to potlining and repair

Badin

	Cases	Controls
ever exposed	2	7
never exposed	20	59

RR = 0.8

Vancouver

	Cases	Controls
ever exposed	3	4
never exposed	7	26

RR = 2.8

Massena

	Cases	Controls
ever exposed	8	21
never exposed	60	183

RR = 1.2

Tennessee

	Cases	Controls
ever exposed	2	18
never exposed	32	84

RR = 0.3

Combined RR of exposure for the four plants = 0.9

Table 23

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
December 31, 1959 or to Date of Death
of the Index Case
Whichever Occurred First

number ever and never exposed
to baked carbon

Badin

	Cases	Controls
ever exposed	6	11
never exposed	16	55

RR = 1.9

Vancouver

	Cases	Controls
ever exposed	1	3
never exposed	9	27

RR = 1.0

Massena

	Cases	Controls
ever exposed	5	11
never exposed	63	193

RR = 1.4

Tennessee

	Cases	Controls
ever exposed	7	4
never exposed	27	98

RR = 6.4**

Combined RR of exposure for the four plants = 2.2*

*Significant at 5% level

**Significant at 1% level

Table 24

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to December 31, 1959 or to Date of Death of the Index Case Whichever Occurred First

number ever and never exposed to anode assembly and rodding

Badin

	Cases	Controls
ever exposed	1	4
never exposed	21	62

RR = 0.7

Vancouver

	Cases	Controls
ever exposed	1	0
never exposed	9	30

RR =

Massena

	Cases	Controls
ever exposed	0	11
never exposed	68	193

RR = 0.0

Tennessee

	Cases	Controls
ever exposed	3	9
never exposed	31	93

RR = 1.0

Combined RR of exposure for the four plants = 0.6

Table 25

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
December 31, 1959 or to Date of Death
of the Index Case
Whichever Occurred First

number ever and never exposed
to other work in the carbon plant

Badin

	Cases	Controls
ever exposed	5	6
never exposed	17	60

RR = 2.9

Vancouver

	Cases	Controls
ever exposed	0	0
never exposed	10	30

RR =

Massena

	Cases	Controls
ever exposed	4	11
never exposed	64	193

RR = 1.1

Tennessee

	Cases	Controls
ever exposed	4	1
never exposed	30	101

RR = 13.5*

Combined RR of exposure for the four plants = 2.3*

*Significant at 5% level

Table 26

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to 10 Years before the Death of the Index Case

number ever and never exposed to the potroom and/or the carbon plant

Badin

	Cases	Controls
ever exposed	17	28
never exposed	2	10

RR = 3.0

Vancouver

	Cases	Controls
ever exposed	5	10
never exposed	3	6

RR = 1.0

Massena

	Cases	Controls
ever exposed	32	59
never exposed	30	65

RR = 1.2

Tennessee

	Cases	Controls
ever exposed	25	52
never exposed	7	12

RR = 0.8

Combined RR of exposure for the four plants = 1.2

Table 27

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to 10 Years before the Death of the Index Case

number ever and never exposed to the potroom

Badin

	Cases	Controls
ever exposed	15	26
never exposed	4	12

RR = 1.7

Vancouver

	Cases	Controls
ever exposed	5	9
never exposed	3	7

RR = 1.3

Massena

	Cases	Controls
ever exposed	27	46
never exposed	35	78

RR = 1.3

Tennessee

	Cases	Controls
ever exposed	19	43
never exposed	13	21

RR = 0.7

Combined RR of exposure for the four plants = 1.2

Table 28

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years before the Death of
the Index Case

number ever and never exposed
to the carbon plant

Badin

	Cases	Controls
ever exposed	7	9
never exposed	12	29

RR = 1.9

Vancouver

	Cases	Controls
ever exposed	2	4
never exposed	6	12

RR = 1.0

Massena

	Cases	Controls
ever exposed	12	22
never exposed	50	102

RR = 1.1

Tennessee

	Cases	Controls
ever exposed	10	16
never exposed	22	48

RR = 1.4

Combined RR of exposure for the four plants = 1.3

Table 29

Respiratory Cancer Mortality in Relation to Years of Exposure to the Potroom and/or the Carbon Plant from the Beginning of Exposure up to 10 Years before the Death of the Index Case

Badin

	Cases	Controls
≥ 10	11	20
< 10	8	18

R.R. = 1.2

	Cases	Controls
≥ 20	4	10
< 20	15	28

R.R. = 0.7

	Cases	Controls
≥ 30	2	5
< 30	17	33

R.R. = 0.8

Vancouver

	Cases	Controls
≥ 10	0	2
< 10	8	14

R.R. = 0.0

	Cases	Controls
≥ 20	0	0
< 20	8	16

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	8	16

R.R. =

Massena

	Cases	Controls
≥ 10	12	31
< 10	50	93

R.R. = 0.7

	Cases	Controls
≥ 20	7	16
< 20	55	108

R.R. = 0.9

	Cases	Controls
≥ 30	1	5
< 30	61	119

R.R. = 0.4

Tennessee

511971 0267

	Cases	Controls
≥ 10	17	28
< 10	15	36

R.R. = 1.5

	Cases	Controls
≥ 20	6	11
< 20	26	53

R.R. = 1.1

	Cases	Controls
≥ 30	2	3
< 30	30	61

R.R. = 1.4

Combined R.R. of exposure for the four plants. (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)

1.0 0.9 0.8

Table 30

Respiratory Cancer Mortality in Relation to Years of Exposure to the Rotroom from the Beginning of Exposure up to 10 Years Before Death of the Index Case

Badin

	Cases	Controls
≥ 10	8	18
< 10	11	20

R.R. = 0.8

	Cases	Controls
≥ 20	2	10
< 20	17	28

R.R. = 0.3

	Cases	Controls
≥ 30	1	5
< 30	18	33

R.R. = 0.4

Vancouver

	Cases	Controls
≥ 10	0	1
< 10	8	15

R.R. = 0.0

	Cases	Controls
≥ 20	0	0
< 20	8	16

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	8	16

R.R. =

Massena

	Cases	Controls
≥ 10	11	21
< 10	51	103

R.R. = 1.1

	Cases	Controls
≥ 20	6	12
< 20	56	112

R.R. = 1.0

	Cases	Controls
≥ 30	1	5
< 30	61	119

R.R. = 0.4

Tennessee

511971 0268

	Cases	Controls
≥ 10	12	21
< 10	20	43

R.R. = 1.2

	Cases	Controls
≥ 20	4	10
< 20	28	54

R.R. = 0.8

	Cases	Controls
≥ 30	1	2
< 30	31	62

R.R. = 1.0

Combined R.R. of exposure for the four plants. (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)

1.0 0.7 0.5

Table 31

Respiratory Cancer Mortality in Relation to Years of Exposure to the Carbon Plant from the Beginning of Exposure up to 10 Years Before the Death of the Index Case

Badin

	Cases	Controls
≥ 10	2	2
< 10	16	36

R.R. = 3.4

	Cases	Controls
≥ 20	2	0
< 20	17	38

R.R. =

	Cases	Controls
≥ 30	1	0
< 30	18	38

R.R. =

Vancouver

	Cases	Controls
10	0	1
< 10	8	15

R.R. = 0.0

	Cases	Controls
≥ 20	0	0
< 20	8	16

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	8	16

R.R. =

Massena

	Cases	Controls
≥ 10	1	9
< 10	61	115

R.R. = 0.2

	Cases	Controls
≥ 20	1	4
< 20	61	120

R.R. = 0.5

	Cases	Controls
≥ 30	0	0
< 30	62	124

R.R. =

Tennessee

	Cases	Controls
≥ 10	5	7
10	27	57

R.R. = 1.5

	Cases	Controls
≥ 20	1	1
< 20	31	63

R.R. = 2.0

	Cases	Controls
≥ 30	1	1
< 30	31	63

R.R. = 2.0

511971 0269

Combined R.R. of exposure for the four plants: (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)

0.9 1.6 4.2

Table 32

Respiratory Cancer Mortality in Relation to
Years Since First Exposed to
the Potroom and/or Carbon Plant
up to 10 Years Before the Death
of the Index Case.

Badin

	Cases	Controls
≥ 10	14	25
< 10	5	13

R.R. = 1.5

	Cases	Controls
≥ 20	9	18
< 20	10	20

R.R. = 1.0

	Cases	Controls
≥ 30	3	7
< 30	16	31

R.R. = 0.8

Vancouver

	Cases	Controls
≥ 10	2	3
< 10	6	13

R.R. = 1.4

	Cases	Controls
≥ 20	0	1
< 20	8	15

R.R. = 0.0

	Cases	Controls
≥ 30	0	0
< 30	8	16

R.R. =

Massena

	Cases	Controls
≥ 10	27	52
< 10	35	72

R.R. = 1.1

	Cases	Controls
≥ 20	15	35
< 20	47	89

R.R. = 0.8

	Cases	Controls
≥ 30	10	16
< 30	52	108

R.R. = 1.3

Tennessee

511971 0270

	Cases	Controls
≥ 10	20	40
< 10	12	24

R.R. = 1.0

	Cases	Controls
≥ 20	10	21
< 20	22	43

R.R. = 0.9

	Cases	Controls
≥ 30	2	6
< 30	30	58

R.R. = 0.6

Combined R.R. of exposure for the four plants. (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)
1.1 0.9 1.0

Table 33

Respiratory Cancer Mortality in Relation to
Years Since First Exposed to the Potroom
Up to 10 Years Before the Death of
the Index Case

Badin

	Cases	Controls
≥ 10	13	23
< 10	6	15

R.R. = 1.4

	Cases	Controls
≥ 20	8	17
< 20	11	21

R.R. = 0.9

	Cases	Controls
≥ 30	2	7
< 30	17	31

R.R. = 0.5

Vancouver

	Cases	Controls
≥ 10	2	3
< 10	6	13

R.R. = 1.4

	Cases	Controls
≥ 20	0	1
< 20	8	15

R.R. = 0.0

	Cases	Controls
≥ 30	0	0
< 30	8	16

R.R. =

Massena

	Cases	Controls
≥ 10	24	39
< 10	38	85

R.R. = 1.4

	Cases	Controls
≥ 20	13	28
< 20	49	96

R.R. = 0.9

	Cases	Controls
≥ 30	9	13
< 30	53	111

R.R. = 1.4

Tennessee

511971 0271

	Cases	Controls
≥ 10	15	33
< 10	17	31

R.R. = 0.8

	Cases	Controls
≥ 20	5	19
< 20	27	45

R.R. = 0.4

	Cases	Controls
≥ 30	1	5
< 30	31	59

R.R. = 0.4

Combined R.R. of exposure for the four plants. (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)
1.2 0.7 1.0

Table 34

Respiratory Cancer Mortality in Relation to Years Since First Exposed to the Carbon Plant Up to 10 Years Before the Death of the Index Case

Badin

	Cases	Controls
≥ 10	3	7
< 10	16	31

R.R. = 0.8

	Cases	Controls
≥ 20	2	2
< 20	17	36

R.R. = 2.1

	Cases	Controls
≥ 30	1	0
< 30	18	38

R.R. =

Vancouver

	Cases	Controls
≥ 10	1	1
< 10	7	15

R.R. = 2.1

	Cases	Controls
≥ 20	0	0
< 20	8	16

R.R. =

	Cases	Controls
≥ 30	0	0
< 30	8	16

R.R. =

Massena

	Cases	Controls
≥ 10	9	21
< 10	53	103

R.R. = 0.8

	Cases	Controls
≥ 20	5	11
< 20	57	113

R.R. = 0.9

	Cases	Controls
≥ 30	2	5
< 30	60	119

R.R. = 0.8

Tennessee

511971 0272

	Cases	Controls
≥ 10	8	13
< 10	24	51

R.R. = 1.3

	Cases	Controls
≥ 20	5	3
< 20	27	61

R.R. = 3.8

	Cases	Controls
≥ 30	1	1
< 30	31	63

R.R. = 2.0

Combined R.R. of exposure for the four plants. (<10 vs ≥10) (<20 vs ≥20) (<30 vs ≥30)

1.0 1.6 1.4

Table 35

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years Before the Death of
the Index Case

number ever and never exposed
to pot tending

Badin

	Cases	Controls
ever exposed	13	24
never exposed	6	14

RR = 1.3

Vancouver

	Cases	Controls
ever exposed	3	4
never exposed	5	12

RR = 1.8

Massena

	Cases	Controls
ever exposed	23	39
never exposed	39	85

RR = 1.3

Tennessee

	Cases	Controls
ever exposed	17	38
never exposed	15	26

RR = 0.8

Combined RR of exposure for the four plants = 1.1

Table 36

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years Before the Death of
the Index Case

number ever and never exposed to tapping

Badin

	Cases	Controls
ever exposed	0	0
never exposed	19	38

RR =

Vancouver

	Cases	Controls
ever exposed	1	0
never exposed	7	16

RR =

Massena

	Cases	Controls
ever exposed	3	11
never exposed	59	113

RR = 0.5

Tennessee

	Cases	Controls
ever exposed	7	12
never exposed	25	52

RR = 1.2

Combined RR of exposure for the four plants = 0.9

Table 37

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to 10 Years Before the Death of the Index Case

number ever and never exposed to tapping and carbon changing

Badin

	Cases	Controls
ever exposed	5	14
never exposed	13	24

RR = 0.8

Vancouver

	Cases	Controls
ever exposed	1	3
never exposed	7	13

RR = 0.6

Massena

	Cases	Controls
ever exposed	7	15
never exposed	55	109

RR = 0.9

Tennessee

	Cases	Controls
ever exposed	6	10
never exposed	26	54

RR = 1.2

Combined RR of exposure for the four plants = 0.9

Table 38

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years Before the Death of
the Index Case

number ever and never exposed
to potroom craning

Badin

	Cases	Controls
ever exposed	0	3
never exposed	19	35

RR = 0.0

Vancouver

	Cases	Controls
ever exposed	0	0
never exposed	8	16

RR =

Massena

	Cases	Controls
ever exposed	2	4
never exposed	60	120

RR = 1.0

Tennessee

	Cases	Controls
ever exposed	3	3
never exposed	29	61

RR = 2.1

Combined RR of exposure for the four plants = 1.0

Table 39

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years Before the Death of
the Index Case

number ever and never exposed
to potroom service and other

Badin

	Cases	Controls
ever exposed	12	23
never exposed	7	15

RR = 1.1

Vancouver

	Cases	Controls
ever exposed	2	6
never exposed	6	10

RR = 0.6

Massena

	Cases	Controls
ever exposed	13	20
never exposed	49	104

RR = 1.4

Tennessee

	Cases	Controls
ever exposed	12	27
never exposed	20	37

RR = 0.8

Combined RR of exposure for the four plants = 1.0

Table 40

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years Before Death of
the Index Case

number ever and never exposed
to green carbon

Badin

	Cases	Controls
ever exposed	3	2
never exposed	16	36

RR = 3.4

Vancouver

	Cases	Controls
ever exposed	0	0
never exposed	8	16

RR =

Massena

	Cases	Controls
ever exposed	1	0
never exposed	61	124

RR =

Tennessee

	Cases	Controls
ever exposed	2	3
never exposed	30	61

RR = 1.4

Combined RR of exposure for the four plants = 2.6

Table 41

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years Before Death of
the Index Case

number ever and never exposed
to potlining and repair

Badin

	Cases	Controls
ever exposed	2	3
never exposed	17	35

RR = 1.4

Vancouver

	Cases	Controls
ever exposed	2	3
never exposed	6	13

RR = 1.4

Massena

	Cases	Controls
ever exposed	6	5
never exposed	56	119

RR = 2.6

Tennessee

	Cases	Controls
ever exposed	2	9
never exposed	30	55

RR = 0.4

Combined RR of exposure for the four plants = 1.2

Table 42

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years Before Death of
the Index Case

number ever and never exposed
to baked carbon

Badin

	Cases	Controls
ever exposed	4	5
never exposed	15	33

RR = 1.8

Vancouver

	Cases	Controls
ever exposed	0	1
never exposed	8	15

RR = 0.0

Massena

	Cases	Controls
ever exposed	5	11
never exposed	57	113

RR = 0.9

Tennessee

	Cases	Controls
ever exposed	6	2
never exposed	26	62

RR = 7.2*

Combined RR of exposure for the four plants = 1.7

*Significant at 5% level

Table 43

Exposure of Respiratory Cancer Cases and Controls
from the Beginning of Exposure up to
10 Years Before Death of
the Index Case

number ever and never exposed
anode assembly and rodding

Badin

	Cases	Controls
ever exposed	1	1
never exposed	18	37

RR = 2.1

Vancouver

	Cases	Controls
ever exposed	1	0
never exposed	7	16

RR =

Massena

	Cases	Controls
ever exposed	0	7
never exposed	62	117

RR = 0.0

Tennessee

	Cases	Controls
ever exposed	2	4
never exposed	30	60

RR = 1.0

Combined RR of exposure for the four plants = 0.7

Table 44

Exposure of Respiratory Cancer Cases and Controls from the Beginning of Exposure up to 10 Years Before the Death of the Index Case

number ever and never exposed to other work in the carbon plant

Badin

	Cases	Controls
ever exposed	3	3
never exposed	16	35

RR = 2.2

Vancouver

	Cases	Controls
ever exposed	0	0
never exposed	8	16

RR =

Massena

	Cases	Controls
ever exposed	3	5
never exposed	59	119

RR = 1.2

Tennessee

	Cases	Controls
ever exposed	3	0
never exposed	29	64

RR =

Combined RR of exposure for the four plants = 2.4

TABLE 46

TEMPERATURE RANGE OF CARBONIZING CHAMBERS
AND EXCESS OF LUNG CANCER REPORTED

Carbonizing Chamber	Temperature Range	Percent Excess of Lung Cancer Reported	
Vertical Retorts	400 - 500 C	27%	[9]
Horizontal Retorts	900 - 1100 C	83%	[9]
Coke Ovens	1200 - 1400 C	255%	[11]
Japanese Gas Generators	1500 C	800%	[11]

The figure shown for coke oven workers is for men with five or more years experience to provide contrast with the British gas workers who had worked at least five years at the retorts.

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Aly, Hekmat K.

MORTALITY AMONG ALUMINUM PLANT WORKERS

This is a case control study of the respiratory tract cancer experience of aluminum reduction workers at the four oldest Alcoa smelters. Three of the plants were prebake, and employees from both potrooms and carbon plants were included. The fourth plant was a mixed Prebake, Soderberg Reduction plant. In the latter, horizontal pin Soderberg cells were utilized for twenty years up to 1949. Horizontal pins were replaced with vertical pins in 1950 and were utilized until 1974 when the Soderberg cell was discontinued.

Subjects who developed respiratory cancer and other male workers were divided into cells whose members were born within five-year periods and who were hired within five-year periods. Each respiratory cancer case had three matched controls randomly selected from the cell.

Work exposures of 134 cases of workers who developed respiratory tract cancer were matched with worker controls from the beginning of exposure up to December 31, 1959, or to the date of death of the cancer patient. Work exposures were characterized as "ever" or "never" exposed to the "potroom and/or carbon plant, potroom, and carbon plant."

The original study population consisted of 8,880 men who worked at the four plants from January 1, 1946, through December 31, 1973 and who worked in aluminum production at least five years. One hundred thirty-four workers developed cancer of the respiratory tract.

Work exposures of subjects and controls were organized by two principal methods:

1. Exposures of 134 workers who developed cancer and three controls for each case were calculated to December 31, 1959, or to date of death of a study case, which ever came first, and
2. Exposures of 121 workers who developed cancer and two controls for each case were calculated to 10 years before death of a case

Work exposures were broadly defined as "potroom," "carbon plant," and different types of work in the potroom and carbon plant. Work experiences were further characterized by lengths of time spent in these areas or on these jobs.

For an estimation of relative risks at each plant, two by two contengency tables were utilized and the level of statistical significance calculated. An estimate of the relative risk for all four plants was also calculated.

The relative risk for respiratory cancer of those "ever" exposed to baked carbon at one plant was significantly greater (at 1% level) than those "never" exposed (relative risk 6.4). This one plant contributed the major weighting to the combined four plant risks for those "ever" exposed (significant at the 5% level) compared to the "never" exposed (relative risk 2.2).

Relative risk for respiratory cancer in the group of employees "ever" exposed to other work in the carbon plant was significantly greater at the 5% level for both the combined four plants and the single plant cited above compared to those "never" exposed to other carbon plant work. The relative risk at the one plant was 13.5 and for the four combined plants, 2.3.

A significantly greater risk (at the 5% level) for this one plant persisted for those "ever" exposed to baked carbon up to 10 years before death of index cases compared to those "never" exposed (Relative Risk 7.2). Combined four plant relative risks of "ever" exposed to "never" exposed was not statistically significant.

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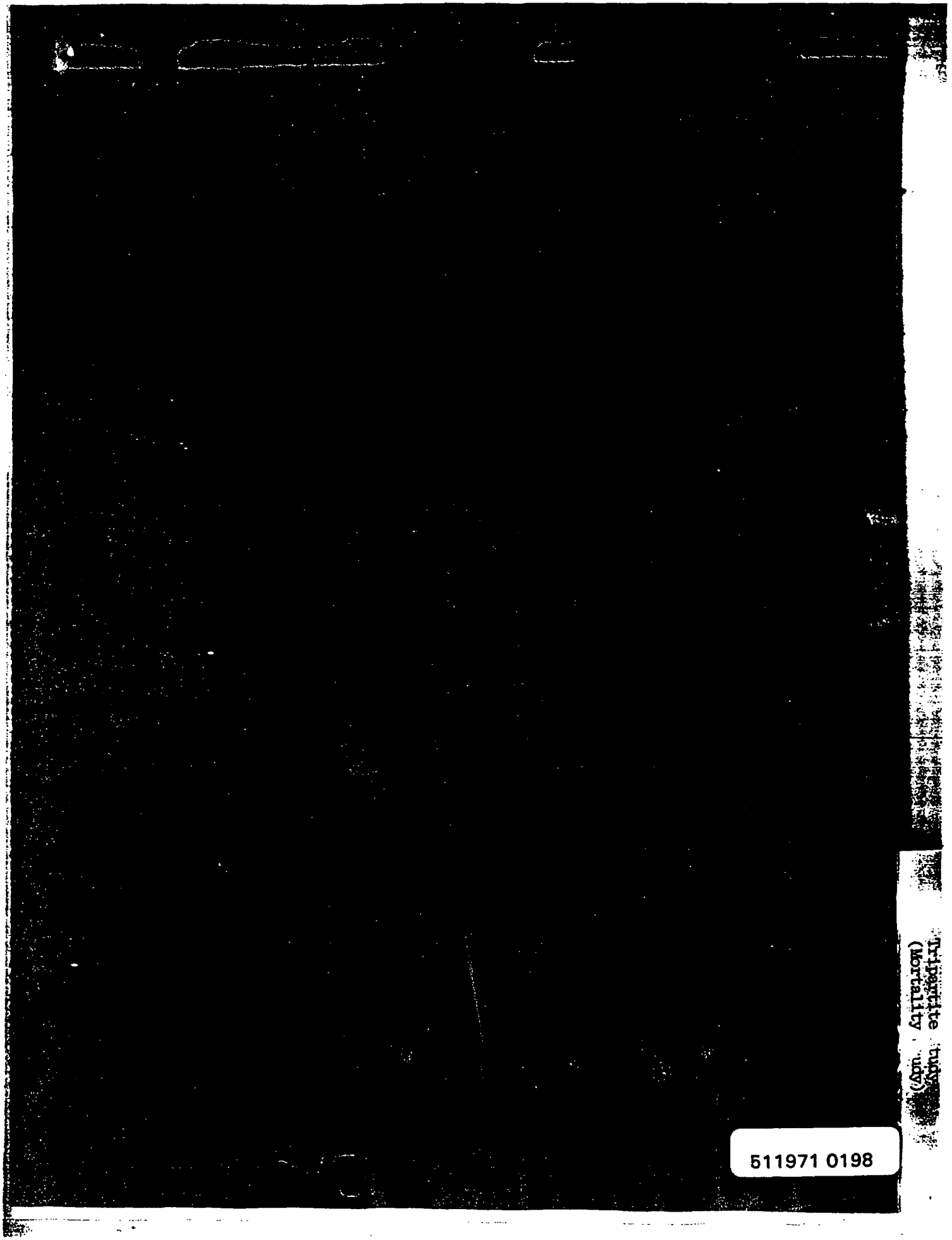

Tripartite study (Mortality only)

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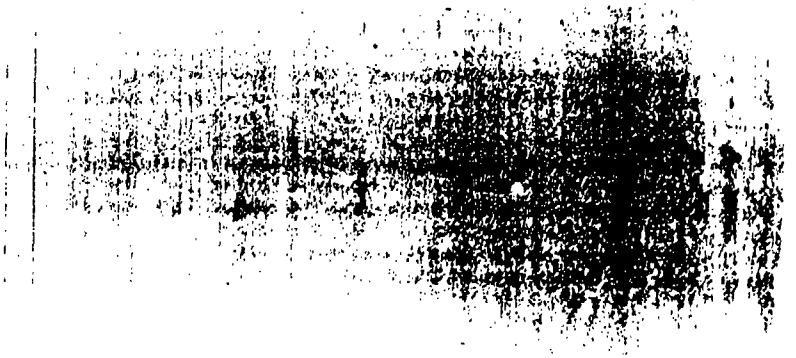
Tripartite Study
(Mortality Study)



Respiratory Cancer Mortality Among Aluminum Plant Workers

by

Hekmat K. Aly