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A Study Of Intestinal Cancer Mortality In A Population Of Canadian Oil Workers

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A STUDY OF INTESTINAL CANCER MORTALITY IN A POPULATION OF CANADIAN OIL WORKERS

by

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ABSTRACT

In 1972, an historical cohort study of the Canadian Imperial Oil Company employee population, during the period 1964 through 1973, was designed with the following purposes: (1) to compare mortality patterns of male oil company employees who were active for at least one year during the 10-year observation period, or retired, with those of the 1969 Canadian male population of the same age; (2) to determine whether or not workers exposed to crude oil or petroleum products on a daily basis were at greater risk of death due to intestinal cancer than non-exposed workers in the same company; exposure, to petroleum or its derivatives, was defined by an employee's place and nature of work; and (3) to compare mortality between refinery and non-refinery groups; refinery workers were identified on the basis of having a job at a refinery site, regardless of whether or not it was associated with an occupational exposure.

The results of mortality comparisons of the population at risk with the Canadian population were clearly favourable to the employee population. All but one of the causes of death examined showed standard mortality ratios (SMR) of less than 100. The exception, malignant neoplasms of other digestive organs (ICDA codes 155-159) with an SMR of 106, was not significantly elevated.

Occupational exposure to petroleum or its products was not associated with increased mortality due to intestinal cancer. It is unlikely that a sizable increase in intestinal cancer mortality could have been missed. Lung cancer mortality was twice as high in exposed workers when compared with non-exposed workers. This difference,

which increased with increasing duration of employment, is believed to represent a specific effect of exposure.

Refinery workers experienced a higher intestinal cancer death rate than non-refinery workers. However, no consistent patterns were observed when specific exposure/refinery subgroups were examined nor was there any "dose-response" relationship apparent. The two-fold increase in intestinal cancer mortality in the refinery group cannot be ascribed with certainty to an occupational carcinogenic exposure.

Specific recommendations for further study, with this population, were made. They include: (1) longitudinal extension of this study; (2) the study of cancer morbidity as well as mortality; (3) further examination of high intestinal and lung cancer mortality risk groups identified in this study, particularly with respect to effects of other variables such as smoking; (4) collecting quantitative as well as qualitative information about potentially hazardous exposures; (5) keeping more comprehensive work histories on all employees and (6) follow-up of all employees who leave the company.

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INTRODUCTION

In the 18th century certain occupational exposures were found to be associated with cancers in workers. Percival Pott (1775) observed that coal soot was the carcinogenic agent associated with scrotal skin cancer in British chimney sweeps.

More frequent exposures to soot and similar substances came about with the industrial revolution. The need for lubricants for machinery gave rise to the mineral oil industry. Also, fuel requirements allowed the coal, gas and petroleum industries to flourish.

Butlin (1892) recognized that scrotal cancer could be associated with mineral oils and other crude carcinogens. Upon examining the occurrence of scrotal cancer among workers exposed to tar, paraffin and shale oil, he speculated that these substances might also be responsible for the increasing occurrence of cancer in internal organs.

Subsequently a series of experiments showed that laboratory animals treated with petroleum oil and fractions thereof were likely to develop tumours of the internal organs, as well as skin cancers (Medical Research Council, 1968; Lushbaugh, 1947; Lorenz and Stewart, 1940).

Since larger numbers of workers have become exposed to tar, paraffin, mineral oils, petrochemicals and substances resulting from the incomplete combustion of these fuels, one might expect to observe an increase of cancer in the internal organs of these workers. Although there have been studies relating skin, lung, bladder and most recently liver cancer to employment in the petroleum industry, intestinal cancer has not been investigated as an occupational tumour. Yet, intestinal cancer has been shown to be more frequent in industrialized countries (Wynder and Shigematsu, 1967). If the risk of death due to intestinal cancer increases with exposure to carcinogenic substances produced by incomplete combustion of fuels, then workers exposed to high daily concentrations of these substances would be at greater risk than the general population. Such a group of workers presents an appropriate population in which to test the hypothesis that exposure to carcinogenic substances in petroleum and its derivatives increases the risk of death from intestinal cancer. This study was developed to test this hypothesis.

1.1 Statement of the Purpose of the Research

The primary purpose of this study was to investigate the possibility that male workers exposed to crude petroleum, and/or its products, ran a greater risk of dying from intestinal cancer than did employees of the same company who were not so exposed.

The secondary purpose was to compare the mortality experience of male company employees with that of the 1969 Canadian male population of the same age.

This study was developed with full cooperation of the management of Imperial Oil Co., Ltd. of Canada, who provided employee records for about 21,000 male employees throughout Canada for the period 1964 through 1973. Among these employee histories was enough information to identify workers who were exposed to crude petroleum and/or its products. In addition, information on variables such as age, geographic location, years in service, and job description was included. The company provided the cause of death for active and retired employees who died between 1964 and 1973.

REVIEW OF THE LITERATURE

Since there have been no studies published that are directly addressed to the question of a relationship between intestinal cancer and occupational exposure to petroleum this review will take the following direction:

Section 2.1 is a brief summary of the petroleum refining process. The process is described for two reasons: (1) to define technical terms which will be used subsequently in this text and (2) to list the known carcinogens which are present in crude petroleum or its breakdown products.

Section 2.2 describes studies which provide experimental support for the assumption that chemicals which exist in crude petroleum, and produots thereof, are carcinogenic in laboratory animals.

Section 2.3 provides an historical account of clinical observations of occupational tumours in workers exposed to coal and petroleum and their derivatives, such as tar and other substances resulting from the incomplete combustion of fuels. The reason for including studies involving the coal industry is that many of the carcinogens found in petroleum derivatives produced by incomplete combustion are also found in coal products.

The final section, 2.4, presents a discussion of previous epidemiological studies directly related to the question of whether or not workers coming in contact with these carcinogens have higher cancer incidence or mortality rates than workers or population cohorts not so exposed.

2.1 The Petroleum Industry: Definition of Processes Which May Lead to the Production of Chemical Carcinogens

Unless otherwise specified, information concerning certain technical processes and substances derived from oil refining was summarized from Purdy (1957).

The range of producing activities in the petroleum industry includes everything from the digging of an oil well to the packaging and shipping of petroleum products. Refining processes refer to those processes employed in the actual production of petroleum products. These include distillation at extremely high temperatures and catalytic cracking, a process by which hydrocarbons are broken down and re-arranged into multiple-sized chains. Some distillation products are listed below in the order of increasing distillation temperature.

Gases

Naphthas (gasoline components, solvents)

Kerosene and stove oil

Light gas oil (diesel fuels and furnace fuel oils)

Heavy gas oil (used in catalytic cracking)

Lubricating oils

Wax (paraffin)

Asphalts or Tars

"Crude oil" and "mineral oil" are terms used throughout the literature as synonyms for petroleum. Shale oil is a specific form of petroleum, with properties somewhat like asphalt, extracted from shale fields. It is a source of lubricating oils. "Pitch", "tar" or "tarry substances" refer to asphalt, one of the more viscous distillation products. "Tar" may also result from catalytic cracking as a heavy residual oil. Mineral oil mists are oil droplets in the atmosphere disseminated from the lubricating oils on machinery. "Paraffin workers" or "wax pressmen" refer to workers employed in the production of wax.

Aromatic hydrocarbons are substances which occur naturally in crude petroleum and as impurities in many of its products. Crude petroleum from various parts of the world differ in the amount of aromatic hydrocarbons which they contain. The catalytic cracking process produces a variety of aromatic hydrocarbons, some of which are used in the manufacturing of solvents and explosives. Aromatic hydrocarbons, characterized by the 6-carbon atoms making up their ring structures, are chemically active and form a variety of hydrocarbons through the attachments of various side chains. However, the carcinogenic properties of petroleum are believed to be mainly associated with the more complex polycyclic aromatic hydrocarbons which are aromatic hydrocarbons with multiple ring structure attachments. An example is benzpyrene. Improved technology such as catalytic cracking has increased the amount and variety of such compounds.

Substances other than polycyclic aromatic hydrocarbons which have been shown to be carcinogenic in laboratory animals are inorganic lead (a petroleum additive) and some petrochemicals such as carbon tetrachloride (used as a solvent), benzidine (a component of dyes and plastics), and some nitroso-compounds (used as solvents and as components of rocket fuel) (World Health Organization, 1972; 1973).

2.2 Animal Experiments on the Carcinogenicity of Petroleum Fractions

In 1915, two Japanese researchers, Yamagiwa and Ichikawa developed an assay method for testing suspected carcinogens on the skin of laboratory animals. They were able to demonstrate the carcinogenic effect that coal tar applications had on the skin of live rabbits. Since then, coal tar, shale oil and atmospheric oil mists have all been shown to produce skin cancers and in some cases gastrointestinal cancers in rabbits, mice or monkeys through various routes of administration (Medical Research Council, 1968).

Fractions of uncracked mineral oils, as well as cracked samples, have also been tested and shown to have high carcinogenic activity in laboratory animals (Cook et al., 1958; Holt et al., 1951; Smith et al., 1951; Sugiura et al., 1956; Twort and Ing, 1928). The British Medical Research Council (1968) documented studies concerning the chemical analysis of mineral oils and described their carcinogenic activity in laboratory animals. Chemical analyses showed that the carcinogens belonged to the group of chemicals known as polycyclic aromatic hydrocarbons. Table 1 lists the crude petroleum fractions and their boiling ranges and indicates the range of greatest carcinogenic activity based on these animal experiments.

With the development of the petrochemical industry, chemicals which are produced on refinery sites other than polycyclic aromatic hydrocarbons have been tested and shown to be carcinogenic in laboratory animals. Inorganic lead, used as a petroleum additive, has a tumourigenic effect on mouse and rat kidney. Chlorinated hydrocarbons, aromatic amines and N-nitroso compounds have also been

Table 1

Range of Carcinogenic Activity in Crude Petroleum Fractions

Fraction[1]	Approximate Boiling Range (C°)	Biological Activity (C°)[2][3]	Chief Uses
Fuel gas	-161.7 to -42.2		Methane, ethane, propane, refinery fuel
Propane	-42.2		Liquified petroleum gas
Butane	- 11.7 to - 0.6		Blend with motor gasoline
Light naphtha	- 1.1 to 148.9		Motor gasoline; feed for catalytic reforming
Heavy naphtha	148.9 to 204.4		Catalytic reformer feed; jet fuels
Kerosene	204.4 to 260.0		
Stove oil	204.4 to 287.8	230 to 270	
Light gas oil	204.4 to 315.6	300 to 400	Furnace fuel oil, diesel fuels
Heavy gas oil	315.6 to 426.7	350 to 390	Catalytic cracking feed
Vacuum gas oil	426.7 to 593.3		Catalytic cracking feed, motor gasoline, furnace fuel, diesel fuels, lubricating oils
Pitch	593 +		Heavy fuel oil, asphalts

1. Purdy, G.A. (1957). Petroleum. 128-129. The Copp Clark Publishing Co. Vancouver, Toronto, Montreal. Note: Temperatures were in degrees Farenheit. I converted them to degrees Celsius.

2. Medical Research Council Report Series 306 (1968). Carcinogenic Action of Mineral Oils. HMSO, London, England.

3. Boiling range of chemicals showing carcinogenic activity.

associated with tumour development in animals. The site specificities have included liver, bladder and lung of various animals. Furthermore, there have been results which implicate aromatic amines and some N-nitroso compounds as carcinogens in the gastrointestinal organs of the rat, mouse and hamster (World Health Organization, 1972).

Appendix I contains a more detailed summary of the carcinogenic activity of constituents of petroleum in laboratory animals. Part A refers to general petroleum substances while Part B refers to specific chemicals which have been tested.

Many factors influence the results of animal experiments. The route of administration used is generally the one by which humans would be exposed. It has been shown that polycyclic hydrocarbons, when painted on the dorsal skin of mice, induce skin cancers. When administered orally, however, stomach tumours occur. Dose, concentration, and duration of administration vary with experiment and with route of administration. The species, strain and sex of the animal under study may have a profound effect on the results. An example is that of the carcinogenic action of benzpyrene, a polycyclic aromatic hydrocarbon. Tumourigenesis was observed in the rat, mouse, guinea pig, and rabbit within a two year latent period while in monkeys it took up to ten years. Male mice show a higher incidence of cancers than do female mice when given 7,12 dimethylbenzanthracene. The choice of species to be used is usually one of practicality based on the length of the latency period. Other factors known to have an effect are the age of the animal and the solvent employed (Grice, 1973).

The validity of extrapolating from results of animal studies to assess potential carcinogenicity in man remains unresolved. Specific conditions of human exposures need to be assessed.

2.3 Historical Aspects

By the early 1900's, it was well noted in the medical literature that occupational exposure to certain by-products of incomplete combustion of coal and petroleum could be associated with specific cancers in man.

Percival Pott's synthesis of clinical observations of scrotal cancer and knowledge of the occupations of his patients not only initiated studies of occupational disease but also gave rise to the area of study known as chemical carcinogenesis (Potter, 1963).

Hueper (1942) gives an excellent historical account of observations of paraffin cancer of the skin. The following studies are summarized from his account. These early studies mainly involved reporting the clinical description and number of cases observed. Cases of skin cancers in Scottish paraffin workers were identified in 1876. Cotton "mule" spinners in the British yarn industry, who were exposed to streams of lubricating oils disseminated from the spindles of the spinning machines, were observed to have a high occurrence of scrotal cancer. The machines were called "mules"; hence, the title "mule spinner". In 1928, Southam estimated that the incidence of scrotal cancer in mule spinners was about 2.5 cases per 1,000 spinners per year. He also made the observation that primary cancers of the lung, tonsil, and stomach co-existed with scrotal cancer in several mule spinners. Cases of cancers were observed among U.S. refinery and cotton workers exposed to paraffin and oils in the early 1900's. Coal tar dyes had been thought to be responsible for bladder and kidney cancer as early as 1895. The responsible agents have since become known as aromatic amines (Hueper, 1942).

Recent clinical observations have isolated what may be a relationship between occupational exposure to vinyl chloride monomer (a petrochemical precursor of plastics) and the occurrence of a rare form of cancer -- angiosarcoma of the liver (Center for Disease Control, 1974).

2.4 Epidemiological Studies of the Carcinogenicity of Petroleum Constituents in Humans

Polycyclic aromatic hydrocarbons are known constituents of petroleum and are well established as carcinogens in laboratory animals. Humans have been exposed to combinations of these chemicals through contact with soot, coal, tar, pitch, mineral oils, tobacco smoke and automobile exhausts (World Health Organization, 1973).

Workers exposed to these hydrocarbons on a daily basis and in concentrated doses might be expected to run a greater cancer risk than the general population.

The emphasis in this review will be on studies in which the occupational exposure was apt to be due to sources of polycyclic aromatic hydrocarbons such as coal tar and petroleum. Studies in which the resulting cancers were in the colon or other digestive organs are of major relevance here. Inorganic lead, chlorinated hydrocarbons and N-nitroso compounds have not been associated with tumour development in man. However, aromatic amines have been shown to have a carcinogenic effect on man and will be mentioned in this review (World Health Organization, 1972).

The outstanding characteristic of the studies cited in Section 2.3 was that the association between mineral oils and cancers in man was based mainly upon clinical observations. Appendix II provides a brief historical summary of cancer risk to man from exposure to sources of polycyclic aromatic hydrocarbons. It includes references to observations mentioned in Section 2.3 as well as epidemiological studies discussed in this section.

In an occupational survey, Peller (1936) claimed that workers in contact with tar had increased cancer rates at a number of sites, including the intestines. He compared British tar workers with other workers in the same social class. Rates were based on "performance-years". The data on deaths from 1921-1923 were extracted from the Registrar General's Decennial Supplement, England and Wales. That he corrected for age and social class makes this a worthwhile study. Also his use of "performance-years" was unique. His results, in the form of age-adjusted incidence rates, showed a rate of 122 per 100,000 performance years in his control group and one of 159, in workers of the same social class exposed to "tarry substances". Included were cancers of the intestines, alimentary glands and urinary organs. As such it is not possible to single out intestinal cancer risk. Raw data were not provided the reader thus making it impossible to perform a statistical analysis on these results.

A 20-year prospective cohort study of cancer morbidity in a refinery population did not reveal a statistically significant increase in intestinal cancers. Hendricks (1959) compared the age-adjusted cancer incidence of the United States white male population with that of a refinery population consisting of 3,000-4,000 workers annually. The cancer incidence rate, 339/100,000 of the refinery population was well within the expected limits. However, when the refinery population was delimited to specific workers, namely wax pressmen, the average annual incidence rate for this group was markedly higher. Wax workers, other than pressmen showed rates similar to that of the U.S. population. Eighty-two wax pressmen, with ten years or more service, represented 3% of the refinery population but accounted for 11% of the cancer cases. The average annual cancer incidence rate was 1,393/100,000. Of the 19 cancer cases in the group of 82 wax pressmen, 11 were scrotal cancer; 6 were gastro-intestinal; 1 was lung cancer and 1 was unclassified. The higher scrotal cancer rate for wax pressmen was statistically significant, while the others were not. However, this population represented a small sample. With a total of only 6 gastrointestinal cancer deaths the results for this site were unreliable.

Mancuso and El-Attar (1967) in a cohort study of dye manufacturing workers found an increase in death due to cancer of the pancreas in workers exposed to the aromatic amines, benzidine and betanaphthylamine. An increased rate was also seen for cancer of the digestive organs and peritoneum (7 deaths observed to 3.54 expected) in the exposed workers, ages 45-64. Expected values were determined by applying age-specific death rates of the non-exposed workers to corresponding populations of exposed workers. The use of an internal control group is justified in an occupational mortality study. However, with small subgroups and small numbers of cancer deaths, this approach is unreliable. There were 3 pancreatic cancer deaths in the exposed group where none was expected. The authors advised further exploration of this observation.

Members of the American Chemical Society, during the period 1948-1967, showed an increase in pancreatic and intestinal cancer deaths in the greater than 64-year age group. This was in contrast to the U.S. professional male population. Proportional mortality rates (PMRs) were used as the statistical measure since a population at risk could not be defined. Conclusions based on PMRs are unreliable since a high risk for a given cause of death may be the result of a real increase for that cause or may be simply due to a decrease in mortality from another category of disease (Li et al., 1969).

The hypothesis that an increased risk of death may be associated with an occupational exposure to an oil mist atmosphere was tested by Pasternach et al. (1972). A 12-year mortality study of newspaper workers was undertaken. The risk of death in 778 pressmen exposed to an oil mist was compared with that of a control group of 1,207 compositors. Age adjusted death rates were calculated for the pressmen, using the compositors as the standard population. No significant differences in mortality patterns were observed in workers (with at least 20 years employment) beginning employment at less than 40 years of age. At more than 40 years of age at beginning employment and after at least 20 years employment the pressmen experienced higher death rates. Cause-specific death rates were not analysed since there were only 75 deaths observed among the pressmen and 129 among the compositors. However, a search for trends revealed no obvious patterns. The small sample size may have precluded finding a real difference even if one had existed.

A survey of 1961 occupational mortality in Britain at the time of the census did not reveal a statistically significant increase in risk of death from intestinal cancer for gas, coke and chemical makers (Adelstein, 1972).

The results of a mortality study of oil refinery workers in the U.S. have recently been made available (Gaffey et al., 1976). Person years of observation were calculated for 17 refinery populations for workers employed between January 1, 1962 and December 31, 1971. The total population was 20,163, representing 137,153 years of observation. There were 1,165 deaths. SMRs were calculated for specific causes of death for the total population of refinery workers as well as for three sub-groups rated for exposure to hydrocarbons as high, moderate and low. Expected deaths were calculated using U.S. male age-and cause-specific death rates. Gastrointestinal cancers were highest in men in the lowest exposure group. Mortality due to genital cancers and lymphomas was greater in the refinery workers than in the general population but the excess was not statistically significant. One problem occurring in this study was the definition of exposure. The exposure for each worker was defined according to the nature of his work on his last record of employment. If a worker were disabled or unable to carry on with a physically taxing job, he might be given a more sedentary position, such as that of a watchman or inspector, during his last few years of employment. If he had a history of heavy exposure in his earlier years, this would be missed. Watchmen were included in the lowest exposure group. Thus, misclassification in the direction of underestimating exposure may have biased these results.

Cohort studies of the occupational mortality experience of coke oven steelworkers in Pennsylvania, U.S.A., have revealed an increase in mortality from lung cancer among topside and side oven workers when compared with workers employed in other parts of the plants. The risk, increasing with the length of employment, was greatest among the top-side workers. Although conclusions based on the small number of deaths involved would be risky, it was noted that employees in the non-oven areas of the coke plant had a high but not statistically significant excess of digestive tract cancers (Lloyd, 1971). Since then, follow-up studies have brought the total population of workers in the study to 58,828 over a period of 14 years. The total deaths during this period were 8,628. Two subgroups were compared: coke oven workers and "non-oven" workers. Results indicate an elevated risk of mortality due to lung and kidney cancer in the oven workers. A statistically significant excess of colon and pancreatic cancer deaths were observed in the "non-oven" by-products workers employed for at least five years. However, in the discussion, the authors raised the issue that racial differences and changes of jobs or work areas in employee histories cast doubt as to occupation as a factor in the etiology of colon cancer (Redmond et al., 1975).

Hammond et al. (1976) examined specific causes of mortality in a group of 5,939 U.S. asphalt workers who were union members between January 1, 1960 and December 31, 1971. The specific interest in asphalt workers was related to the high exposure of these workers to benzpyrene, a known carcinogen. Mortality ratios were based on expected deaths calculated from the U.S. male life tables for the same years. Resulting ratios were not tested for statistical significance. Lung cancer mortality was highest in the workers with 20 or more years employment. Elevated death rates from cancers of other sites were also observed in this group. The SMR for Colon and Rectal cancer was 1.46

for workers with 9-19 years since joining the union and 1.32 for workers with 20+ years. Smoking histories for these workers were not available. Thus, it was not possible to explore the question of a synergistic effect, of smoking and exposure to asphalt fumes, which could be associated in the etiology of lung cancer.

Dr. J. Fowler, Medical Director of Imperial Oil Co. Ltd. of Canada attempted to compare mortality due to intestinal and other digestive system cancers in Ontario refinery workers with that of non-refinery workers, from 1965 to 1969. The refinery and non-refinery groups were each compared with Ontario males of similar age. Table 2 shows that the SMR of 181 for intestinal cancer was high but fell short of statistical significance while that of 216 for other digestive system cancers was significantly elevated. The non-refinery population showed SMRs of less than 100 for both of these causes, indicating no excess mortality due to intestinal or other digestive system cancers in this group.

The most obvious shortcoming of these results is the small numbers of deaths involved. Person years of observation were based on estimates of average annual company populations. The definition and classification of "refinery" workers did not exclude office workers and personnel not directly involved in refining processes, who would tend to have occupations similar to those of the "non-refinery" workers.

A statement made by Hueper in 1942 is appropriate here.

> "These incomplete data may suffice to illustrate the uncertain and contradictory character of the evidence obtained in regard to the occupational incidence of alimentary malignancy. General agreement seems to exist upon one point; namely, an excessive frequency of cancer of the digestive organs is present in individuals exposed for

Table 2

Standard Mortality Ratios for Intestine and Other Digestive Organ[1] Cancers for Ontario Refinery and Non-Refinery Populations of Imperial Oil, Ltd. (1965 - 1969)

Cancer site	Refinery[2] Observed deaths	Refinery[2] Expected[3] deaths	Refinery[2] SMR	Non-Refinery Observed deaths	Non-Refinery Expected deaths	Non-Refinery SMR
Intestine	7	3.87	181	1	3.52	<100
Other Digestive Organs	7	3.24	216[4]	3	3.09	<100

[1] ICDA 8th Revision Codes (1965); 153, 154 (Intestine and Rectum); 155-159 (Other Digestive Organs).

[2] Refinery population 9,111 person years; Non-refinery population 15,038 person years.

[3] Expected deaths were based on age-and cause-specific death rates for Ontario males, 1965-69.

[4] Statistically significant at the 5% level, assuming that the site-specific number of cancer deaths was distributed as a Poisson variable. The probability of the difference between observed and expected deaths being due to chance was calculated from Table 39 of Pearson and Hartley (1966).

occupational reasons to tar or tarry products."[1]

It is 33 years later and the question of intestinal cancer as an occupational risk has still to be resolved. These equivocal results gave rise to the present study.

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1 Hueper, W.C. (1942). Occupational Tumors and Allied Diseases. The Ryerson Press Canada, 314.

MATERIALS AND METHODS

3.1 Source of Data

Imperial Oil Co., Ltd. of Canada supplied the data for this study. The company has refineries, marketing and producing departments and administrative offices throughout most of Canada. It employs 10,000 to 11,000 males per year in its refineries and other operations.

The Personnel Department supplied information on active company employees, as well as information on annuitants (retired employees on pension) and deaths for the 10-year period, 1964-1973. Incomplete information prior to 1964 precluded the extension of the observation period any further.

An annuitant was defined as any employee who retired at the usual age or any employee who left service before retirement age who was involved with the company's vesting scheme. The latter will be referred to in subsequent sections as "deferred annuitants". Until January 1, 1966, all employees with at least 15 years service with the company automatically took part in the vesting scheme which allowed them a claim to a retirement pension upon reaching age 65. In 1966, a change in company policy obliged employees with 10 years of service who left the company prior to retirement to be in the pension plan.

The Medical Department of the Oil company keeps all notifications of deaths on record. In most cases, the Medical Director is informed of cause of death. Thus, the necessary death information was available for subsequent verification.

3.2 Form and Content of Data

Lists of active company employees were provided on computer tapes which covered the time periods 1964 to 1968 and 1969 to 1973. Annuitant information was made available on computer tape. Deferred annuitant information was in list form and death information was provided on punch cards.

The computer tape for 1964-1968 contained the following information for each employee, for each year:

Name (Given, Surname)

Title (Mr., Mrs., Miss)

Employee Number (corresponding to alphabetical listing of surname)

Department Number (indicated the type of department, such as refinery, accounting, etc., as well as the location within the given province, and the job function of the given employee. For example, "770069" meant comptroller's office, Toronto, corporate accounting; "33203Q" meant chemical plant, Sarnia refinery.)

Job Title (Job Description, e.g. chemist, warehouseman, etc.)

Job Category (i.e. occupational scale: professional, administrative, clerical, etc.)

Age and Years Service, as of December 31 of data year

The 1969-1973 information contained the foregoing as well as the following items:

Status (Active, Retired, Terminated)

Retirement date

Death date

The annuitant tape and deferred annuitant listings gave information similar to the above for each former employee.

The death information cards contained identifying information (e.g. name, employee number, new department number at time of last employment) as well as:

Date of birth

Province of death

Date of death

Cause of death (as coded on the death certificate)

Age at death

Verification code (e.g. "v" if death was verified)

This information was sufficient to establish a study population for the 10-year period from the listings of 21,732 male employees. Job histories were complete over this 10-year period for all of the active employees and most of the retired personnel.

4.1 General Methods

Since the population size was so large (21,732) it was more expedient to combine all the data collecting, editing and storage tasks in a computer systems approach than to deal with this information manually. Most of the computer work was done by means of a Control Data Corporation (CDC) Cyber 73/14, a batch processing machine. Programs were either custom designed in FORTRAN or, where possible, packaged programs were used. These were adapted from the Statistical Package for the Social Sciences (SPSS) (Nie et al., 1970). All programming services were available through the Social Sciences Computing Laboratory at the University of Western Ontario.

4.1.1 Cohort Design

Since longitudinal data were available for a period of 10 years a retrospective cohort design was chosen. All the relevant events (i.e. causes and effects) had occurred by the time the study was underway. Specifically, the study population of all male employees and annuitants of the Oil Company from 1964 through 1973 had experienced the exposure under study and the population was, therefore, defined in terms of the characteristic exposure. For the percentage of the population who died, mortality, the study effect, had occurred by the onset of the study. Thus, the issue of awaiting final events, which is a costly disadvantage in some cohort studies, was averted. Since the population at risk can be defined in a cohort study, direct measures of risk may be calculated (MacMahon and Pugh, 1970).

The observation period of this study spanned the 10 years from January, 1964 through December, 1973.

4.1.2 Definition of Exposure

Exposure was defined as daily contact with crude petroleum, gas or breakdown products thereof. The following exposure categories were defined with the help of Mr. John Johnston, Director of Hygiene of Imperial Oil Co., Ltd.:

1 = refinery, exposed

2 = refinery, non-exposed

3 = non-refinery, exposed

4 = non-refinery, non-exposed

5 = mixed history of exposure/non-exposure

6 = moderate exposure group

7 = mixed history refinery, exposed/non-refinery, exposed

8 = mixed history refinery, non-exposed/non-refinery, non-exposed

9 = not enough information for definition

0 = no information available

A worker was classified by the company as a refinery worker on the basis of his department number. Thus, any worker at a refinery site regardless of his job was regarded as a refinery worker.

Each worker was further classified as exposed on a daily basis to crude oil or its breakdown products, on the criteria of location and function numbers. Examples of this group would be those workers involved in "producing", either at a refinery site or at a non-refinery marketing plant.

It soon became apparent that some function codes were non-specific and that one function code could imply many different jobs with varying degrees of exposure to crude oil or its products. An example of this was function number 108. This function number was given when an employee, close to retirement, was placed in a pre-retirement job that was physically less taxing. This number indicated the state but not the job the man had been doing. However, the job description, which indicated the type of work, was also available. Job descriptions were used, in these cases of non-specific function codes, to determine the exposure category. Appendix III shows the job descriptions and the corresponding code numbers which were assigned.

The moderately exposed group, defined on the basis of exposure as much as two weeks of every month, was retained in the non-exposed group because of its size. Persons in this group might be agents, or field auditors, who travelled from site to site checking equipment, or engineers at a refinery site.

A mixed-exposure group was defined as follows: any change in exposure status for at least one year, during the 10 years of observation. Since the group turned out to be small (1.6% of the total population at risk) it was decided that any member should be allocated to the exposed category if at least 50% of his employment years were spent exposed. This group was not included with the moderate exposure group because it was not deemed appropriate to include persons exposed for a solid period of time then removed from exposure with those exposed regularly throughout their careers but not daily. A code has been retained for this group in case extension of the study should require it.

The reasons for retaining a refinery as well as an exposure classification were:

(1) To repeat the initial 5-year study undertaken by Dr. Fowler (Section 2.4).

(2) The definition of exposure could lead to failure to detect any differences due to factors other than exposure to crude oil or its products. It is possible that merely having been at a refinery site on a daily basis exposed workers to some carcinogenic agent, not directly related to exposure to petroleum.

(3) Finer breakdown by refinery and exposure could perhaps identify groups of workers at particularly high risk.

General problems in the definition of exposure may be summarized:

(1) The definition of exposure was subjective. It was based on the opinion of the Director of Hygiene. No quantitative or qualitative environmental measurements were available.

(2) Exposure information was available only between 1964 and

1973. The work history of an employee prior to 1964 was assumed to be similar to that observed during the observation period. The evidence in favour of this assumption was the small percentage of mixed exposures observed (1.6%).

(3) In 1969, a new set of 9-digit department, location, function codes replaced the original 6-digit codes. This presented a problem when assigning exposure since the old codes were not all readily translated into the new codes. Rather than convert the old numbers to the new the following approach was taken. All of the yearly listings up to 1969, in an employee's record, were compared for the 6-digit department, location, function codes. If all were identical, only the 1969 listings were retained. The same was done on the new 9-digit code for the years 1969 through 1973. Again, if these were the same for all years, the last record was kept. If not, all the years' listings with differing information were kept. The next step defined exposure based on the department, location, function numbers for the retained listings in an employee's record. Listings for a given employee were then compared for exposure category. If the exposure code was the same for each listing, only the final listing was kept. If there were exposure code differences, the employee's complete record was printed out and checked manually. Thus, the pre-1969 listings were compared with post-1969 listings for each employee record. In equivocal cases, the Director of Hygiene helped to determine whether the different exposures were indicative of real changes in exposure or

merely problems in coding.

(4) Errors may have occurred in the classification procedure itself. The two most likely types of errors were decisions based on faulty information and random errors such as key-punch mistakes.

The outcome, cause of death, was not known by the investigator at the time of classification assignments. Thus, if inaccuracies did occur, they were not biased by this type of knowledge.

4.1.3 Outcome

Outcome was defined as mortality due to intestinal and rectal cancer. The reasons for including cancers of the rectum with intestinal cancer deaths were (1) the total number of cancer deaths was too small to permit finer breakdown by site; (2) there has been controversy concerning the pathological definition of the rectosigmoid junction and clinical ambiguity in assigning cancers at that site to the large bowel or rectum; and (3) there is no strong evidence to suggest that the etiologies for these two sites would differ (Everson and Cole, 1969). There were no cancers of the small intestine in this group, which was not surprising given the low proportion of cancers at this site compared with other sites in the digestive system (Everson and Cole, 1969). Ascertainment was based on the cause of death from company records which were verified subsequently by searching death certificates. The underlying cause of death, as coded on the registration, was taken as the cause of death.

All provincial registrars, except one, either verified the death information sent to them by the Medical Director of the company or gave me permission to verify the records at the Vital Statistics Section of Statistics Canada. The U.S. Department of Health, Education and Welfare cooperated in the verification procedure of employees who had retired to and subsequently died in the United States.

Special regulations in one Canadian province governing confidentiality of death records prohibited release of cause of death information for specific deaths. However, Statistics Canada was permitted to verify cause of death information and report it in the form of numbers of deaths by cause. The grouped data did not suggest that the changes would make any difference with respect to the final results. Grouped verification added 4 deaths due to malignant neoplasms (of sites other than the intestines) which had been previously ascribed to diseases of the circulatory system.

Two intestinal neoplasm deaths before verification were replaced by two rectal neoplasm deaths after verification. Assuming these changes occurred with respect to the same individuals, this could be expected to have little effect in the final analysis since all intestinal and rectal cancer deaths were summed.

Table 3 shows the results of the verification process by province. The total number of unverified records remains 25, resulting in a percentage of verified deaths of 98.4. No attempt was made to verify deaths in foreign countries other than the U.S. Therefore, in the foreign subclass 18 of 45 deaths (40%) were unverified.

The "cause of death" codes were in two forms. Before 1969, all causes of death were coded by accepted criteria of the ICD, 7th Revision (World Health Organization, 1957), while those deaths from 1969 through 1973 were based on the ICDA, 8th Revision (U.S. Department

Table 3

Verification of Deaths

Imperial Oil Male Employees, All Ages, 1964-1973

Place of Death Province	Total Number of Deaths	Records Which Could Not Be Verified
Newfoundland	16	1
New Brunswick	13	-
Nova Scotia	136	-
P.E.I.	3	-
Quebec	270	1
Ontario	686	2
B.C.	156	2
Saskatchewan	49	-
Manitoba	35	-
Alberta	149	1
N.W. Territories	1	-
Yukon	-	-
Foreign	45	18
Total	1,551	25[1]

[1] Percentage unverified deaths = 25/1,551 x 100 = 1.6%.

of Health, Education and Welfare, 1965). Therefore, it became necessary to check each cause of death by year in order to classify all deaths in a common system. The 8th Revision was chosen, as all future work with this file would undoubtedly have deaths coded in the most recent form.

4.2 Definition of the Population at Risk

The material provided by the company was sufficient for defining a population at risk. An employee was included in the population at risk if he had spent at least one year as an employee with the company and if, when he terminated, he had more than five years service with the company.

4.2.1 Data Collection and Editing

Steps were taken to merge and edit all the data provided. Appendix IV includes the details of these steps at various stages of transition from the original data to the final format used.

4.2.2 Exclusions from the Population at Risk

(1) Females. There were few females employed in positions which might expose them directly to petroleum and derivatives, thus females were excluded from the study.

(2) Summer (or Vacation) Students. Many of the students were employed in positions in which they were not exposed to petroleum and derivatives. Those who were exposed accumulated short total exposure times.

(3) Short-term Employees. All employees terminating during the 10-year observation period with less than 5 years service at

termination were labelled short-term employees. The distribution of terminations by years service (Figure 1) shows that 50% of the terminations occurred in employees with less than or equal to 5 years service. This group was generally young in age and somewhat unstable in that they tended to work for a period, then took leave and returned after a noticeable absence. The decision to exclude them was a practical one, in that tracing them would be almost impossible. However, this was probably a safe decision for the following reasons: (1) this group was particularly young and therefore unlikely to show large numbers of cancer deaths since cancer generally affects older age groups; and (2) long exposure and latent periods are usually necessary before occupational carcinogens show their effect; therefore this group of workers would likely never have been exposed long enough for a carcinogenic effect to occur.

Another group of short-term workers excluded from the study were employees who were active in 1973 but had not yet fulfilled one full year's service with the company. If this study is continued they will of course be returned to the population at risk.

The reason for including workers still active in 1973 even if they had less than 5 years service, was that unlike the terminated short term workers this group remained active through 1973. It was practical to include them, as further follow-up would be easier if the study period should be extended to future years.

(4) Unclassified Annuitants. There were 19 employee records which lacked information for exposure classification. All of these were annuitants who died in 1964 or 1965. An attempt made to locate

Figure 1

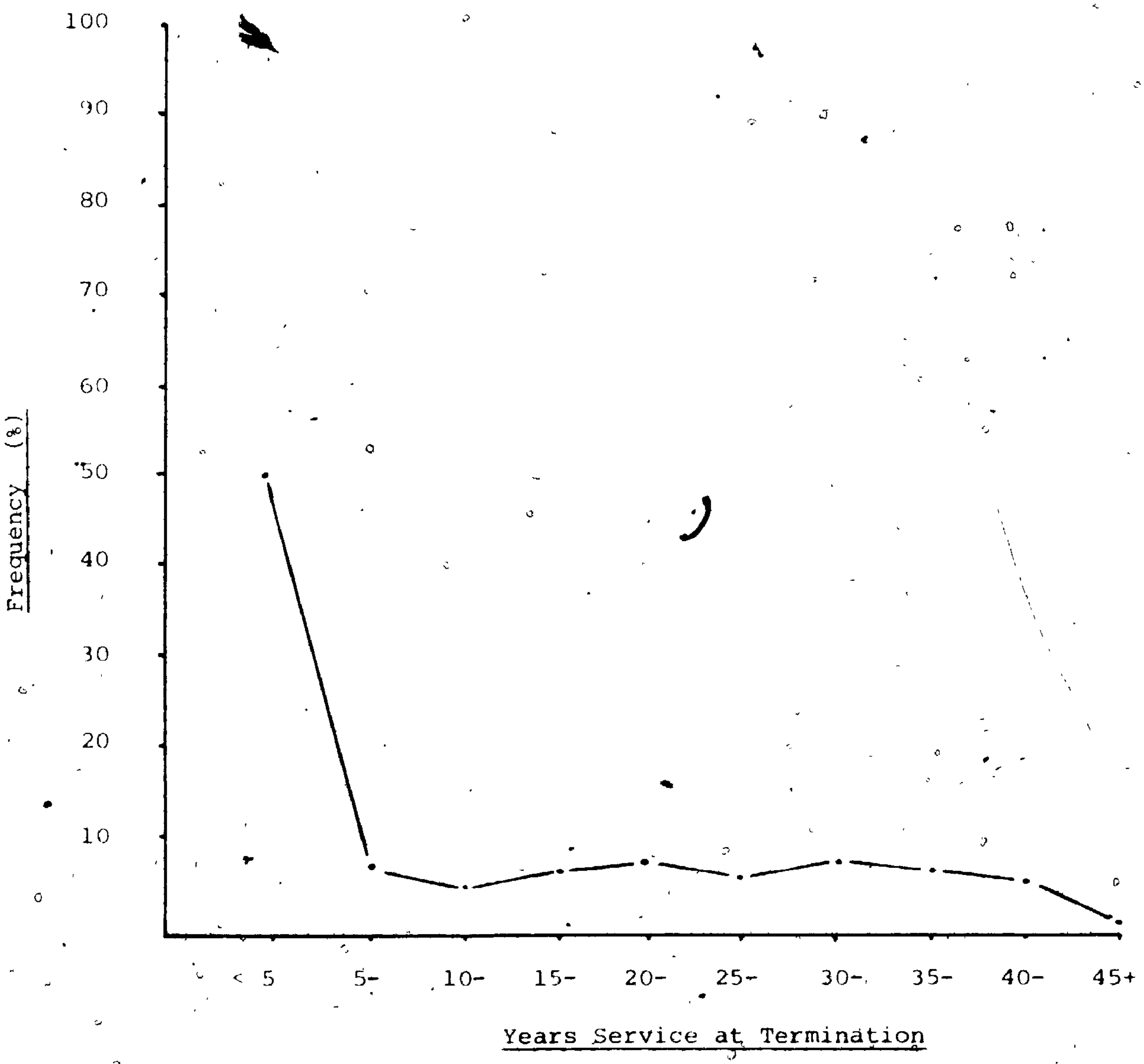


Fig. 1. Terminated employees distributed by years service at termination.

further employment information in the company archives was unsuccessful.

Table 4 shows the distribution of cause of death for all male employees excluded from the Population at Risk.

4.2.3 Final Population at Risk

The population at risk for the purpose of analysis was made up of 15,032 male employees who, if terminated, had spent at least 5 years with the company or who were observed for some or all of the 10-year observation period, 1964 through 1973. Figure 2 shows how active employees and annuitants may have been present during the observation period.

A population hierarchy in Figure 3 shows the distribution of the population at risk by exposure classification and status at the end of the observation period.

Lost-to-Follow-Up

The employees who were "lost-to-follow-up" were those who left the company and, because of insufficient length of employment, did not remain on the deferred annuitant listings. They would have had between 5 and 15 years service. There were 865, or 5.8% of the population at risk who were in this category. Thus the follow-up rate of this study was 94.2%. This may be slightly inflated since being designated a "deferred annuitant" did not necessarily imply follow-up by the company. In fact, no attempt is made to contact these annuitants until they reach pension age. This could result in a time lag between

Table 4

Distribution of Cause of Death Among All Male Employees Excluded From Study

Death Due to[1]	Short-Term Employees (N = 6681)	Unclassified Annuitants (N = 19)
Malignant Neoplasms (140-209)	1 (Genito-Urinary)	1 (Intestinal)
Endocrine, Metabolic Disease (240-279)		1 (Diabetes Mellitus)
Diseases of:		
Circulatory System (390-458)	4	13
Respiratory System (460-519)	1	2
Digestive System (520-577)	1	1
Accidents, Poisonings, Suicides (800-999)	14	1
Total	21	19

[1] ICDA, 8th Revision (1965); codes shown in brackets.

Figure 2

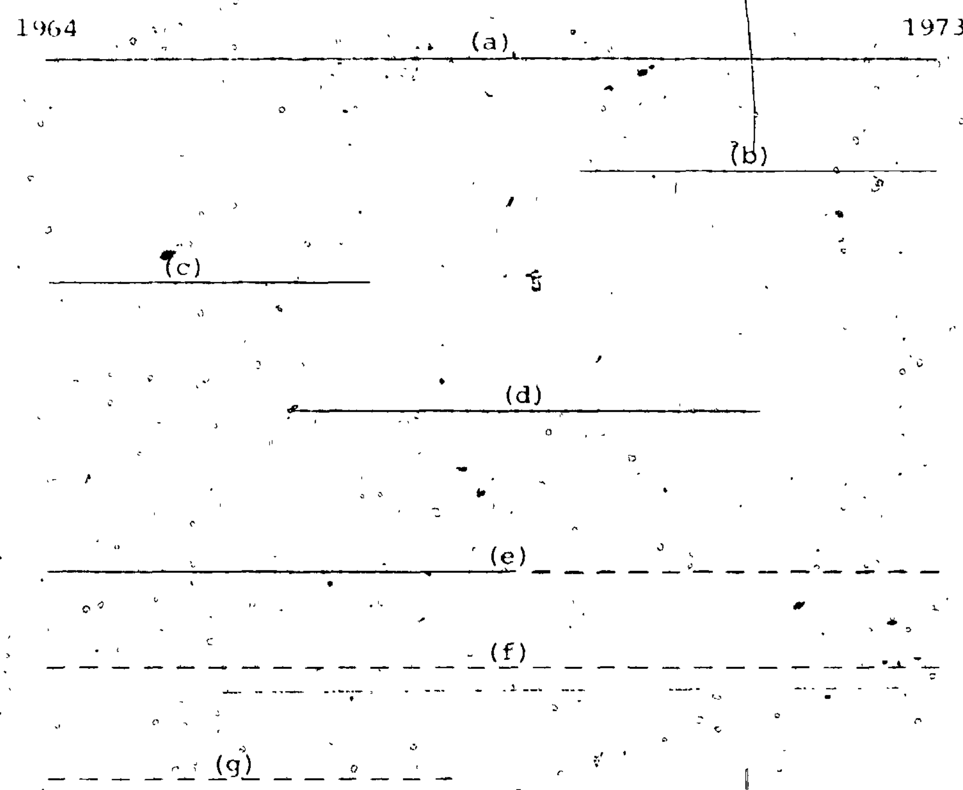


Fig. 2. Ways in which active employees and annuitants may have entered and exited the observation period.

(a), (b) Active for at least one year during the 10-year observation period and still present in 1973, the last year of the study period.

(c), (d) Active employee for at least 5 years during the observation period, but terminating at some time in the 10-year span; termination due to death or resignation.

(e) Active employee during portion of the 10-year period. Termination due to retirement with participation in the company's pension scheme, thus remaining under observation.

(f), (g) Retired employee, receiving pension or on line for deferred pension, under observation. Termination due to death.

Figure 3

Population Hierarchy

Male Oil Company Employees

1964-1973

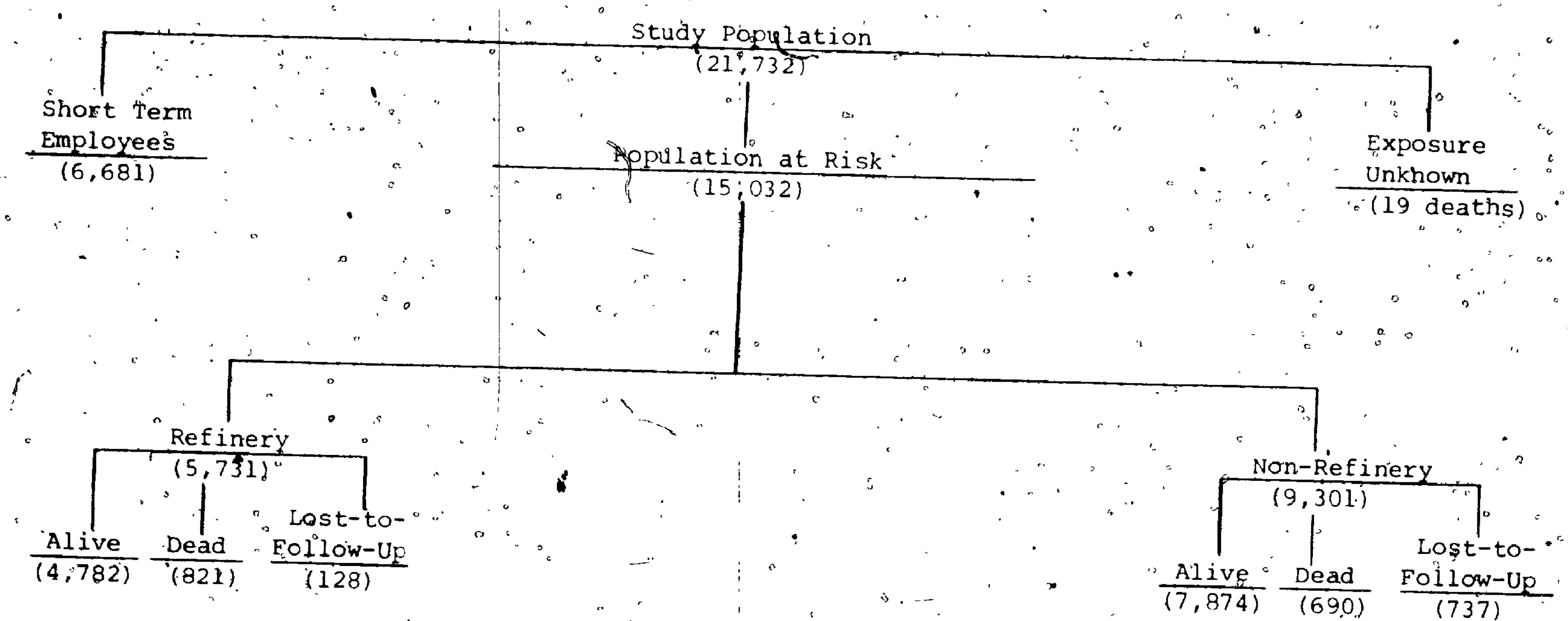
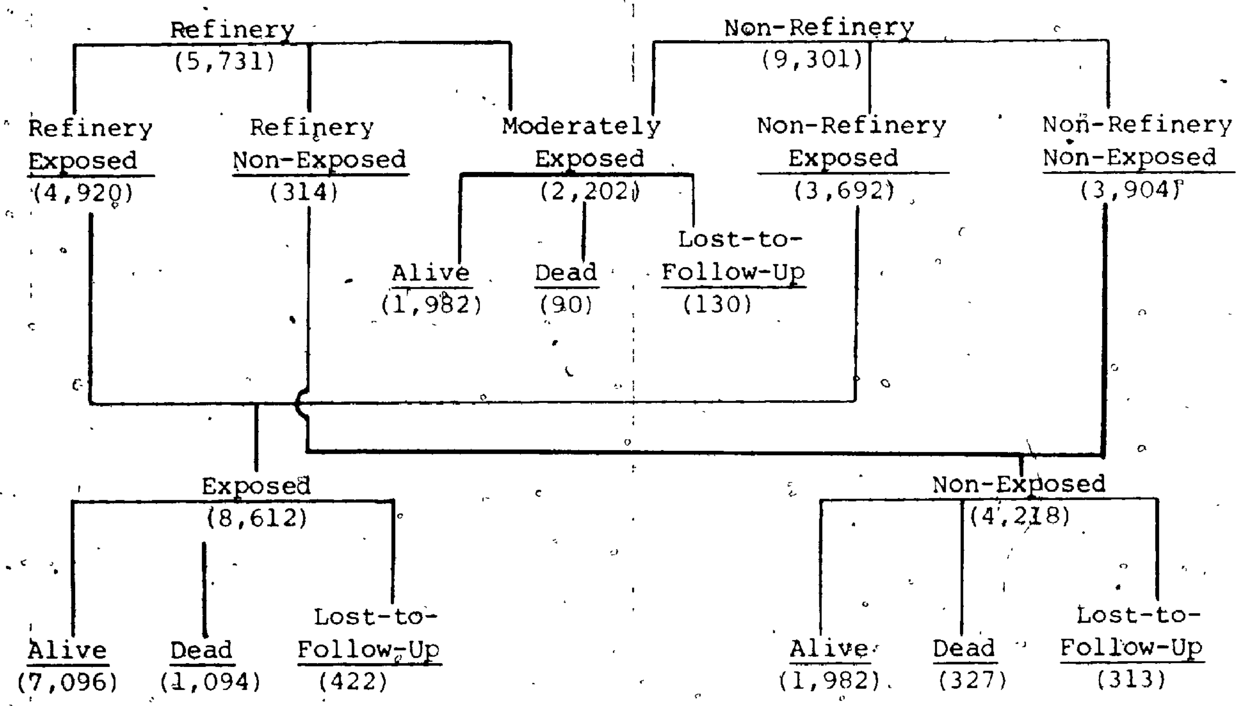


Figure 3
(Cont'd)



the occurrence of a death and the notification of the event to the Medical Department. However, the company's experience has been that beneficiaries would notify the company of deaths when they occurred. Also, there is no reason to expect that notification would differ among workers who had experienced varying degrees of exposure to petroleum.

STATISTICAL METHODS

5.1 Descriptive Methods

Frequency distributions of the study population by certain variables were examined. Product-moment correlations between certain variables, which could be related to mortality, were also performed. Computer programs for these calculations were borrowed from the Statistical Package for the Social Sciences (Nie et al., 1970).

5.2 Measures of Mortality

Various measures of mortality were applied depending upon whether the total population was being compared with the Canadian population or whether internal sub-group population comparisons were being made. These are outlined below.

Since "person years" was the denominator employed in all of the mortality comparisons, a description of the calculation of person years follows. Employees may have entered or exited at any time during the 10-year observation period. Each person was followed over the study period and contributed 1 person year to the appropriate age group for each year that he was observed. The assumptions made were:

(1) If an employee was shown to be present for a given year he was given credit for one full year of observation.

(2) If an employee terminated, without opportunity for further follow-up, or died, he was given credit for ½ year of observation for that year; the assumption being that terminations and deaths were evenly distributed throughout the year. An annuitant would still be observed subsequent to terminating employment. Hence, he would

continue to contribute person years of observation either until death or 1973, the last observation year of the study.

(3) Assuming that birthdays were evenly distributed throughout the year, an employee was moved up one year of age at each mid-year of observation.

5.2.1 Standard Mortality Ratios (SMR)

SMRs were calculated, using the method described by Hill (1971), in order to compare cause-specific mortality of the company population with that of Canadian males of the same age. The 1969 Canadian Population death rates were used to calculate expected deaths (Dominion Bureau of Statistics, 1969). The basic formula for this calculation is:

$$SMR = o/e \times 100$$

where

SMR = Standard Mortality Ratio for specific cause

o = the number of observed deaths in the employee population

e = the number of expected deaths in that population obtained by age-specific calculations

i.e. $e = \Sigma\ (PY \times M)$, where PY = number of person years in the i^{th} age group and M = death rate of the standard population in the i^{th} age group.

This method was also used to compare refinery mortality with that of non-refinery and exposed group mortality with that of the non-exposed group. Since direct comparisons were desired between refinery and non-refinery groups and between exposed and non-exposed groups, non-refinery death rates were used to calculate expected deaths in the refinery population and non-exposed worker mortality rates were used to calculate expected deaths in the exposed population. Raw data necessary for these calculations are included in Appendix VII and Appendix VIII. A computer program was written to perform the person years calculation as well as the calculation of Standard Mortality Ratios. Appendix X contains a copy of this program.

5.2.2. Age-Specific and Age-Adjusted Death Rates

In the detailed analysis of Intestinal and Rectal Cancer mortality and Other Digestive System Cancer mortality, age-specific rates were examined in inter-group comparisons. This was advantageous in the event that a summary figure might mask an effect in one age group. Age-specific death rates (per 10,000) were calculated in the conventional manner (Hill, 1971) but with person years as the denominator.

To examine the effects of certain variables on the cancer mortality of interest, age-adjusted rates were compared. The rates were adjusted by the direct method (Hill, 1971) with the employee population at risk as the standard. As the number of deaths per cell declined with each dichotomization of variable, it was necessary to conflate the population by 5-year age groupings at age 40 to the following 3 groups: 40-64; 65-79; 80+. An example of the calculation of directly adjusted rates, is included in Appendix VI. Data necessary for these calculations are in Appendix VII and Appendix VIII.

5.3 Testing for Statistical Significance

5.3.1 Standard Mortality Ratios

Standard Mortality Ratios were not tested for statistical significance as no method is available for dealing with person years.

5.3.2 Differences between Death Rates

Actual numbers of deaths were compared with the numbers which would have been expected, had the proportion of deaths been equivalent to the proportion of the population in which they had occurred (Doll and Hill, 1956). Inter-group comparisons were based on the Chi^2 test (Yate's correction) with 1 degree of freedom. The advantage of this method is that the person years do not enter into the calculation directly. The person years for given age group i is divided by the total person years. This proportion is then used to calculate the cause-specific deaths expected in this age group. An example of this calculation may be found in Appendix VI.

When sub-group comparisons were desired, age-specific and age-adjusted relative risks were calculated by dividing the rate in one group by the rate in the other.

RESULTS

6.1 Description of the Population at Risk

This section will be devoted to a description of the population at risk and to a comparison of its mortality experience with the mortality of the 1969 Canadian male population of comparable age.

6.1.1 Variables Expected to Affect Mortality

The employee population was geographically distributed throughout all provinces. Age and geographic location are known to have an effect on the probability of death (Table (11), Appendix V). Therefore, these variables were considered in the analysis of the data. Years of service, as a measure of duration of exposure, was also a variable of itnerest in examining effects of exposure.

Other variables which may have been related to mortality differences were year of birth, age and year at beginning employment and age and years of service at the beginning of the observation period. The relationship of these variables to age and years of service at least observation was examined by displaying a correlation matrix (Figure 1, Appendix V). All but one of the variables showed high correlations with age at last observation and/or years of service at last observation. The correlations of age at beginning employment with the other variables were not high. This could suggest a high turnover of workers or perhaps the hiring of transient employees of all ages from other oil companies.

Table 5 shows that a large proportion (78%) of the population at risk was present in 1964 at the beginning of observation and that small proportions were added annually thereafter. The distributions, of the population at risk by age, years in service, status at last

Table 5

Distribution of the Population at Risk by the Beginning Year of Observation in the Study

Year of Beginning Observation	Frequency Number	Frequency Percent
1964	11,725	78.0
1965	219	1.5
1966	324	2.2
1967	394	2.6
1968	374	2.5
1969	388	2.6
1970	503	3.3
1971	279	1.9
1972	236	1.6
1973	590	3.9
Total	15,032	100.0

observation and geographic location were examined (Tables 1-4, Appendix V).

Nearly 30% of the population were under age 40 at last observation; about 80% were under age 65. Over half of the population at risk had more than 20 years of service with the company. The frequency of employees with 5 or less years of service, and still active in 1973, was 14.5%. Nearly 58% of the population at risk were active at last observation. A total of 10% died during the 10-year period. Eighty percent of these deaths occurred in retired personnel.

The population at risk was not evenly distributed geographically. Over 50% of the employees were located in Ontario (40.1%) and Quebec (12.8%) while 35% were in the Western Provinces. The remaining 8% and 3.8% were in the Atlantic Provinces and Other Locations (offshore, foreign subsidiaries, N.W. Territories), respectively.

6.1.2 Mortality of the Population at Risk

The number of deaths in this population was 1,511. Of these, 99.6% occurred in the group of employees already under observation in 1964.

Table 6 shows the distribution of deaths by major cause in the population at risk. About 60% of the deaths were due to diseases of the Circulatory System. The next major cause, accounting for 20% of the deaths, was malignant neoplasms. The distribution of the 301 deaths due to malignant neoplasms, by site, is shown in Table 7. Appendix V shows selected causes of death by age (Table 5) and province (Table 6). Over 50% of the deaths due to malignant neoplasms occurred in workers employed in Ontario and Quebec sites. Eighty

Table 6

Distribution of Deaths by Major Cause in the Population at Risk, 1964-1973

Major Cause of Death[1]	Number	Percent
Infectious and Parasitic Diseases (001-136)	9	0.6
Malignant Neoplasms (140-209)	301	19.9
Other Neoplasms (210-239)	4	0.3
Endocrine, Nutritional and Metabolic Diseases (240-279)	29	1.9
Mental Disorders (290-315)	2	0.1
Diseases of:		
Blood and Blood Forming Organs (280-289)	5	0.3
Nervous System and Sense Organs (320-389)	16	1.1
Circulatory System (390-458)	905	59.9
Respiratory System (460-519)	90	6.0
Digestive System (520-577)	51	3.4
Genito-urinary System (580-607)	19	1.3
Skin and Subcutaneous Tissue (680-709)	1	0.1
Musculoskeletal and Connective Tissue (710-738)	2	0.1
Congenital Anomalies (740-759)	1	0.1
Symptoms and Ill-Defined Conditions (780-796)	17	1.1
Accidents, Poisonings and Violence (800-999)	59	3.9
Total	1,511	100.1

[1] See footnote 1, Table 4.

Table 7

Distribution of Deaths Due to Malignant Neoplasms in the Population at Risk, 1964-1973

Specific Cause of Death due to Malignant Neoplasms[1]	Number	Percent
Buccal Cavity and Pharynx (140-149)	7	2.3
Esophagus and Stomach (150, 151)	33	11.0
Large Intestine and Rectum (153, 154)	42	14.0
Other Digestive Organs (155-159)	33	10.9
Trachea, Bronchus, Lung (162)	82	27.2
Other Respiratory Organs (160, 161, 163)	4	1.3
Bone, Connective Tissue, Skin (170-174)	12	4.0
Prostate (185)	25	8.3
Urinary Organs (188, 189)	19	6.3
Other and Unspecified Sites (190-199)	19	6.3
Lymphatic and Hematopoietic System (200-209)	25	8.3
Total	301	99.9

[1] See footnote 1, Table 4.

Table 12

Distribution of Exposed and Non-Exposed Groups

by Duration of Employment, All Ages, 1964-1973

Duration of Employment (years)	Exposed		Non-Exposed	
	Number	Percent	Number	Percent
0-5	1170	13.6	1012	15.8
6-10	887	10.3	906	14.1
11-15	530	6.2	527	8.2
16-20	1203	14.0	955	14.9
21+	4822	56.0	3020	47.0
Total	8612	100.1	6420	100.0

Table 8

Standard Mortality Ratios (SMR) for Selected Causes of Death for the Population at Risk, All Ages, 1964-1973

Death Due to[1]	Number of Deaths Obs./Exp.[2]	SMR[3]
All Causes (001-999)	1,511/1,801.0	83.9
Malignant Neoplasms (140-209)	301/366.0	82.2
Diseases of:		
Circulatory System (390-458)	905/960.6	94.2
Respiratory System (460-519)	90/129.7	69.4
Malignant Neoplasms of:		
Intestines, Rectum (152, 153, 154)	42/51.6	81.4
Other Digestive Organs (155-159)	33/31.0	106.3
Trachea, Bronchus, Lung (162)	82/94.0	87.0
Prostate (185)	25/33.6	74.4
Urinary Bladder, Kidney (188, 189)	19/22.9	83.1
Lymphatic and Hematop. System (200-209)	25/35.9	69.7
Accidents, Poisonings, Violence (800-999)	59/152.6	38.6
Number of Employees	15,032	
Number of person years	120,636	

1 See footnote 1, Table 4.

2 Expected deaths were based on 1969 age and cause-specific death rates for Canadian males.

3 Data for calculating SMRs are in Table (5), Appendix V; Table (1), Appendix VII; and Table (1), Appendix VIII.

All geographic comparisons were made using these groupings.

Table 9 shows the SMRs for selected causes of death by geographic group. For a number of causes of death, in the Western Provinces and in Ontario/Quebec, employee mortality was significantly lower than mortality among Canadian males in general. Nowhere was employee mortality significantly above national mortality for any cause of death. For some causes there was variation from region to region in the employee/national comparisons. In the Ontario/Quebec employees, the SMR for intestinal and rectal cancer was 112 while both the Atlantic and Western Provinces had SMRs below 100. The SMRs for Malignant Neoplasms of Other Digestive Organs (ICDA 155-159) were above 100 in employee groups in the Atlantic Provices and in Ontario/Quebec but the SMR for this cause of death was below 100 in the Western Provinces.

6.2 Comparing Exposed and Non-Exposed Populations

The exposed population consisted of 8,612 employees, 79.9% of whom were under observation at the beginning year of observation (1964). Seventy-five percent of the 6,420 non-exposed employees were under observation in 1964. Table 10 shows the distributions of these groups by year of beginning observation in the study.

6.2.1 Variables Expected to Affect Mortality

The distributions by age at end of observation, duration of employment and geographic location were examined for exposed and non-exposed populations. Tables 11, 12 and 13 show these distributions. The exposed group had a larger proportion of workers older than 65 than did the non-exposed. Seventy-six percent of the exposed population had

Table 9

Standard Mortality Ratios (SMR) for Selected Causes of Death for the Population at Risk by Geographic Location, Age ≥ 40, 1964-1973

	Geographic Location							
	Atlantic Provinces		Ontario Quebec		Western Provinces		Other	
Death Due To[1]	Obs/Exp[2]	SMR[3]	Obs/Exp	SMR	Obs/Exp	SMR	Obs/Exp	SMR
All Causes (001-999)	153/176.6	86.6	920/1006.9	91.4	367/480.8	76.3	43/63.5	67.7
Malignant Neoplasms (140-209)	34/36.1	94.1	175/209.1	83.7	79/105.4	75.0	7/13	53.6
Diseases of Circulatory System (390-458)	85/98.2	86.5	572/558.1	102.5	213/271.1	78.6	30/[illegible]	86.4
Diseases of Respiratory System (460-519)	11/13.5	81.2	56/71	78.8	20/34.9	57.3	21/47.5	44.5
Malignant Neoplasms of Intestines, Rectum (152-154)	2/5.3	37.9	34/30.2	112.2	6/14.0	42.5	-	-
Malignant Neoplasms of Other Digestive Organs (155-159)	4/3.1	128.5	23/17.9	128.5	6/8.6	69.3	-	-
Malignant Neoplasms of Trachea, Bronchus, Lung (162)	10/9.2	108.8	44/70.2	62.6	24/28.3	64.8	4/3.6	111.4
Malignant Neoplasms of Prostate (185)	4/3.6	110.2	15/19.7	76.0	6/8.6	69.8	-	-
Malignant Neoplasms of Urinary Bladder, Kidney (188, 189)	1/2.5	42.5	11/8.2	134.0	7/6.2	112.2	-	-
Malignant Neoplasms of Lymphatic and Hematopoietic System (200-209)	3/3.2	93.4	9/18.2	49.5	10/9.3	107.2	-	-
Accidents, Poisonings, Violence (800-999)	7/10.7	65.6	24/59.7	40.2	15/35.6	42.1	[illegible]/3.8	26.4
Total Person Years	7,640.5		43,618.5		27,698.0		2,[illegible]	

1. See footnote 1, Table 4.

2. See footnote 2, Table 8.

3. Data for SMR calculations are in Table (3-6), Appendix VII and Table (2), Appendix VIII

Table 10

Distribution of Exposed and Non-Exposed Groups
by Year of Beginning Observation in the Study, All Ages,
1964-1973

Year	Exposed Number	Exposed Percent	Non-Exposed Number	Non-Exposed Percent
1964	6885	79.9	4840	75.4
1965	113	1.3	106	1.7
1966	158	1.8	166	2.6
1967	201	2.3	193	3.0
1968	171	2.0	203	3.2
1969	220	2.6	168	2.6
1970	296	3.4	207	3.2
1971	135	1.6	144	2.2
1972	141	1.6	95	1.5
1973	292	3.4	298	4.6
Total	8612	99.9	6420	100.0

(Frequency)

Table 11

Distribution of Exposed and Non-Exposed Groups by Age at Last Observation, Full Age Range, 1964-1973

	Frequency			
	Exposed		Non-Exposed	
Age Group	Number	Percent	Number	Percent
15-39	2083	24.2	2543	39.6
40-44	887	10.3	510	7.9
45-49	970	11.3	807	12.6
50-54	936	10.9	674	10.5
55-59	857	10.0	482	7.5
60-64	676	7.8	474	7.4
65-69	702	8.2	317	4.9
70-74	611	7.1	236	3.7
75-79	424	4.9	190	3.0
80-84	285	3.3	119	1.9
85+	181	2.1	68	1.1
Total	8612	100.1	6420	100.1

Table 12

Distribution of Exposed and Non-Exposed Groups

by Duration of Employment, All Ages, 1964-1973

Duration of Employment (years)	Exposed Number	Exposed Percent	Non-Exposed Number	Non-Exposed Percent
0-5	1170	13.6	1012	15.8
6-10	887	10.3	906	14.1
11-15	530	6.2	527	8.2
16-20	1203	14.0	955	14.9
21+	4822	56.0	3020	47.0
Total	8612	100.1	6420	100.0

Table 13

Distribution of Exposed and Non-Exposed Groups

by Geographic Location, All Ages, 1964-1973

Geographic Location (Province)	Exposed		Non-Exposed	
	Number	Percent	Number	Percent
Ontario	3186	37.0	2838	44.2
Alberta	1694	19.7	1877	29.2
Quebec	1220	14.2	707	11.0
Nova Scotia	631	7.3	241	3.8
British Columbia	511	5.9	336	5.2
Saskatchewan	360	4.2	152	2.4
Offshore	484	5.6	1	.0
Manitoba	254	2.9	103	1.6
Newfoundland	126	1.5	50	.8
New Brunswick	69	.8	56	.9
Northwest Territories	45	.5	13	.2
Foreign/Subsid.	17	.2	34	.5
P.E.I.	15	.2	12	.2
Total	8612	100.0	6420	100.0

more than 11 years service with the company while 70% of the non-exposed workers were in this category. A slightly larger percentage of exposed workers had more than 21 years of employment, 56% compared with 47% in the non-exposed group. Geographic distributions varied, with larger proportions of non-exposed workers in Ontario and Alberta and more exposed workers in Quebec and Nova Scotia. Since the exposure groups were not entirely comparable for age and geographic distribution, adjustments were made in analysis. Years in service, as a measure of duration of exposure, was also examined in detail.

6.2.2 Mortality Comparisons of Exposure Groups

Tables (7) and (8), Appendix V, show the distributions of deaths by major cause and of cancer deaths by site in the exposed and non-exposed workers. There were 1,094 deaths in the exposed group and 417 in the non-exposed group. Diseases of the Circulatory System were responsible for about 60% of deaths in both groups. Mortality due to Malignant Neoplasms accounted for about 20%. The non-exposed workers had 84 cancer deaths and the exposed 217. Deaths from cancer of the Trachea, Bronchus and Lung (ICDA 162) accounted for the largest proportion of cancer deaths in both groups while deaths from Intestinal Cancer (ICDA 153, 154) accounted for close to 15% of cancer deaths in both groups.

Table 14 shows the SMRs for selected causes of death for the exposed workers. The expected deaths were based on non-exposed rates. The exposed group showed generally higher mortality than the non-exposed group. The two exceptions were deaths due to Other Digestive Organ Cancers (ICDA 155-159) and malignant neoplasms of the Lymphatic and

Table 14

Standard Mortality Ratios (SMR) for Selected Causes of Death for Exposed Workers, Age ≥ 40, 1964-1973

Death Due To[1]	Number of Deaths Obs/Exp[2]	SMR
ALL CAUSES (001-999)	1085/853.4	127
Malignant Neoplasms (140-209)	215/160.8	134
Diseases of Circulatory System (390-458)	644/561.0	115
Diseases of Respiratory System (460-519)	71/42.2	168
Malignant Neoplasms of Intestines, Rectum (152, 153, 154)	29/26.2	111
Malignant Neoplasms of Other Digestive Organs (155-159)	20/23.9	84
Malignant Neoplasms of Trachea, Bronchus, Lung (162)	67/31.7	211
Malignant Neoplasms of Prostate (185)	18/16.4	110
Malignant Neoplasms of Urinary Bladder, Kidney (188, 189)	14/9.5	147
Malignant Neoplasms of Lymphatic and Hematopoietic System (200-209)	13/18.3	71
Accidents, Poisonings, Violence (800-999)	42/5.5	764
Number of Employees	6,523	
Number of Person Years	50,534	

[1] See footnote 1, Table 4.

[2] Expected deaths were based on the non-exposed group (age ≥ 40) rates. Data for these calculations are in Tables (7-9), Appendix VII and Table (1), Appendix VIII.

and Hematopoietic System (200-209) which had SMRs less than 100. Mortality from Diseases of the Circulatory System (390-458), Diseases of the Respiratory System (460-519) and Cancer of the Trachea, Bronchus and Lung (162) was significantly higher in the exposed workers. Accidents, Poisonings and Violence (800-999) were much higher in the exposed group, indicating hazards which should be studied further. Deaths due to Malignant Neoplasms of the Intestine and Rectum (153, 154), Prostate (185) and Urinary Bladder and Kidney (188, 189) were slightly higher for the exposed workers.

6.2.3 Intestinal Cancer Mortality in Exposed and Non-Exposed Workers

Table 15 shows age-specific and age-adjusted Intestinal and Rectal Cancer (ICDA 153, 154) mortality rates per 10,000 person years by exposure group. No consistent excess of intestinal cancer mortality among the exposed workers was evident.

Intestinal Cancer Mortality by Geographic Location for Exposed and Non-Exposed Groups

Table 16 shows the age-adjusted rates per 10,000 person years by geographic location for the exposure groups. The low relative risks do not support the conclusion that the exposed workers in these locations ran a greater risk of intestinal cancer mortality than the non-exposed workers.

Intestinal Cancer Mortality and Duration of Exposure by Exposure Group

Age-adjusted rates for intestinal cancer by duration of exposure for exposed and non-exposed workers are shown in Table 17. There were

Table 15

Age-Specific and Age-Adjusted Intestinal Cancer[1] Mortality Rates per 10,000 Person Years in Exposed and Non-Exposed Groups, Age ≥ 40, 1964-1973

Age	Rates/10,000 Person Years Exposed	Non-Exposed	Relative Risk[2]
40-64	2.6 (10)[3]	2.3 (6)	1.1
65-79	10.2 (11)	6.5 (3)	1.6
80+	48.6 (8)	60.3 (4)	0.8
Age-adjusted Rates[4]	5.3	4.7	1.13

[1] ICDA Codes 153 and 154.

[2] Risk in exposed relative to non-exposed. None of these risks was significantly different from 1, $P < 0.05$. Tests of significance were based on Chi^2 with Yates correction, 1 degree of freedom (Doll and Hill, 1956).

[3] Numbers of deaths shown in parentheses.

[4] Direct adjustment with the employee population at risk (age ≥ 40) as the standard.

[5] Data for these calculations are in Table (10), Appendix VII. Appendix VI has an example of the calculation of the direct method of age-adjustment.

Table 16

Age-Adjusted Intestinal Cancer[1] Mortality Rates per 10,000 Person Years by Geographic Location in Exposed and Non-Exposed Groups, Age ≥ 40, 1964-1973

Geographic Location	Age-Adjusted[2] Rates per 10,000 Person Years Exposed	Non-Exposed	Relative Risk[3]
Atlantic Provinces	3.4 (2)[4]	-	-
Ontario/Quebec	7.6 (23)	7.1 (11)	1.1
Western Provinces	2.7 (4)	2.2 (2)	1.2

[1] See footnote 1, Table 15.

[2] Direct adjustment with the employee population at risk (age ≥ 40) in these provinces as the standard.

[3] See footnote 2, Table 15.

[4] See footnote 3, Table 15.

[5] Data for these calculations are in Table (11), Appendix VII.

Table 17

Age-Adjusted Intestinal Cancer[1] Mortality Rates per 10,000 Person Years by Duration of Employment in Exposed and Non-Exposed Groups, Age ≥ 40, 1964-1973

Duration of Employment (years)	Age-Adjusted[2] Rates per 10,000 Person Years Exposed	Non-Exposed	Relative Risk[3]
11-20	6.7 (6)[4]	-	-
21-30	3.5 (8)	3.7 (5)	0.9
31+	6.6 (15)	5.8 (8)	1.1

1 See footnote 1, Table 15.

2 Direct adjustment with the employee population at risk (age ≥ 40; duration of service > 10 years) as the standard.

3 See footnote 2, Table 15.

4 See footnote 3, Table 15.

5 Data for these calculations are in Table (12), Appendix VII.

no intestinal cancer deaths in workers with less than eleven years of employment with the company. In both exposed and non-exposed groups, the rate of intestinal cancer deaths increased between the 21-30 year employment group and the 31 year and over employment group. In neither group did the rate in the exposed workers exceed that in the non-exposed. The exposed workers in the 11-20 years service group showed a higher rate than the workers exposed for more than 20 years. This analysis fails to offer convincing evidence that either the fact or duration of exposure is related to the level of intestinal cancer.

6.2.4 Comparisons of Exposed and Non-Exposed Workers for Cancers of Other Sites

Exposed workers experienced a significantly higher mortality (SMR = 211) due to lung cancer than non-exposed workers (Table 14). Table 18 shows the age-specific and age-adjusted death rates for cancer of the lung and cancer of the lymphatic and hematopoietic system among exposed and non-exposed workers. It is evident that the significant increase in lung cancer deaths among exposed workers occurred in those who were younger than 80 years old.

The lower risk of lymphatic cancer death in the exposed group was not statistically significant.

The lung cancer mortality difference between exposed and non-exposed workers specific for geographic area is shown in Table 19. The relative risks of the age-adjusted rates for the exposed group varied by location. Although there was no increased risk of lung cancer mortality in exposed workers over non-exposed in the Atlantic Provinces, the exposed in Ontario/Quebec had a slightly greater risk (RR = 1.7)

Table 18

Age-Specific and Age-Adjusted Lung and Lymphatic[1] Cancer Mortality Rates per 10,000 Person Years in Exposed and Non-Exposed Groups, Age ≥40, 1964-1973

Rates per 10,000 Person Years

Age	Lung Cancer			Lymphatic and Hematopoietic System Cancer		
	Exposed	Non-Exposed	Relative Risk[2]	Exposed	Non-Exposed	Relative Risk[2]
40-64	7.3 (28)[3]	2.3 (6)	3.2**	1.0 (4)	1.5 (4)	0.67
65-79	33.5 (36)	17.3 (8)	1.9**	4.6 (5)	6.5 (3)	0.71
80+	18.2 (3)	15.1 (1)	1.2	24.2 (4)	30.2 (2)	0.80
Age-Adjusted Rates[4]	12.5	5.5	2.3**	2.3	3.4	0.68

1 ICDA codes 162 (Lung Cancer); 200-209 (Lymphatic and Hematopoietic System Cancer).

2 Risk in exposed relative to non-exposed; risks significantly different from 1 have been starred (*), $P < 0.05$; (**) $P < 0.01$. Based on Chi^2 with 1 degree of freedom (Doll and Hill, 1956).

3 See footnote 3, Table 15.

4 See footnote 4, Table 15.

5 Data for these calculations are in Tables (7) and (8), Appendix VII and Table (1), Appendix VIII.

Table 19

Age Specific and Age Adjusted Lung[1] Cancer Mortality Rates per 10,000 Person Years by Geographic Location in Exposed and Non-Exposed Groups, Age ≥ 40, 1964-1973

Geographic Location	Age	Rates per 10,000 Person Years: Exposed	Rates per 10,000 Person Years: Non-Exposed	Relative Risk[2]
Atlantic Provinces	40-64	11.8 (5)[3]	6.1 (1)	1.9
	65-79	24.3 (3)	42.6 (1)	.57
	80+	-	-	-
	Age-Adjusted Rate[4]	13.8	12.7	1.1
Ontario/Quebec	40-64	6.3 (12)	2.8 (4)	2.2
	65-79	28.6 (18)	13.4 (4)	2.1
	80+	20.0 (2)	53.0 (2)	0.38
	Age-Adjusted Rate	10.8	6.2	1.7
Western Provinces	40-64	-	1.3 (1)	-
	65-79	22.2 (6)	7.7 (1)	2.9
	80+	364.1 (14)	52.1 (1)	7.0
	Age-Adjusted Rate	14.4	3.7	3.9

1 ICDA Code 162.

2 See footnote 2, Table 15.

3 See footnote 3, Table 15.

4 See footnote 2, Table 16.

5 Data for these calculations are summarized in Table I(1), Appendix VII.

and those in the Western Provinces had a 4-fold increase in risk. However, these increases were not statistically significant at $P < 0.05$.

Table 20 shows the lung cancer mortality in exposed and non-exposed workers by duration of employment. There were no lung cancer deaths in those with 10 or less years in service. The exposed workers, employed for 11-20 years, when compared with non-exposed workers had a relative risk of 9.4. Since there was only one lung cancer death in the non-exposed group, this result is not very reliable. There was no discernible gradient in risk with increasing duration of employment in the exposed population.

Since there were only 22 cancer deaths from the Hematopoietic and Lymphatic sites, no attempt was made to analyse these results by geographic location and duration of employment.

6.3 Comparing Refinery and Non-Refinery Populations

The reasons for comparing refinery and non-refinery workers have been outlined in Section 4.1.2. There were 5,731 refinery workers (38.1%) and 9,301 non-refinery workers (61.9%) in the population at risk. Of the refinery group, 81.4% were under observation at the beginning of the observation period compared with 75.9% of the non-refinery group. Table 21 shows the distributions of these two groups by year of beginning observation in the study.

6.3.1 Variables Expected to Affect Mortality

The following three variables were retained in subsequent comparisons of refinery and non-refinery populations: age, geographic

Table 20

Age-Specific and Age-Adjusted Lung[1] Cancer Mortality Rates per 10,000 Person Years by Duration of Employment in Exposed and Non-Exposed Groups, Age ≥ 40, 1964-1973

Duration of Employment (years)	Age	Rates/10,000 Person Years— Exposed	Non-Exposed	Relative Risk[2]
11-20	40-64	7.5 (6)[3]	2.0 (1)	3.75
	65-79	48.6 (5)	–	–
	80+	–	–	–
	Age adjusted rate[4]	15.0	1.6	9.4
21-30	40-64	6.6 (13)	–	–
	65-79	39.6 (12)	44.7 (4)	0.89
	80+	25.2 (2)	–	–
	Age adjusted rate	13.4	8.5	1.6
31+	40-64	9.6 (9)	6.6 (5)	1.45
	65-79	28.5 (19)	12.0 (4)	2.38
	80+	15.7 (1)	24.0 (1)	0.65
	Age adjusted rate	13.4	8.1	1.7

[1] See footnote 1, Table 19.

[2] See footnote 2, Table 15.

[3] See footnote 3, Table 15.

[4] See footnote 2, Table 17.

[5] Data for these calculations are summarized in Table (12), Appendix VII.

Table 21

Distribution of Refinery and Non-Refinery Groups by Year of Beginning Observation in the Study, All Ages, 1964-1973

	Frequency			
	Refinery		Non-Refinery	
Year	Number	Percent	Number	Percent
1964	4664	81.4	7061	75.9
1965	50	.9	169	1.8
1966	91	1.6	233	2.5
1967	138	2.4	256	2.8
1968	115	2.0	259	2.8
1969	119	2.1	269	2.9
1970	198	3.5	305	3.3
1971	100	1.7	179	1.9
1972	83	1.4	153	1.6
1973	173	3.0	417	4.5
Total	5731	100.0	9301	100.0

location, and duration of employment in years.

The distributions of these variables in refinery and non-refinery groups are shown in Tables 22-24. Analyses were made specific for age to rule out the possibility that any age-specific effect could be masked by standardization. Years in service was retained as a measure of duration of exposure; geographic location was examined to detect specific geographic differences.

Larger proportions of the refinery population were in the older age groups (more than 55 years old) compared with the non-refinery population. Thirty percent of the refinery workers were younger than age 44 while 46% of the non-refinery workers were in this age group. These differences, although not extreme, were allowed for as they were likely to affect mortality patterns.

The distribution by duration of employment (Table 23) showed 65% of the refinery group in the longest exposure category (more than 20 years) compared with 45% of the non-refinery group.

There was a disproportionate number of non-refinery workers in Alberta and a corresponding excess of refinery workers in Ontario and Quebec. It was shown in Section 6.1.3 that mortality varied in the population at risk by geographic location. Therefore some analyses were performed to control for this variable.

6.3.2 Comparison of Mortality in Refinery Workers with that in Non-Refinery Workers

Among refinery workers there were 821 deaths and among non-refinery workers, 690 deaths. Diseases of the Circulatory System accounted for 60% of the deaths in both groups. About 20% of the

Table 22

Distribution of Refinery and Non-Refinery Groups by Age at Last Observation, Full Age Range, 1964-1973

	Frequency			
	Refinery		Non-Refinery	
Age	Number	Percent	Number	Percent
15-39	1228	21.4	3109	33.4
40-44	489	8.5	1197	12.9
45-49	624	10.9	1153	12.4
50-54	629	11.0	981	10.5
55-59	574	10.0	765	8.2
60-64	504	8.8	646	6.9
65-69	512	8.9	507	5.5
70-74	469	8.2	378	4.1
75-79	315	5.5	299	3.2
80-84	242	4.2	162	1.7
85+	145	2.5	104	1.1
Total	5731	99.9	9301	99.9

Table 23

Distribution of Refinery and Non-Refinery Groups by Duration of Employment, All Ages, 1964-1973

Duration of Employment (years)	Frequency			
	Refinery		Non-Refinery	
	Number	Percent	Number	Percent
0-5	700	12.2	1482	15.9
6-10	459	8.0	1334	14.3
11-15	199	3.5	858	9.2
16-20	671	11.7	1487	16.0
21+	3702	64.6	4140	44.5
Total	5731	100.0	9301	99.9

Table 24

Distribution of Refinery and Non-Refinery Groups

by Geographic Location, All Ages, 1964-1973

Geographic Location (Province)	Frequency			
	Refinery		Non-Refinery	
	Number	Percent	Number	Percent
Ontario	2,695	47.0	3,3[illegible]	35.8
Alberta	784	13.7	2,787	30.0
Quebec	857	15.0	1,070	11.5
Nova Scotia	565	9.9	307	3.3
British Columbia	359	6.3	488	5.2
Saskatchewan	258	4.5	254	2.7
Offshore	-	-	485	5.2
Manitoba	157	2.7	200	2.2
Newfoundland	1	-	175	1.9
New Brunswick	2	-	123	1.3
Northwest Territories	48	0.8	10	.1
Foreign/subsidiary	5	0.1	46	.5
Prince Edward Island	-	-	27	.3
Total	5,731	100.0	9,301	100.0

deaths in both groups were due to malignant neoplasms. The refinery group had 28 deaths from cancer of the large intestine and rectum while the non-refinery group had 14 such deaths. Table (9), Appendix V, shows the distribution of deaths by major cause and Table (10), Appendix V, shows the distribution of cancer deaths by site for refinery and non-refinery populations.

Table 25 shows SMRs for some major causes and for specific neoplasms among refinery workers who were 40 or more years old at last observation. Expected deaths were based on age-specific mortality rates of the non-refinery population. All, except one, of the SMRs were greater than the standard of 100. Deaths from All Causes; Malignant Neoplasms; Malignant Neoplasms of the Intestines and Rectum, Other Digestive Organs; and Accidents, Poisonings and Violence, were higher for the refinery workers. The exception, Malignant Neoplasms of the Lymphatic and Hematopoietic System showed a significantly lower SMR for the refinery group.

6.3.3 Intestinal and Other Digestive System Cancer Mortality in Refinery and Non-Refinery Workers

Refinery and non-refinery groups were analysed for differences in intestinal and other digestive system cancer mortality. Age differences, variation in geographic distribution and duration of exposure were also examined for these groups.

Mortality Differences by Age

Table 26 shows the age-specific death rates per 10,000 person years and summary age-adjusted rates per 10,000 person years for the

Table 25

Standard Mortality Ratios (SMR)

for Selected Causes of Death

for Refinery Workers, Age ≥ 40, 1964-1973

Death Due to[1]	Number of Deaths Obs/Exp[2]	SMR
All Causes (001-999)	816/718.5	114
Malignant Neoplasms (140-209)	164/132.4	124
Diseases of Circulatory System (390-458)	487/455.3	107
Diseases of Respiratory System (460-519)	54/41.0	132
Accidents, Poisonings, Violence (800-999)	27/16.9	160
Malignant Neoplasms of Intestines, Rectum (152, 153, 154)	28/15.1	185
Malignant Neoplasms of Other Digestive Organs (155-159)	21/11.6	181
Malignant Neoplasms of Trachea, Bronchus, Lung (162)	43/39.1	110
Malignant Neoplasms of Prostate (185)	15/10.9	138
Malignant Neoplasms of Urinary Bladder, Kidney (188,189)	10/8.3	120
Malignant Neoplasms of Lymphatic and Hematopoietic Systems (200-209)	7/15.0	47
Number of Employees	4,515	
Number of Person Years	35,604.5	

1. See footnote 1, Table 6.

2. Expected deaths were based on the Non-refinery group (age ≥ 40) rates. Data for these calculations are in Tables (13) - (15), Appendix VII and Table (1), Appendix VIII.

Table 26

Age-Specific and Age-Adjusted Intestinal and Other Digestive Organ[1] Cancer Mortality Rates per 10,000 Person Years in Refinery and Non-Refinery Groups, Age ≥ 40, 1964-1973

Rates/10,000 Person Years

Age	Intestinal Cancer			Other Digestive Organ Cancer			Total		
	Refinery	Non-Refinery	Relative Risk[2]	Refinery	Non-Refinery	Relative Risk	Refinery	Non-Refinery	Relative Risk
40-64	3.8 (10)[3]	1.6 (6)	2.4	2.3 (6)	2.1 (8)	1.1	6.1 (16)	3.6 (14)	1.7
65-79	12.0 (10)	5.6 (4)	2.0	13.4 (11)	1.3 (1)	10.3**	26.0 (21)	7.0 (5)	3.7*
80+	59.0 (8)	42[illegible] (4)	1.4	30.0 (4)	31.0 (3)	1.0	89.0 (12)	73.0 (7)	1.2
Age-Adjusted Rates[4]	6.9	3.5	2.0*	4.7	2.7	1.7	11.6	6.2	1.9**

1. ICDA Codes 153, 154 (Intestinal Cancer); 155-159 (Other Digestive Organ Cancer); 153-159 (Total).
2. Risk in Refinery relative to Non-Refinery. Risks significantly greater than 1 have been starred, (*), $P < 0.05$; (**), $P < 0.01$. Based on Chi^2 with 1 degree of freedom. *(Doll & Hill, 1956).
3. See footnote 3, Table 15.
4. See footnote 4, Table 15.
5. Data for these calculations are in Table (16), Appendix VII.

refinery and non-refinery groups. In each of the three age groups the rates were highest in the refinery group. The relative risk of dying from intestinal cancer was twice as great for refinery workers as for non-refinery workers. This difference was statistically significant at $P < 0.05$. For other digestive system cancers, however, only in the 65-79 year age group was there a significantly higher mortality (RR = 10.3) in the refinery group. The age-adjusted rates showed the refinery mortality for the total digestive cancers to be about twice that of the non-refinery group.

The Effect of Geographic Location on Intestinal Cancer Mortality Differences between Refinery and Non-Refinery Groups

Since it had been shown that mortality due to intestinal cancer in the population at risk varied by province, age-adjusted rates were compared for the three geographic areas defined earlier. The "Other" category was excluded as there were no intestinal cancer deaths in this group. Table 27 shows the age-specific and age-adjusted death rates per 10,000 person years for Intestinal and Total Intestinal and Other Digestive Organ Cancer for refinery and non-refinery groups in the three geographic areas. The relative risk of refinery to non-refinery was generally higher than 1.0 but the only significant increase was seen in the Ontario/Quebec workers in the 65-79 year age group where the relative risk of refinery to non-refinery Total Digestive cancer mortality was 4.8.

Duration of Employment and Intestinal Cancer Mortality

Age-adjusted intestinal cancer and total intestinal and other

2 OF/DE 3

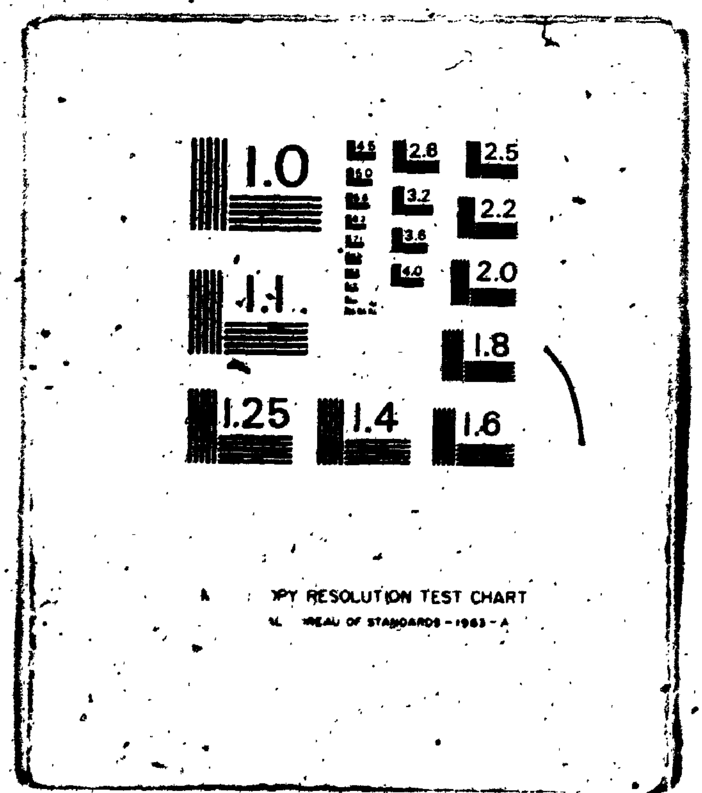


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Table 27

Age-Specific and Age-Adjusted Intestinal and Other Digestive Organ[2] Cancer Mortality Rates per 10,000 Person Years by Geographic Location in Refinery and Non-Refinery Groups, Age ≥ 40, 1964-1973

Rates/10,000 Person Years

	Intestinal Cancer			Total Intestinal and Other Digestive Organ Cancer		
	Refinery	Non-Refinery	Relative Risk[3]	Refinery	Non-Refinery	Relative Risk
Atlantic Provinces						
40-64	7.3 (2)[3]	-	-	7.3 (2)	6.4 (2)	1.1
65-79	-	-	-	19.6 (1)	-	-
80+	-	-	-	53.8 (1)	-	-
Age-Adjusted Rates[4]	-	-	-	10.9	5.0	2.2
Ontario/Quebec						
40-64	4.6 (7)	2.8 (5)	1.6	7.2 (11)	5.6 (10)	1.3
65-79	17.4 (9)	7.3 (3)	2.4	34.7 (18)	7.3 (3)	4.8*
80+	68.4 (6)	79.4 (4)	0.86	91.2 (8)	138.9 (7)	.66
Age-Adjusted Rates	8.8	5.8	1.5	14.7	9.7	1.5

1. ICDA Codes 153, 154 (Intestinal Cancer); 153-159 (total Intestinal and other Digestive Organ Cancer).
2. See footnote 2, Table 26.
3. See footnote 3, Table 15.
4. See footnote 2, Table 16.
5. Data for these calculations are summarized in Tables (17) and (18), Appendix VII.

Table 27
(Cont'd)

Western Provinces

	Intestinal Cancer			Total Intestinal and Other Digestive Organ Cancer		
	Refinery	Non-Refinery	Relative Risk	Refinery	Non-Refinery	Relative Risk
40-64	2.6 (2)	.65 (1)	4.0	5.1 (4)	1.3 (2)	3.9
65-79	-	-	-	5.1 (1)	4.9 (1)	1.0
80+	70.3 (2)	34.2 (1)	2.0	105.4 (3)	34.2 (1)	3.1
Age-Adjusted Rates	6.7	1.5	4.5	7.9	2.9	2.7

Table 31

Specific Cancer Mortality by Job Description

Standard Mortality Ratios (SMR), Age ≥ 40, 1964-1973

Class	Job Title	SMR[1] by Site: Intestine	Other Digestive Organs	Lung	Lymphatic and Hematopoietic System
Refinery, Exposed	Services: Laundry, custodial, watchmen, inspectors (N=156)	293.8 (3)[2]	-	-	-
Refinery/Non-Refinery Exposed	Mechanics, boilermakers, pipefitters (N=1496)	167.8 (13)	134.0 (8)	111.0 (17)	-
Refinery, Exposed	Operations, Processing, Field supervisors, Dewaxing, Asphalt Stills, Crude Stills, Clay Press (N=1303)	118.9 (7)	108.0 (5)	86.9 (10)	127.7 (4)
Non-Exposed	Office Workers (including executives) (N=2546)	113.0 (11)	67.2 (5)	65.4 (12)	99.8 (5)
Non-Refinery Exposed	Garage Workers, Route Salesmen (N=807)	68.7 (2)	94.4 (2)	146.0 (7)	-
Moderate, Exposed	Marketing Plant, Clerks (N=609)	68.9 (2)	-	166.2 (9)	131.8 (2)
Refinery, Exposed	Utilities, Building Trades, Boilerhouse (N=226)	116.4 (2)	-	200.4 (5)	-
Moderate, Exposed	Engineers (N=625)	-	357.5 (4)	-	-
Exposed	Packaging, Shipping (N=494)	-	-	98.3 (5)	230.0 (3)

1 Expected deaths were based on the total employee population at risk (age ≥ 40).

2 See footnote 3, Table 15

3 Data for the calculations are in Tables (2) and (23), Appendix VII and Table (3), Appendix VIII.

Table 28

Age-Adjusted Intestinal Cancer and Total Intestinal and Other Digestive Organ[1] Cancer Mortality by Duration of Employment in Refinery and Non-Refinery Groups, Age $\geq$ 40, 1964-1973

Age-adjusted[4] Rates/10,000 Person Years

Duration of Employment	Intestinal Cancer			Total Intestinal Cancer and Other Digestive Organ Cancer		
	Refinery	Non-Refinery	Relative Risk[2]	Refinery	Non-Refinery	Relative Risk
11-20	14.0 (6)[3]	-	-	14.0 (6)	0.8 (1)	17.5**
21-30	5.6 (9)	1.8 (4)	3.1	12.0 (18)	4.8 (10)	2.5
31+	6.1 (13)	6.5 (10)	0.9	12.6 (25)	10.3 (16)	1.2

1. See footnote 1, Table 27.
2. See footnote 2, Table 26.
3. See footnote 3, Table 15.
4. See footnote 2, Table 17.
5. Data for these calculations are summarized in Tables (19) and (20), Appendix VII.

Table 29

Age-Specific and Age-Adjusted Lung and Lymphatic[1] Cancer Mortality Rates per 10,000 Person Years in Refinery and Non-Refinery Groups, Age ≥ 40, 1964-1973

Rates per 10,000 Person Years

Age	Lung Cancer			Lymphatic and Hematopoietic System Cancer		
	Refinery	Non-Refinery	Relative Risk[2]	Refinery	Non-Refinery	Relative Risk
40-64	5.8 (15)[3]	5.0 (19)	1.16	0.77 (2)	1.6 (6)	0.48
65-79	31.8 (26)	25.1 (18)	1.27	3.7 (3)	7.0 (5)	0.53
80+	14.8 (2)	20.9 (2)	0.71	14.8 (2)	41.8 (4)	0.35
Age-Adjusted Rates[4]	10.9	9.2	1.18	1.7	3.7	0.46

1 See footnote 1, Table 18.

2 Risk in Refinery relative to Non-Refinery. None of these risks was significantly different from 1, $P < 0.05$. Tests of significance were based on Chi^2 with Yates correction, 1 degree of freedom (Doll and Hill, 1956).

3 See footnote 3, Table 15.

4 See footnote 4, Table 15.

5 Data for these calculations are in Table (13) and (14), Appendix VII and Table (2), Appendix VIII.

person years in the refinery and non-refinery groups for lung cancer and cancer of the lymphatic and hematopoietic system. Although the relative risk of mortality due to lymphatic cancer was less among refinery workers when compared with non-refinery workers, this difference was not statistically significant. The relative risk for lung cancer in refinery, compared with non-refinery workers, was slightly greater than one.

6.4 Intestinal and Lung Cancer Mortality in the Other Exposure Groups

All of the above analyses were concentrated on the major refinery and exposure groups. In Section 4, subsets of these groups were defined (e.g. refinery, exposed; refinery, non-exposed; non-refinery, exposed; non-refinery, non-exposed; and moderately exposed). Figure 3, Section 4, shows the number of workers in these subgroups. Table 30 shows the age-adjusted intestinal and lung cancer mortality rates in these groups. The results for the refinery, non-exposed and the moderately exposed groups were not included as the numbers of deaths were too low. The relative risks shown were based on the non-refinery, non-exposed rates. The refinery, exposed and the non-refinery, non-exposed groups had the highest mortality rates for intestinal cancer. Hence, the most exposed and the least exposed groups showed about the same intestinal cancer mortality risk. Still, being exposed at a refinery site did carry the greatest risk of intestinal cancer. Both exposed groups showed around a 2-fold lung cancer mortality risk over the non-refinery, non-exposed group.

6.5 Risk of Specific Cancer Mortality by Job Description

Table 30

Age-Adjusted Intestinal and Lung Cancer[1] Mortality Rates per 10,000 Person Years in Exposure Subgroups, Age ≥ 40, 1964-1973

Exposure Subgroup	Age-Adjusted[4] Rates per 10,000 Person Years		Relative Risk[2]	
	Intestinal Cancer	Lung Cancer	Intestinal Cancer	Lung Cancer
Refinery Exposed (N=4,920)	7.2 (26)[3]	11.9 (42)	1.1	1.7
Non-Refinery Exposed (N=3,692)	1.7 (3)	13.6 (25)	0.27	2.0
Non-Refinery Non-Exposed (N=3,904)	6.4 (11)	6.9 (12)	1.0	1.0

1 ICDA 8th Revision Codes 153, 154 (Intestinal Cancer) and 162 (Lung Cancer).

2 Relative to a risk of 1 in non-refinery, non-exposed group.

3 See footnote 3, Table 15.

4 See footnote 4, Table 15.

5 Data for these calculations are summarized in Tables (21) and (22), Appendix VII.

An examination of cancer mortality, by groups of employees with specific jobs, was undertaken to determine if high risk jobs could be identified. Only those groups with two or more deaths due to cancer of the following sites were included: Intestine and Rectum, Other Digestive Organs, Lung, Lymphatic and Hematopoietic System. Table 31 shows the SMRs for these groups. The two highest intestinal cancer risk groups were those workers who were associated with services at a refinery site (e.g. laundry, custodial, watchmen, inspectors) and a highly exposed group of mechanics, boilermakers and pipefitters. The highest "Other Digestive System" cancer mortality was experienced by the Engineers, a group which had been considered moderately exposed. Those employed in the utilities and building trades had the highest lung cancer SMR. Marketing plant workers and plant clerks showed a lung cancer SMR of 166. The excess Lymphatic and Hematopoietic System cancers were distributed mainly among workers in packaging and shipping (SMR = 230), Marketing plant (SMR = 132) and those in operations and processing (SMR = 127.7). All of these workers were moderately or highly exposed to petroleum or its derivatives. The numbers of deaths by job description were low and therefore any interpretation of these results would be risky. Appendix IX lists the workers who died of intestinal cancer and shows, among other variables, the job description for each. About 1/3 of these workers were mechanics by trade.

Table 31

Specific Cancer Mortality by Job Description

Standard Mortality Ratios (SMR), Age ≥ 40, 1964-1973

Class	Job Title	SMR[1] by Site: Intestine	Other Digestive Organs	Lung	Lymphatic and Hematopoietic System
Refinery, Exposed	Services: Laundry, custodial, watchmen, inspectors (N=156)	293.8 (3)[2]	-	-	-
Refinery/Non-Refinery Exposed	Mechanics, boilermakers, pipefitters (N=1496)	167.8 (13)	134.0 (8)	111.0 (17)	-
Refinery, Exposed	Operations, Processing, Field supervisors, Dewaxing, Asphalt Stills, Crude Stills, Clay Press (N=1303)	118.9 (7)	108.0 (5)	86.9 (10)	127.7 (4)
Non-Exposed	Office Workers (including executives), (N=2546)	113.0 (11)	67.2 (5)	65.4 (12)	99.8 (5)
Non-Refinery Exposed	Garage Workers, Route Salesmen (N=807)	68.7 (2)	94.4 (2)	146.0 (7)	-
Moderate, Exposed	Marketing Plant, Clerks (N=609)	68.9 (2)	-	166.2 (9)	131.8 (2)
Refinery, Exposed	Utilities, Building Trades, Boilerhouse (N=226)	116.4 (2)	-	200.4 (5)	-
Moderate, Exposed	Engineers (N=625)	-	357.5 (4)	-	-
Exposed	Packaging, Shipping (N=494)	-	-	98.3 (5)	230.0 (3)

1 Expected deaths were based on the total employee population at risk (age ≥ 40).

2 See footnote 3, Table 15

3 Data for the calculations are in Tables (2) and (23), Appendix VII and Table (3), Appendix VIII.

DISCUSSION AND CONCLUSIONS

The present study was undertaken with the purpose of examining a possible relationship between intestinal cancer mortality and occupational exposure to carcinogenic hydrocarbons.

No excess mortality from cancer of the intestine or other digestive organs in workers exposed to crude petroleum and its products, compared with non-exposed workers, was demonstrated. Furthermore, comparisons of exposed and non-exposed workers specific for age, geographic area and duration of employment failed to reveal any differences in intestinal and other digestive cancer mortality. The results, therefore, do not support the hypothesis that occupational exposure to petroleum or its breakdown products is related to the development of intestinal cancer.

7.1 Ways in Which a Real Difference May Have Been Missed

7.1.1 Inadequate Sample Size

That no real difference in intestinal cancer mortality was detected between exposure groups might be attributed to an inadequate sample size.

Since the exposed group had 62% of the follow-up experience of the total population at risk (at least 40 years old), one would expect to observe 62% of the intestinal cancer deaths in the exposed group, if death were unassociated with exposure. If the true proportion of intestinal cancer deaths in the exposed group had been 75% (this would result in a relative risk of 3), the probability of detecting an association between mortality and exposure at the 5% level of significance may be calculated (Donner, 1977). The probability of detecting such a difference is 0.82. If, however, the true proportion of intestinal cancer deaths were 70% of all such deaths (this would correspond to a relative risk of 2.33), then the probability of detecting an association is approximately 0.37. Thus, if the relative risk is 3.0 or more, the power of detecting an association between exposure and intestinal cancer mortality will exceed 0.80, which is the generally accepted minimum value for a "good" test. If the true relative risk is less than 3.0, more subjects are needed to detect a significant association. However, it was felt that a relative risk of at least 3 would provide stronger evidence of a real occupational hazard. The number of subjects should have been large enough to detect such a difference between the exposure groups. The formulae for the above calculations are in Appendix VI, (Estimate of Sample Size Limitations).

7.1.2 <u>Definition of Exposure</u>

Since the term "refinery worker", as defined by the Company, referred to work on a refinery site and since such work did not necessarily expose the worker to crude petroleum or its products, "exposure" to petroleum was redefined (Section 4.1.2). To be sure, this was a subjective definition and failure to separate adequately exposed and non-exposed groups could have been responsible for not finding a difference in intestinal cancer mortality between exposure groups. A natural marker, lung cancer mortality, existed as an indication of some separation of exposure classes.

It has been shown that lung cancer may be associated with occupational or environmental exposure to petroleum or specifically, aromatic hydrocarbons. Lloyd et al. (1970) showed that steelworkers working in the coke plant ran a risk of lung cancer that was 2½ times that of men in the total cohort of steelworkers. The mortality ratio for lung cancer in a cohort study of unionized roofers, with 20 or more years since joining the union, was 1.59; with 40 or more years, 2.47 (Hammond et al., 1976). In a study of geographic patterns of lung cancer Blot and Fraumeni (1976) showed that mortality rates for lung cancer among white males were almost twice as high in mostly rural counties with more than 1% employed in the petroleum industry than in rural counties with no petroleum industries. Doll et al. (1972) found that the lung cancer mortality rate, among British coal workers exposed to coal carbonization products, was 3.82/1000 population compared with a rate of 2.13/1000 in British males of the same age.

The results of the present study, which showed a 2-fold excess of lung cancer mortality in the exposed group, were in agreement with the foregoing studies, thus supporting the contention that some separation of exposed from the non-exposed was achieved.

7.1.3 Bias Due to Changes in Exposure

Changes in exposure may have occurred when employees made job changes or were promoted. Since the information required to follow changes in exposure throughout each employee's entire period of employment was unavailable, the frequency of exposure change was examined for the 10-year study period. Change in exposure was found to occur in only 1.6% of the company employees. This low frequency offers some evidence that such changes were unlikely to interfere seriously with the accuracy of classification. However, it is possible that some of the managerial, custodial and clerical staff might have been exposed, refinery workers early in their careers before onset of observation in this study. If an early exposure did in fact lead to intestinal cancer later in life the promotions to managerial staff, as well as accommodations to less arduous custodial work for disabled workers, and the concomitant change in exposure status could result in a dilution of the exposed, non-exposed differences being examined.

7.1.4 Definition of Mortality

The measure of outcome was dependent on death verification. The accuracy of cause of death information on death certificates could be questioned. This should not bias the results but might have reduced the number of cancer deaths if all such deaths were not correctly identified, thereby aggravating the problem of evaluating differences based upon small numbers of deaths.

7.1.5 Lost-to-Follow-Up

It was shown in Section 4.2.3 that 5.8% of the population at risk were lost-to-follow-up. If more exposed workers were lost-to-follow-up and exposure were related to intestinal cancer it is possible that a real difference could have been missed. In fact the percentage of lost-to-follow-up was greater in the non-exposed group, 6.9% (4.9% in the exposed). Also, the refinery group had fewer lost-to-follow-up than the non-refinery group, 2.2% to 7.9%. It is therefore unlikely that the pattern of loss in the two exposure groups has obscured a mortality difference.

There is the possibility that the company may not have been notified of all deaths among persons presumed part of the study population because they were members in the pension scheme; particularly those who were deferred annuitants. Since it was not possible to separate deferred annuitants from all annuitants in order to compare distributions in the exposure and refinery groups, it is not possible to speculate upon the extent to which incomplete notification may have obscured real differences. However, it is unlikely that the exposure status of the deferred annuitants bore any relationship to death notification; therefore, the effect of incomplete notification should not be that of bias but of reduction in the numbers of deaths.

7.2 Intestinal Cancer Risk in Refinery Workers

Although the principal hypothesis was not supported by the study results, there was an interesting tendency for refinery workers to have a risk of both intestinal cancer (153, 154) and of intestinal and other digestive organ cancers (153-159) combined, about twice as great as that in the non-refinery workers. The excess risk in refinery workers was present in all geographic areas with enough deaths to allow for the calculation of death rates.

If this difference were a reflection of the presence of some carcinogenic agent on a refinery site one would expect to see some evidence of a dose-response relationship in the form of increasing risk of intestinal cancer mortality with increasing years of employment. Duration of employment as a measure of exposure did not reveal any dose-response relationship in the refinery group. The greatest risk occurred in the lowest exposure category (11-20 years). This could be interpreted in several ways. If a carcinogenic agent were responsible for the higher intestinal cancer mortality in the refinery group, 11-20 years of exposure may be the maximum time required for these cancers to appear with no increase with time occurring thereafter. Another possibility is that measure of duration of employment is not necessarily equivalent to duration of work on a refinery site. Yet another possibility involves the method of calculating the person years at risk in each duration of exposure group. Wagoner and Infante (1976) have pointed out a methodological problem in assigning years of service in a cohort study on the basis of the total years at last observation. They argue that workers in a 15+ years category would have passed through the 10-15 year category and would have run the risk associated with that category at that time. If the observation period of the study were long enough, some of the person years by age would be distributed in the 15+ years category but some would also have to be distributed in the less than 15 years group. By assigning all the person years contributed by a given employee to the years service category based on total years at last observation, the population in person years in the higher years service categories will be inflated. Thus it is possible that increased death rates in these higher categories would be masked. Taking this principle into account, person years in the exposed and refinery groups were reallocated over the years service categories as well as the appropriate age groups for the 10 observation years. Age adjusted lung cancer death rates in exposed workers were calculated for comparison of duration of exposure before and after the correction was made. The same calculation was performed for intestinal cancer mortality in refinery workers. Table 32 shows the results of the addition of this correction factor. The corrected intestinal cancer rates were nearly equal over duration of employment

Table 32

Age-Adjusted[1] Mortality Rates per 10,000 Person Years by Duration of Employment Before and After Application of Correction Factor

	Rates per 10,000 Person Years			
	Refinery Intestinal Cancer[2] with		Exposed Lung Cancer with	
Duration of Employment (years)	Standard Method	Correction Factor	Standard Method	Correction Factor
11-20	14.0 (6)[3]	7.3 (6)	15.1 (11)	10.1 (11)
21-30	5.6 (9)	5.9 (9)	13.4 (27)	14.7 (27)
31+	6.1 (13)	7.5 (13)	13.8 (29)	19.6 (29)

1. See footnote 2, Table 17.
2. ICDA 8th Revision Codes 153, 154 (Intestinal Cancer); 162 (Lung Cancer).
3. See footnote 3, Table 15.
4. Data required for these calculations are in Tables (12) and (19), Appendix VII and Table (5), Appendix VIII.

groups, indicative of no dose-response relationship. However, the lung cancer rates, based on the new denominator, in the exposed workers did show an increasing trend with increasing years of employment.

7.3 Other Exposure Groups

Being exposed at a refinery site carried the greatest intestinal cancer mortality risk, although this risk was not significantly above that in the least exposed non-refinery group. This finding operates against the hypothesis that there is some carcinogen at refinery sites which may be associated with intestinal cancer. However, the number of deaths in each cell was low thus making these rates somewhat unreliable. If misclassification of exposure had occurred (Section 7.1.3), particularly with respect to the managerial staff, this could explain the results in the non-refinery, non-exposed group.

7.4 Lymphatic Cancer Mortality

Lymphatic cancer mortality was significantly lower in the refinery group than in the non-refinery group. Exposed workers showed a slightly lower lymphatic cancer death rate than the non-exposed workers. These results were not completely consistent with the results of the U.S. refinery mortality study (Gaffey et al., 1976) in which refinery workers showed higher lymphatic cancer mortality than U.S. males of the same age. However, when the U.S. refinery data were analysed by exposure (high, moderate or low), the lowest exposure class gave the highest SMR. This suggests a subtle similarity between these two studies.

The following are possible explanations for the apparent discrepancy in the results of the two studies:

(1) The populations studied were different.

(2) The definitions of refinery and exposure groups were different.

(3) Only lymphatic cancers (ICDA 200-203, 204) were included in the U.S. study while this study included leukemias as well (ICDA 200-209).

(4) The number of lymphatic cancer deaths was too low (22 in this study and 25 in the Gaffey study) to allow any real differences to appear.

7.5 Differences Which Were Detected in This Study

The major findings in this study were the 2-fold greater intestinal cancer risk in refinery workers when compared with non-refinery workers of the same age and a similarly increased lung cancer risk in workers, exposed to petroleum and/or its derivatives, compared with non-exposed workers.

7.5.1 Intestinal Cancer Risk

When refinery and non-refinery populations were compared, there appeared to be a consistently greater intestinal and other digestive organ cancer mortality in the refinery workers. Adjustment for geographic distribution diluted these differences but, nonetheless, intestinal cancer remained higher in refinery workers. The loss of significance could be related to the small number of deaths in each cell upon addition of the geographic variable. There was no dose-response relationship between refinery work and years on the job. When exposure to petroleum was defined for all workers no intestinal cancer mortality differences were observed between exposure groups. Therefore, there is little support for the contention that oil refining is responsible for an occupational intestinal cancer risk. One cannot ignore the refinery, non-refinery intestinal cancer differences. It is possible that carcinogens other than those present in petroleum may exist in large enough amounts at refineries to be responsible for these observed differences. Still another possibility is that of a synergy between exposure to petroleum and other risk factors associated with being a refinery worker. Against this possibility is the finding that the exposed refinery workers and the non-exposed, non-refinery workers had the greatest intestinal cancer mortality in the total work population. Nonetheless, an analysis by job description did identify some high intestinal cancer risk groups, particularly the mechanics and pipefitters.

7.5.2 Lung Cancer Risk

The 2-fold greater risk of lung cancer mortality in exposed workers lends itself to more concern. When an appropriate adjustment was made in cumulating person years over duration of employment, a dose-response relationship was observed between exposure and lung cancer mortality. Smoking histories for these workers were not known. Therefore it is difficult to know if smoking may have had some effect on the lung cancer rates in this study. Bias could have occurred if exposed workers had different smoking habits than non-exposed workers. There is no evidence to support this possibility. In fact, exposed workers are more restricted in their smoking on the job because of the high flammability of petroleum products. That there was consistency of these results with other studies in which workers were exposed to similar carcinogenic substances lends credence to the observation that lung cancer mortality increases with increased exposure to petroleum.

SUMMARY AND RECOMMENDATIONS

The major findings of this study were:

(1) Occupational exposure to petroleum or its products was not associated with increased mortality due to intestinal cancer. It is unlikely that a sizable increase in mortality in the exposed workers could have been missed.

(2) Lung cancer mortality was twice as high in exposed workers relative to non-exposed workers; an increase in years of exposure resulted in increased lung cancer mortality. This increase is believed to represent a specific effect of exposure.

(3) Refinery workers experienced a higher intestinal cancer death rate than non-refinery workers. Given current evidence the increase cannot be ascribed with certainty to an occupational carcinogenic exposure.

(4) High intestinal cancer mortality risk was associated with specific jobs.

(5) The general mortality experience of the company employees compared favourably with the Canadian standard.

8.1 Recommendations

Specific recommendations follow from these results. As a consequence of encountering many unanticipated problems during the collection and editing of the company's employee records, some general suggestions regarding occupational studies will be made subsequently.

8.1.1 Specific Recommendations

(1) A longitudinal extension of this study ought to be undertaken. Since the end point of the 10-year observation period (1973), 3 more years of information have accumulated. The inclusion of data for a further five years would add about 700 more deaths to the mortality experience. With new petrochemicals being produced, a constant observation of effects is justified.

(2) Morbidity as well as mortality ought to be monitored. In this study, cases of intestinal cancer were known to have been documented on medical records but could not be used in results, because the worker had not yet died or, indeed, died of causes other than intestinal cancer. Studying mortality is but a beginning step in occupational monitoring.

(3) High risk groups identified in this study should be examined in a more comprehensive way. Medical records should contain information about smoking, alcohol consumption, and dietary histories on high risk workers so that synergistic effects may be measured; and confounding effects could be eliminated.

(4) Quantitative, as well as qualitative information about exposure levels of all chemicals and agents, which may be hazardous to an employee's health, should be collected and made available. There is a need for precise exposure estimates of biochemical compounds as well as measurements of particle size.

(5) An employee's record should contain a complete history of exposures and levels of exposures in his past and present jobs in the company as well as similar information from previous jobs with other companies.

(6) Follow-up of all workers, including short-term employees, should

be maintained. The effects of some exposures (e.g. vinyl chloride monomer) are not always dependent upon long periods of exposure or long latent periods.

8.1.2 General Recommendations

More general recommendations include comprehensive record linkage studies either by government or industry. Newcombe (1974) has suggested an approach to this type of monitoring which would include linking of work histories from social insurance and industry with medical insurance and death records. This would allow for constant follow-up of workers, even if they were transient.

A common inter-industry system of job classification and exposure codes would allow for more accurate, larger studies; particularly if an exposure hazard emerged unexpectedly.

The recording of occupation on death certificates is presently inadequate in terms of identifying specific occupations, particularly since only the last known occupation is usually recorded. Perhaps it is unrealistic to expect the death record to contain detailed work histories when a record linkage system would be more efficient and more accurate.

Lastly, there is at present no appropriate standard population upon which to base occupational studies. The general Canadian population is usually less fit than the selected working population under study. Therefore, comparisons between company employees and the general population would necessarily show the company employees to an advantage. A solution would be to have statistics made available on the employed population, through Statistics Canada on a regular basis.

APPENDIX I

APPENDIX I

Part A

CARCINOGENICITY OF TARS AND PETROLEUM FRACTIONS IN LABORATORY ANIMALS[1]

Year	Animal	Substance	Route of Administration	Tumour Site
1915 1921	Rabbit	Coal Tar	SA	Skin
			O	Appendix, Intestines
1918	Mouse	Coal Tar	SA	Skin
			IR	Rectum
1922	Mouse	Shale Oil	SA	Skin
1948	Mouse	Mineral Oil	O	Alimentary Tract
1950	Monkey	Oil Mist	INH	Stomach

Key:

- SA skin application
- SI implantation
- SC subcutaneous injection
- O oral
- IP intraperitoneal
- INH inhalation
- IR intrarectal
- IV intravenous
- IM intramuscular
- IT intratracheal

[1] Hueper (1942); Medical Research Council (1968).

APPENDIX I

Part B

CHEMICAL CARCINOGENS IN PETROLEUM: EFFECTS ON LABORATORY ANIMALS[1]

Chemical Group Substance	Use	Animal	Route of Administration	Tumour Site
Inorganic Substances				
Lead	Petroleum additive	Mouse	O	Kidney
		Rat	O,SC,IP	Kidney, testes, pituitary
Chlorinated Hydrocarbons				
Carbontetrachloride	Solvent cleaning agent	Mouse	O	Liver
			SC	None
			SC & fast neutrons	Liver
			IR	Liver
		Rat	INH,SC	Liver
		Hamster	O	Liver
		Trout	O	Liver
		Dog	O	None
Aromatic Amines				
Benzidine	Dye	Rat	O	Liver
	Rubber hardener		SC	Liver, acoustic gland, colon
	Plastic film	Hamster	O	Liver
		Dog	O	Bladder
		Mouse	SC	Liver
N-Nitroso-Compounds				
Dimethylamine	Chemical industrial solvent	Mouse	O	Liver, lung, kidney
	Rocket fuel	Rat	O	Liver, lung, kidney
		Hamster	O	Liver
		Guinea pig	O	Liver
		Rabbit	O	Liver, lung
		Mouse	SC	Liver, lung
		Hamster	SC	Liver, nasal cavity
Dimethylhydrazine		Rat	SC	Intestine

[1] World Health Organization International Agency for Research in Cancer (1972, 1973).

Chemical Group Substance	Use	Animal	Route of Adminis-tration	Tumour Site
N-nitrosodie-thylamine	Copolymer (softener)	Mouse	O	Esophagus, liver, lung, forestomach
	Lubricant (additive)	Rat	O	Liver, lung, eso-phagus, kidney
		Hamster	INH,O,SC	Trachea, lung, liver, nasal cavity, bronchi
		Guinea pig	O	Liver, lung
		Rabbit	O	Liver, lung
		Dog	O,SC	Liver
		Pig	O	Liver, kidney
		Monkey	O,IP	Liver
		Fish	O	Liver
		Mouse	SA	Nasal cavity
		Rat	IP,INH	Liver
		Mouse	SC	Lung, liver
		Guinea pig	SC	Liver
		Mouse	IP	Lung
		Rat	IV	Kidney, ovary
			IR	Liver
		Parakeet	IM	Liver
Nitrosomethyl-urea	Polymerizer	Rat	O	Forestomach, brain, kidney, skin, jaw, intestines
		Hamster	O	Jaw, oral cavity, intestines
		Guinea pig	O	Stomach, pancreas, earduct, lumbar nerve, leukemia
		Mouse	SA	Leukemia, skin
		Rat	SA	Skin
		Hamster	SA	skin
		Hamster	IT	Pharynx, bronchi, eso-phagus, forestomach
		Mouse	SC	Thymus, myocardium, lung, spleen, lymph nodes, liver, kidney, bone marrow, leukemia
		Hamster	SC	Site, lung, lymph nodes
		Mouse	IP	Thymus, lung, lym-phomas, liver
		Rat	IP	Peritoneal cavity, kidney, forestomach
		Hamster	IP	Intestines
			IV	Intestines, jaw, oral cavity

Chemical Group Substance	Use	Animal	Route of Administration	Tumour Site
Nitrosomethylurea		Rat	IV	CNS, Stomach, intestines, kidney
		Rabbit	IV	CNS, Intestines
		Dog	IV	CNS, Lung, spleen, heart
Polycyclic Aromatic Hydrocarbons (PAH)				
Benzanthracene (BA)		Mouse	O	Lung, liver, forestomach
		Rat	SA	skin
		Hamster	SA	None
		Mouse	SC	Site, lung
		Rat	SC, IV	None
		Mouse	SI	Bladder
Benzofluoranthenes		Mouse	SA, SC	Site
Benzopyrenes		Rat	IT	Lung
			SI	Intrabronchial
			O, IV	Mammary gland
			SC	Site
			SA	Skin
		Mouse	O	Forestomach, lung, leukemia
			SA	Skin
		Hamster	O	Esophagus, forestomach, intestines
			SC	Site
			SA	Melanoma
			INH	Trachea, bronchi
		Guinea pig	SA, SC	None
		Rabbit	SA, SC	Papillomas, skin
		Duck	INH	Lung
		Monkey	INH	Lung
		Marmoset	SC	Site
		Newt	SC	Site
		Mouse	IP	Abdomen
		Rat	IP	Mammary, uterus
Crysene		Mouse	SA	Skin
			SC	Site
			IP	None
3-Methylcholanthrene		Mouse	O	Lung, liver, GI tract, forestomach

Chemical Group Substance	Use	Animal	Route of Administration	Tumour Site
Dimethylbenzanthracene		Mouse	O	Forestomach, lung, heart, intestines, mammary
			SC	Site
			SA	Skin, mammary
		Hamster	SA	None
		Rat	INH	Lung
			SC	Site
		Guinea pig	SC	Site
		Pigeon	SC	Site
		Mouse	Lung injection	Lung
		Frog	Kidney injection	Kidney

Appendix II

Cancer Risk To Man From Exposure To Sources Of

Polycyclic Aromatic Hydrocarbons (PAH)[1]

Year Reported	Source	PAH If Known	Occupation	Tumour Site(s)
1775	Soot	B(a)P[2]	Chimney Sweeps	scrotum
1875	Coal, Tar		Paraffin Workers	skin, scrotum
1876	Shale Oil	B(a)P	Shale Oil Workers	skin, scrotum
1892	Soot	B(a)P	Chimney Sweeps	skin, internal organs
	Coal, Tar Pitch	Creosote Anthracene	Coal, Tar and Pitch Workers	skin
Early 1900's	Shale Oil	B(a)P	Mulespinners, Textile Workers	lung, tonsil, stomach, scrotum, skin
1910	Paraffin Oil		Refinery Workers	skin
1928	Oil Mist		Engineers	Larynx, lung, stomach
1936	Tarry Substances		Tar Workers	gastrointestinal
1946	Carbon Black[3]		Rubber Workers	skin, scrotum

[1] Arcos (1959), Hueper (1942), Peller (1936), Weil (1952), World Health Organization (1973).

[2] B(a)P is the abbreviation for benzopyrene.

[3] Carbon black has been shown to contain several PAH's, among which are pyrene, fluoranthene, B(a)P, ananthrene, benzoperylene, coronene.

- continued on next page -

Year Reported	Source	PAH If Known	Occupation	Tumour Site(s)
1947	Coal, Gas, Tar	B(a)P	Coal, Tar Workers	lung
1950	Mineral Oils	B(a)P	Engineers	larynx, lung, stomach
1952	Isopropyl Oil, Coal Tar Products		Coal Gas Workers	nasal
1955	Cutting Oils	B(a)P	Metal Workers, Machinists, Tool Setters, Operators	skin, scrotum
1967	Coal Tar		Gas Plant Workers	lung
1968	Oils, Emulsions Transformer Oils, Mould Oils Grease		Nut/Bolt Manfg., Elect. Substances, Brick/Tile Making, Concrete Moulding, Forging, Rubber mixing, Rope/Jute Metal Working	tumours, site specificity not given
1971	Coal, Gas, Tar		Steel Workers, Coke Plants	lung
1972	Coal, Gas		Coke Plant, Topman	lung, scrotum, bladder, skin

APPENDIX III

RECODED JOB TITLES

Refinery

00	Title not available
01	Gauger
02	Utilities, Building trades, Boilerhouse
03,11	Operations, Processing, Field supervisors, Dewaxing, Asphalt stills, Crude stills, Clay press
04	Firemen
05	Stores and Tools
06	Packaging, Shipping
07	Mechanics, Boilermakers, Pipefitters
08	Chemists
09	Garage
10	Services: Laundry, Custodial, Watchmen, Inspectors
12	Electrician
13	Handyman, Labourer
14	Barrelhouse
20	Services (Custodial)
25	Office types
27	Draftsmen

Non-Refinery

21	Exploration, Pipeline
22	Marine
23	Producing--Gas

Non-Refinery (continued)

29	Marketing--Shipping, Transportation, Filling
30	Air station
31	Gauger
32	Utilities, Services
33	Producing--Process, Operations
34	Firemen
35	Stores and Tools
36	Marketing--Plant
37	Mechanics
38	Chemists
39	Marketing--Garage, Route Salesmen
40	Services, Maintenance
45	Office types
47	Draftsmen

Refinery or Non-Refinery

52	(Refinery)--Engineers
53	(Refinery)--Managers
56	(Refinery)--Clerks
61	Exploration, Geophysics--(Non-Refinery)
62	(Non-Refinery)--Engineers
63	(Non-Refinery)--Managers
64	Safety, Environment--(Non-Refinery)
65	Field auditors, Agents, (Non-Refinery)
66	Plant clerk marketing
67	Computers--(Refinery)

APPENDIX IV

APPENDIX IV

Part A

STEPS TAKEN TO MERGE AND EDIT THE DATA

For convenience in following these steps, a flow chart is included on the next page.

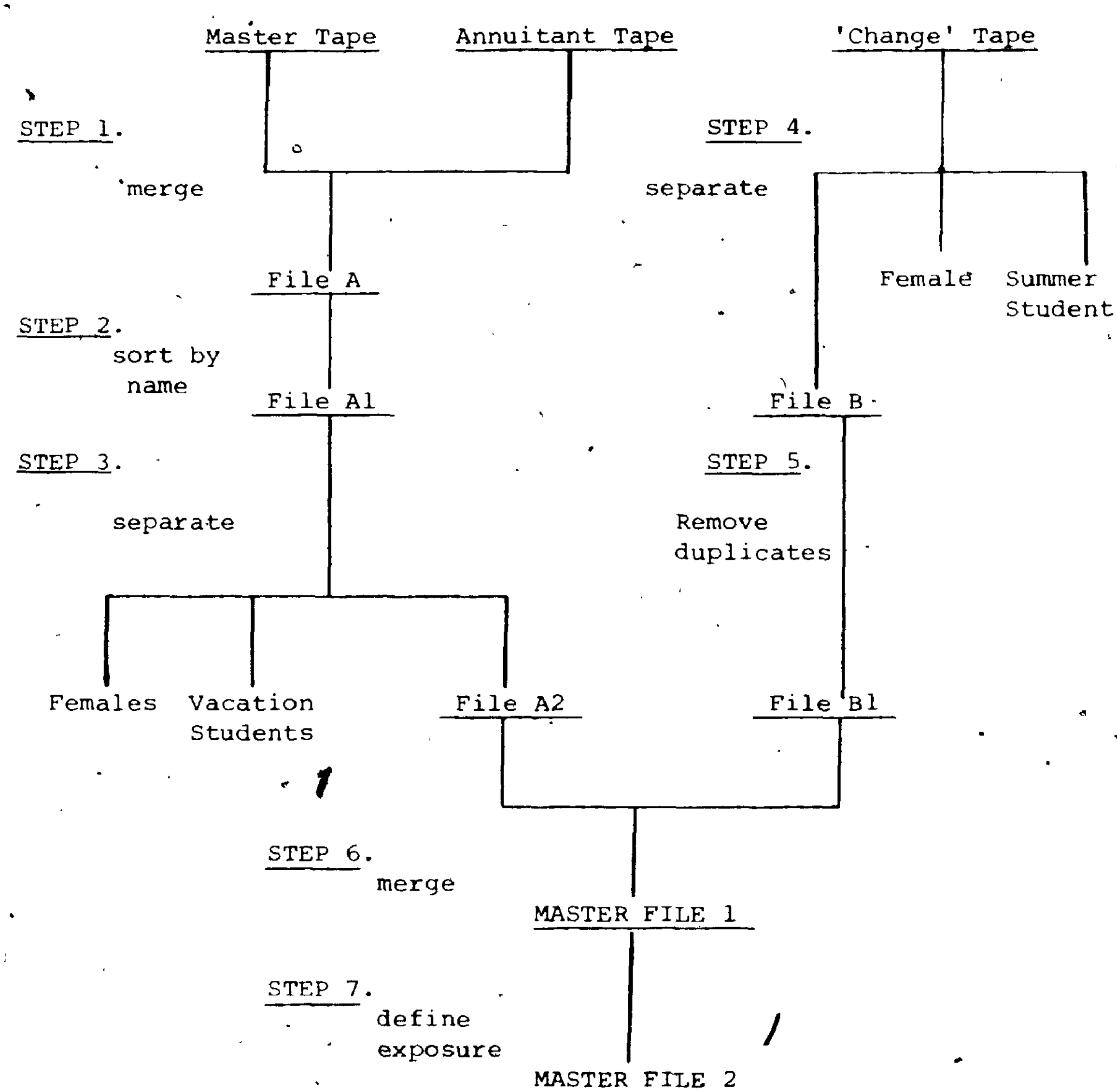
STEP 1. A master tape of the records of active employees from 1964 through 1968, and 1973, was merged with a tape consisting of all retired employees, collecting annuities between 1964 and 1973, to form File A.

STEP 2. File A was sorted alphabetically so that all the listings for each employee were together and each employee was in alphabetical order by surname. The alphabetical list was called File A1. Note: there were multiple listings in the record of each employee at this point as there was a listing for each year in which he was present. The aim was to condense all the information to one listing per employee.

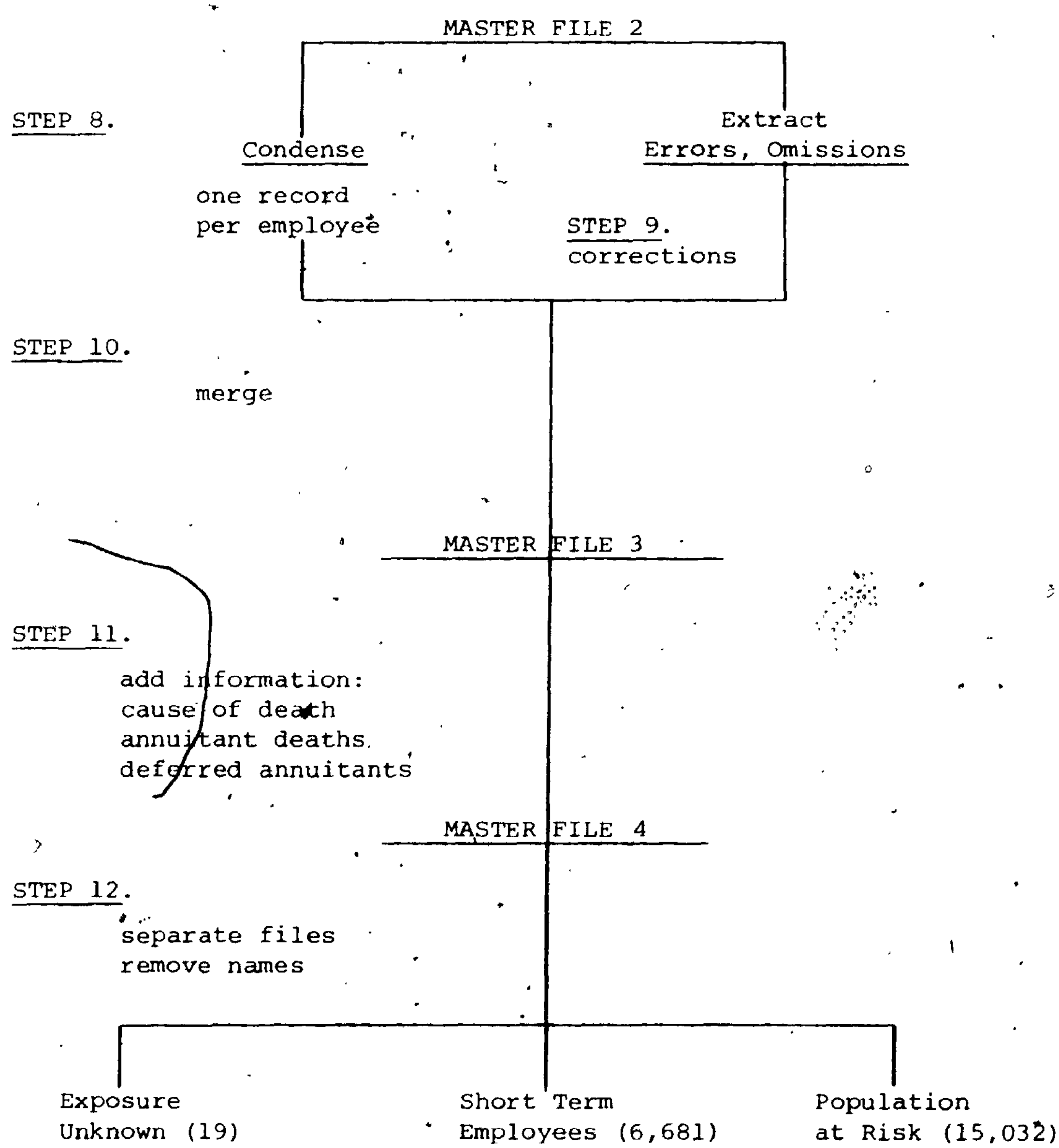
STEP 3. Females and Vacation Students were removed from File A1, leaving the remaining records in File A2.

STEP 4. Another set of listings on tape consisted of employee records for the five years 1969 through 1973. These records were edited at the company for changes in information and only those listings with unique information in an employee's history were included; this was called the 'Change Tape'.

Steps for Merging and Editing Data



Steps for Merging and Editing Data
(Cont'd)



Females and Vacation Students were removed from the 'Change Tape'.

STEP 5. A search for duplicate records on the "change tape' revealed a few, which were removed. Thus, File B1 was created.

STEP 6. Files B1 and A2 were merged to combine information from 1964 through 1973. This became Master File 1 after another check revealed duplicate records which were subsequently removed.

STEP 7. Exposure class was assigned to each record (see section 4.1.2. for definition of exposure class).

STEP 8. The multiple listings for each employee were condensed to the final listing, leaving one record for each employee. Cases in which an employee had different exposures among his records were identified as "mixed exposures". These totalled 2,608 records.

STEP 9. Checks for missing information and errors were designed and implemented in the following ways:

(1) Fields were searched for missing information (blanks).

(2) Numerical ranges were defined for most fields. (e.g. age had to be greater than 15 or less than 100). If a number fell out of the range, the record was printed.

(3) Errors in increments of years service were monitored against increments in years of age.

(4) An active record in 1973 or a termination date between 1964 and 1973 had to be found for each employee.

All records with any of the above inconsistencies were printed for further checking. There were 2,205 records with obvious errors or omissions. They were checked against company files and subsequently corrected. Also, "mixed exposures" were removed from the Master File and printed out for further study in this step.

STEP 10. Corrected records from STEP 9, as well as "mixed exposure" records were labelled, summarized and returned to the Master File which had been reduced to 1 record per employee.

STEP 11. Cause of death was added to the records of employees and annuitants who had died. Information on live deferred annuitants was merged with the Master File records. Duplicate employee numbers became apparent at this time. A search for duplicate numbers resulted in the identification of 25 cases where an employee number had been recycled. In each case, one record belonged to a former employee who had died while the other was associated with a recently hired employee. As most employee numbers ended with an even digit, this problem was easily rectified by changing the last digit to the next consecutive odd number. First, a check was made to ascertain that the assigned new number was not already in use. These newly assigned numbers were given to the older employee in each pair.

At this point it was possible to remove employee names as they were no longer required for identification. The final step (12) resulted in a tape containing 15,032 employees constructed as the Population At Risk, a subfile of 19 records of employees for whom there was no exposure information and a subfile of short term employees. The final step in the preparation of the population at risk as to set up an SPSS file and store it on magnetic tape for computer analysis.

APPENDIX IV

Part B

MODIFICATIONS OF ORIGINAL DATA

The following data format lists, at the various stages of deletions, insertions and changes, are included in order to give some indication of the chronological development of the final data set.

The first identifies the information available in the original volumes of manpower listings.

The second represents the computerized version after each employee's history had been compressed to a single final record. Exposure class was defined. Changes in Geographic Location over the 10-year observation period were included for analysis. Termination and death dates were inserted. Exposure years were recoded and a field was reserved to accommodate changes (by number of years) in exposure class.

The third lists the data, at the final stage, in preparation for analysis.

DATA FORMAT I

September 1973

1. Title; Names were present but have been omitted here for purposes of confidentiality.

2. Type of Employment (i.e. regular, non-regular, etc.)

3. Employee Number -- 6 digits, alphabetical code

4. Old Department, location, function number

5. Job title

6. Job category; occupational scale

01	unclassified		06	salaried operations
02	plant		07	salaried clerical
03	office	Administration	08	wage laborer
04	prof. & tech.	Supervisory	09	salesman
05	prof. & tech.		00,10	unknown

7. Age at data year

8. Years service at data year

DATA FORMAT 2

June 1974

1. Exposure Class

   1 Refinery, exposed
   2 Refinery, non-exposed
   3 Non-refinery, exposed
   4 Non-refinery, non-exposed
   5 Mixed exposed/non-exposed
   6 Moderate exposure
   7 Mixed exposed refinery/non-refinery
   8 Mixed non-exposed refinery/non-refinery

2. Geographic Location

   1 Ontario
   2 Quebec
   3 British Columbia
   4 Alberta
   5 Saskatchewan
   6 Manitoba
   7 Newfoundland
   8 Nova Scotia
   9 New Brunswick
   10 Prince Edward Island
   11 Northwest Territories
   12 Offshore
   13 Foreign

3. Employee Number

4. Exposure Years

   1 0 - 5
   2 6 - 10
   3 11 - 15
   4 16 - 20
   5 20 +

If code in 1st column, means exposed years; if in 2nd column, means non-exposed years. Mixed exposure histories show numbers in both columns.

5. Geographic Change

Four two-digit columns allow for up to four changes in geographic location over the 10-year observation period.

6. Department } as of 1969
7. Location }
8. Function }
9. Job Title
10. Job Category
11. Age of Data Year
12. Years Service
13. Sex
    M - Male
    F - Female
14. Status
    A Active
    T Terminated, Lost-to-follow-up
    F Retired (Annuitant, Deferred annuitant)
    D Died while employed
    Z Died after retirement
15. Year of Termination
16. Month of Termination
17. Reason for Termination
    89 laid off
    90 disability
    91 discharge
    92 resigned
    93, 94 transfer to subsidiary/affiliate
    95 regular retirement
    96 early retirement
    97 disability retirement
    98 retired (no pension)
    99 death
18. Department, Location, Function (pre-1969)
19. Death Year
20. Death Month
21. Data Year (1964 - 1973)

DATA FORMAT 3

November 1975

1. Refinery
   - 0 non-refinery
   - 1 refinery

2. Error
   - 1 greater than 16 years old or more than 49 years service
   - 2 age, years service increment inconsistent
   - 3 combination of 1 and 2
   - 5 mixed exposure history
   - 7 multiple terminations, break in history

3. Exposure Class (see 1., June 1974 Data)

4. Geographic Location (see 2., June 1974 Data)

5. Employee Number

6. Department }
7. Location } as of 1969
8. Function }

9. Job Code (see Appendix III)

10. Job Category (see 6., September 1973 Data)

11. Age at termination or in 1973, if still active

12. Years Service

13. Status (see 14., June 1974 Data)

14. Termination Year

15. Termination Month

16. Reason for Termination (see 17., June 1974 Data)

17. Department, Location, Function (pre-1969)

18. Death Year

19. Death Month

20. Year of Last Observation

21. Death Cause 1^{o} (001-999)

22. Death Cause 2^{o} (001-999)

23. Age at Last Observation

24. Year of Birth

25. Year Beginning Employment

26. Age Beginning Employment

27. Age (see 11) recoded into 5-year groups

0	Under 15	8	50 - 54
1	15 - 19	9	55 - 59
2	20 - 24	10	60 - 64
3	25 - 29	11	65 - 69
4	30 - 34	12	70 - 74
5	35 - 39	13	75 - 79
6	40 - 44	14	80 - 84
7	45 - 49	15	85 +

28. Years Service (see 12) recoded

1	0 - 5
2	6 - 10
3	11 - 15
4	16 - 20
5	21 +

29. Age Last Observation Recoded (see 23, 27)

30. Year of Birth Recoded

1	1865-1869	12	1920-1924
2	1870-1874	13	1925-1929
3	1875-1879	14	1930-1934
4	1880-1884	15	1935-1939
5	1885-1889	16	1940-1944
6	1890-1894	17	1945-1949
7	1895-1899	18	1950-1954
8	1900-1904	19	1955-1959
9	1905-1909	20	1960-1964
10	1910-1914	21	1965-1969
11	1915-1919	22	1970-1974

31. Year Beginning Employment Recoded (see 25, 30)

32. Age Beginning Employment Recoded (see 26, 27)

33. Year Beginning Observation

34. Year Last Observation

35. Years Service Beginning Observation

36. Years Service Beginning Observation Recoded (see 28, 35)

37. Age Beginning Observation

38. Age Beginning Observation Recoded (see 27, 37)

Appendix V

Table (4)

Distribution of Population

at Risk by Province

Geographic Location (Province)	Frequency Number	Percent
Ontario	6,024	40.1
Alberta	3,571	23.8
Quebec	1,927	12.8
Nova Scotia	872	5.8
British Columbia	847	5.6
Saskatchewan	512	3.4
Offshore	485	3.2
Manitoba	357	2.4
Newfoundland	176	1.2
New Brunswick	125	.8
N.W. Territories	58	.4
Foreign/Subsidiaries	51	.3
Prince Edward Island	27	.2
Total	15,032	100.0

APPE 'DIX V

CORRELATION MATRIX

INTERRELATIONSHIPS OF VARIABLES WHICH COULD BE RELATED TO MORTALITY

	Years Service at Last Observation	Age at Last Observation	Year of Birth	Year Beginning Employment	Years Service Beginning Observation	Age Beginning Observation	Age Beginning Employment
Years Service at Last Observation	1.00[1]	.76	- .73	- .80	.85	.63	.02
Age at Last Observation		1.00	- .98	- .90	.85	.96	.41
Year of Birth			1.00	.91	- .84	- .97	- .42
Year Beginning Employment				1.00	- .91	- .88	- .03
Years Service Beginning Observation					1.00	.82	.03
Age Beginning Observation						1.00	.41
Age Beginning Employment							1.00

1. The number in each cell is the correlation coefficient, r. Each r was statistically significant at $P<0.0001$

Appendix V

Table (1)

Distribution of the Population

at Risk by Age at Last Observation,

Full Age Range, 1964-1973.

Age Group		Frequency Number	Percent
15-39		4,337	28.8
40-44		1,686	11.2
45-49		1,777	11.8
50-54		1,610	10.7
55-59		1,339	8.9
60-64		1,150	7.7
65-69		1,019	6.8
70-74		847	5.6
75-79		614	4.1
80-84		404	2.7
85+		249	1.7
	Total	15,032	100.0

Appendix V

Table (2)

Distribution of the Population
at Risk by Years Service
at Last Observation,
All Ages, 1964-1973.

Years Service		Frequency Number	Percent
0 - 5		2,182	14.5
6 -10		1,793	11.9
11-15		1,057	7.0
16-20		2,158	14.4
21+		7,842	52.2
	Total	15,032	100.0

Appendix V

Table (3)

Distribution of the Population at Risk by Status at Last Observation, All Ages, 1964-1973.

Status	Frequency Number	Percent
Active	8,693	57.8
Retired (Alive)	3,963	26.4
Died in Retirement	1,189	7.9
Died in Service	322	2.1
Terminated (Lost-to-Follow-up)	865	5.8
Total	15,032	100.0

Appendix V

Table (4)

Distribution of Population

at Risk by Province

Geographic Location (Province)	Frequency Number	Percent
Ontario	6,024	40.1
Alberta	3,571	23.8
Quebec	1,927	12.8
Nova Scotia	872	5.8
British Columbia	847	5.6
Saskatchewan	512	3.4
Offshore	485	3.2
Manitoba	357	2.4
Newfoundland	176	1.2
New Brunswick	125	.8
N.W. Territories	58	.4
Foreign/Subsidiaries	51	.3
Prince Edward Island	27	.2
Total	15,032	100.0

Appendix V

Table (5)

Distributions of Selected Causes of Death by Age

for the Population at Risk, Full Age Range, 1964-1973.

Cause of Death

Age Group	All Causes (001-999)[1]		Malignant Neoplasms: All (140-209)		Large Intestine (incl. rectum) (153,154)		Other Digestive Organs (155-159)		Bronchus, Trachea, Lung (162)	
	#	%	#	%	#	%	#	%	#	%
19-39	25	1.7	5	1.7	-	-	-	-	-	-
40-44	23	1.5	5	1.7	1	2.4	-	-	1	1.2
45-49	43	2.8	13	4.3	-	-	1	3.0	5	6.1
50-54	91	6.0	26	8.6	6	14.3	5	15.2	5	6.1
55-59	139	9.2	34	11.3	5	11.9	3	9.1	6	7.3
60-64	168	11.1	37	12.3	4	9.5	5	15.2	17	20.7
65-69	197	13.0	49	16.3	4	9.5	4	12.1	18	22.0
70-74	248	16.4	41	13.6	4	9.5	5	15.2	12	14.6
75-79	247	16.3	43	14.3	6	14.3	3	9.1	14	17.1
80-84	196	13.0	32	10.6	8	19.0	3	9.1	4	4.9
85+	134	8.9	16	5.3	4	9.5	4	12.1	-	-
Total	1,511		301		42		33		82	

[1] ICDA codes, 8th Edition (1965), in brackets.

Appendix V

Table (6)

Distribution of Selected Causes of Death
by Geographic Location (Province) for the Total Population at Risk

Geographic Location	All Causes		Malignant Neoplasms: All (140-209)[1]		Large Intestine Rectum (153,154)		Other Digestive (155-159)		Bronchus Lung Trachea (162)	
	#	%	#	%	#	%	#	%	#	%
Ontario	680	45.0	122	40.5	26	61.9	15	45.4	27	32.9
Alberta	141	9.3	21	7.0	1	2.4	1	3.0	5	6.1
Quebec	256	16.9	57	18.9	8	19.0	8	24.2	17	20.7
Nova Scotia	124	8.2	29	9.6	2	4.8	4	12.1	8	9.8
British Columbia	128	8.5	28	9.3	2	4.8	3	9.0	9	11.0
Saskatchewan	63	4.2	16	5.3	1	2.4	2	6.0	6	7.3
Offshore	40	2.6	6	2.0	-	-	-	-	3	3.6
Manitoba	43	2.8	14	4.6	2	4.8	-	-	4	4.9
Newfoundland	16	1.0	3	1.0	-	-	-	-	1	1.2
New Brunswick	14	0.9	4	1.3	-	-	-	-	1	1.2
Northwest Territories	2	0.1	-	-	-	-	-	-	-	-
Foreign	1	0.1	1	0.3	-	-	-	-	1	1.2
Prince Edward Island	3	0.2	-	-	-	-	-	-	-	-
Total	1,511	....	301	....	42	....	33	....	82	....

[1] See footnote 1., Table (5), this Appendix.

Appendix V

Table (7)

Distribution of Deaths by Major Cause

for Exposed and Non-Exposed Groups, All Ages,

1964-1973

Cause of Death[1]	Exposed		Non-Exposed	
	Number	Percent	Number	Percent
Infectious & Parasitic Diseases (001-136)	5	.5	4	1.0
Malignant Neoplasms (140-209)	217	19.8	84	20.1
Other Neoplasms (210-239)	3	.3	1	.2
Endocrine, Nutritional, Metabolic (240-279)	22	2.0	7	1.7
Diseases of Blood and Blood Forming Organs (280-289)	5	.5	-	-
Mental Disorders (290-315)	1	.1	1	.2
Diseases of:				
Nervous System & Sense Organs (320-389)	9	.8	7	1.7
Circulatory System (390-458)	646	59.0	259	62.1
Respiratory System (460-519)	71	6.5	19	4.6
Digestive System (522-577)	40	3.7	11	2.6
Genitourinary System (580-607)	14	1.3	5	1.2
Skin & Subcutaneous Tissue (680-709)	-	-	1	.2
Musculoskeletal & Connective Tissue (710-738)	1	.1	1	.2
Congenital Anomalies (740-759)	1	.1	-	-
Symptoms & Ill-defined (780-796)	13	1.2	4	1.0
Accidents, Poisonings & Violence (800-999)	46	4.2	13	3.1
Total	1,094	100.1	417	99.9

1. See footnote 1, Table (5), this Appendix.

Appendix V

Table (8)

Distribution of Cancer Deaths by Site in

Exposed and Non-Exposed Groups, All Ages,

1964-1973

Cause of Death[1]	Exposed Number	Exposed Percent	Non-Exposed Number	Non-Exposed Percent
Malignant Neoplasms of:				
Buccal Cavity & Pharynx (140-149)	6	2.8	1	1.2
Esophagus & Stomach (150,151)	28	12.9	5	6.0
Intestines & Rectum (152-154)	29	13.4	13	15.5
Other Digestive Organs (155-159)	20	9.2	13	15.5
Trachea, Bronchus, Lung (162)	67	30.9	15	17.8
Other Respiratory Organs (160,161,163)	3	1.4	1	1.2
Bone, Connective Tissue, Skin (170-174)	5	2.3	7	8.3
Prostate (185)	18	8.3	7	8.3
Urinary Organs (188,189)	14	6.4	5	6.0
Other Unspecified Sites (190-199)	13	6.0	6	7.1
Lymphatic & Hematopoietic System (200-209)	14	6.4	11	13.1
Total	217	100.0	84	100.0

1. See footnote 1, Table (5), this Appendix.

Appendix V

Table (9)

The Distribution of Deaths by Major Cause

in Refinery and Non-Refinery Groups,

All Ages, 1964-1973

Cause of Death[1]	Refinery		Non-Refinery	
	Number	Percent	Number	Percent
Infectious & Parasitic Diseases (001-136)	4	0.5	5	0.7
Malignant Neoplasms (140-209)	165	20.1	136	19.7
Other Neoplasms (210-239)	3	0.4	1	0.1
Endocrine, Nutritional & Metabolic (240-279)	20	2.4	9	1.3
Diseases of Blood & Blood-Forming Organs (280-289)	4	0.5	1	0.1
Mental Disorders (290-315)	0	-	2	0.3
Diseases of:				
Nervous System & Sense Organs (320-389)	5	0.6	11	1.6
Circulatory System (390-458)	489	59.6	416	60.3
Respiratory System (460-519)	54	6.6	36	5.2
Digestive System (520-577)	29	3.5	22	3.2
Genitourinary System (580-607)	9	1.1	10	1.4
Skin & Subcutaneous Tissue (680-709)	0	-	1	0.1
Musculoskeletal System & Connective Tissue (710-738)	0	-	2	0.3
Congenital Anomalies (740-759)	1	0.1	0	-
Symptoms & Ill-defined Conditions (780-796)	10	1.2	7	1.0
Accidents, Poisonings & Violence (800-999)	28	3.4	3	4.5
Total	821	100.0	690	99.8

1. See footnote 1, Table (5), this Appendix.

Appendix V

Table (10)

The Distribution of Cancer Deaths by Site in Refinery and Non-Refinery Groups, All Ages, 1964-1973

Cause of Death[1]	Refinery		Non-Refinery	
	Number	Percent	Number	Percent
Malignant Neoplasms of:				
Buccal Cavity & Pharynx (140-149)	4	2.4	3	2.2
Esophagus & Stomach (150-151)	18	10.9	15	11.0
Large Intestines & Rectum (153-154)	28	17.0	14	10.3
Other Digestive Organs (155-159)	21	12.7	12	8.8
Trachea, Bronchus, Lung, (162)	43	26.1	39	28.7
Other Respiratory Organs (160,161,163)	2	1.2	2	1.5
Bone, Connective Tissue, Skin (170-174)	4	2.4	8	5.9
Prostate (185)	15	9.1	10	7.4
Urinary Organs (188,189)	10	6.1	9	6.6
Other & Unspecified Sites (190-199)	13	7.9	6	4.4
Lymphatic & Hematopoietic System (200-209)	7	4.2	18	13.2
Total	165	100.0	136	100.0

1. See footnote 1, Table (5), this Appendix.

APPENDIX V

Table (11)

Crude Death Rates and Age-Adjusted[1] Death Rates per 1,000 Males in Canada and Provinces, 1969

Province	Crude Death Rate	Age-Adjusted Death Rate
Newfoundland	6.8	7.9
Prince Edward Island	10.5	8.3
Nova Scotia	10.2	9.1
New Brunswick	8.9	8.6
Quebec	7.8	9.2
Ontario	8.5	8.7
Manitoba	9.6	8.1
Saskatchewan	9.6	7.5
Alberta	7.8	7.6
British Columbia	10.0	8.6
Yukon	8.3	9.7
N.W. Territories	8.1	10.6
Canada	8.5	8.6

1. Standardized to the 1956 Canadian Census population; Dominion Bureau of Statistics (1969).

APPENDIX VI

Examples of Statistical Calculations Employed in the Analysis of the Data

APPENDIX VI

Example 1

Example of the Calculation of an Age-Adjusted Rate Using the Direct Method[1] on the Employee Population

Age Group (1)	Refinery Person Years (2)	Number of Deaths (3)	Age Specific Death Rate/ 10,000 Person Years (4)	Employee Population Person Years (5)	Expected Deaths (6)
(a) 40 - 64	26,064.0	10	3.8	64,383.5	24.5
(b) 65 - 79	8,187.5	10	12.0	15,363.0	18.4
(c) 80 +	1,353.0	8	59.0	2,310.0	13.6
			TOTAL	(7) 82,057.0	(8) 56.5
					(9) 6.9

To determine the age specific death rate, divide row value in column (3) by corresponding row value in column (2); multiply times 10,000

e.g. 10/26,064 x 10,000 = 3.8

to give value in column (4).

Multiply column (4) value times population in column (5), divide by 10,000 to get the number of deaths (column (6)) expected in the standard population. Total row values in column (6). Then divide (8) by (7) multiply times 10,000 to get (9) standardized intestinal cancer death rate/10,000 person years for the refinery group.

1. Hill (1971).

APPENDIX VI

Example 2

Differences between Death Rates: A Test for Statistical Significance

The following gives an example of a method (Doll and Hill, 1956) used for calculating the statistical significance of differences between death rates:

Exhibit 1

Person Years[1]

Age Group	Exposed Number	Exposed Percent	Non-Exposed Number	Non-Exposed Percent	Total
40-64	38153.5	59.3	26230.5	40.7	64384
65-79	10734.5	69.9	4628.5	30.1	15363
80+	1647.0	71.3	663.0	28.7	2310
Total					82057

Exhibit 2

Number of Lung Cancer Deaths[2]

	Exposed Observed	Exposed Expected	Non-Exposed Observed	Non-Exposed Expected	Total
40-64	28	20.2	6	13.8	34
65-79	36	30.8	8	13.2	44
80+	3	2.8	1	1.2	4
Total	67	53.8	15	28.2	82

Expected deaths, in Exhibit 2, are calculated by applying the population percentages, arrived at in Exhibit 1, to the total number of deaths in each age category. The Chi^2 test with Yate's correction and with 1 degree of freedom is then applied, employing these numbers of observed and expected deaths.

1. See Appendix VIII, Table (1)
2. See Appendix VII, Table (10)

APPENDIX VI

Estimate of Sample Size Limitations

Given that the exposed group of workers had 62% of the follow-up experience one would expect to observe 62% of the intestinal cancer deaths in the exposed group, if death were unassociated with exposure. One can then ask the question: If the true proportion of deaths in the exposed group is 0.75, what is the probability of detecting an association between mortality and exposure? The following equation may be solved:[1.]

$$\text{Probability} = \Pr\left[\frac{\frac{X}{42} - 0.62}{\sqrt{\frac{(0.62)(0.38)}{42}}} > 1.96 \Big/ p = 0.75\right]$$

$$= \Pr\left[\frac{\frac{X}{42} - 0.62}{0.075} > 1.96 \Big/ p = 0.75\right]$$

$$= \Pr\left[\frac{\frac{X}{42} - 0.75 + 0.75 - 0.62}{(0.075)} > 1.96 \Big/ p = 0.75\right]$$

$$= \Pr\,[\,Z > 1.96 - 1.73\,], \text{ since } Z = \frac{X - \mu_x}{\sigma_x} \quad \text{(Armitage, 1971)}$$

$$= \Pr\,[\,Z > 0.23\,]$$

$$= 0.82$$

This corresponds to a relative risk of 3.0; $\frac{p_1}{p_1 + p_2} = 0.75$ for p_1/p_2

1. This approach to the problem was designed by Donner (1977).

If the true proportion of deaths in the exposed group had been 70% of the deaths then the probability of detecting an association is approximately

$$Pr\ [\ Z > 1.96 - (\frac{0.70-0.62}{0.075})\ ] = Pr\ [\ Z > 0.89\ ]$$

$$= 0.37$$

This corresponds to a relative risk of 2.33.

APPENDIX VII

Tables Showing Data Required for Calculating
Expected Deaths and Death Rates
in the Text Tables

APPENDIX VII

Table (1)

1969 Death Rates[1]/1000 Canadian Males by Age and Selected Causes of Death

AGE GROUP	Rates/1000 Males										
	15-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Death Due To:[2]											
ALL CAUSES (001-999)	1.8	3.4	5.7	9.3	15.0	23.1	37.0	52.8	77.2	123.8	212.1
Malignant Neoplasms (140-209)	0.2	0.6	1.1	2.1	3.6	5.7	8.9	11.7	14.8	21.6	24.5
Diseases of Circulatory System (390-458)	0.2	1.2	2.4	4.6	7.6	12.2	20.3	29.8	46.1	75.6	138.1
Diseases of Respiratory System (460-519)	-	0.1	0.3	0.4	0.8	1.6	2.8	4.5	6.4	11.2	23.6
Malignant Neoplasms of:											
Intestines, Rectum (152-154)	-	0.1	0.1	0.3	0.4	0.8	1.2	1.8	2.4	3.9	4.5
Other Digestive Organs (155-159)	-	-	0.1	0.2	0.3	0.5	0.8	1.1	1.2	1.8	1.8
Trachea, Bronchus, Lung (162)	-	0.1	0.3	0.6	1.2	2.0	2.8	3.1	3.0	2.5	2.2
Prostate (185)	-	-	-	-	0.1	0.3	0.7	1.3	2.3	4.3	5.8
Urinary Bladder, Kidney (188, 189)	-	-	-	0.1	0.2	0.4	0.6	0.8	1.1	1.7	1.8
Lymphatic and Hematopoietic System (200-209)	-	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.2	1.8	1.7
Accidents, Poisonings, Violence (800-999)	1.1	1.0	1.2	1.1	1.3	1.3	1.5	1.7	2.2	3.1	5.7

[1] Dominion Bureau of Statistics (1969)

[2] See Footnote 1, Table (5), Appendix V.

APPENDIX VII

Table (2)

Observed Numbers of Deaths for Selected Causes by Age and Death Rates/ 1000 Person Years for the Population at Risk, Age ≥ 40, 1964-1973

Death Due To:[1]	Age Group	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+	TOTAL
		Death Rates/1000 Person Years										
All Causes (001-999)		(23)[2]	(43)	(91)	(139)	(168)	(197)	(248)	(247)	(196)	(134)	1,486
		1.4	2.8	7.2	12.9	18.5	22.7	48.9	77.7	117.5	208.6	
Diseases of Circulatory System (390-458)		(9)	(20)	(44)	(80)	(99)	(117)	(156)	(151)	(132)	(92)	900
		0.5	1.3	3.5	7.4	10.9	16.5	30.7	47.5	79.2	143.2	
Diseases of Respiratory System (460-519)		(1)	(1)	(1)	(6)	(7)	(10)	(19)	(20)	(13)	(12)	90
		0.1	0.1	0.1	0.6	0.8	1.4	3.7	6.3	7.8	18.7	
Malignant Neoplasms (140-209)		(5)	(13)	(26)	(34)	(37)	(49)	(41)	(43)	(32)	(16)	296
		0.3	0.9	2.1	3.2	4.1	6.9	8.1	13.5	19.2	24.9	
Malignant Neoplasms of:												
Intestines, Rectum (153, 154)		(1)	-	(6)	(5)	(4)	(4)	(4)	(6)	(8)	(4)	42
		0.1	-	0.5	0.5	0.4	0.6	0.8	1.9	4.8	6.2	
Other Digestive Organs (155-159)		-	(1)	(5)	(3)	(5)	(4)	(5)	(3)	(3)	(4)	33
		-	0.1	0.4	0.3	0.6	0.6	1.0	0.9	1.8	6.2	
Trachea, Bronchus, Lung (162)		(1)	(5)	(5)	(6)	(17)	(18)	(12)	(14)	(4)	-	82
		0.1	0.3	0.4	0.6	1.9	2.5	2.4	4.4	2.4	-	
Prostate (185)		-	-	(1)	-	-	(7)	(4)	(5)	(5)	(3)	25
		-	-	0.1	-	-	1.0	0.8	1.6	3.0	4.7	
Urinary Bladder, Kidney (188, 189)		-	(1)	-	(4)	(3)	(5)	(4)	(1)	-	(1)	19
		-	0.1	-	0.4	0.3	0.7	0.8	0.3	-	1.6	
Lymphatic and Hemato-poietic System (200-209)		-	(1)	(1)	(4)	(2)	(4)	(3)	(1)	(5)	(1)	22
		-	0.1	0.1	0.4	0.2	0.6	0.6	0.3	3.0	1.6	
Accidents, Poisonings Violence (800-999)		(5)	(7)	(7)	(4)	(8)	(2)	(7)	(5)	(2)	(1)	48
		0.3	0.5	0.6	0.4	0.9	0.3	1.4	1.6	1.2	1.6	

[1] See Footnote 1, Table (5), Appendix V.

[2] Numbers of Deaths are in Brackets.

APPENDIX VII

Table (3)

Deaths for Selected Causes by Age in the Population at Risk, Atlantic Provinces, Age ≥ 40, 1964-1973

AGE GROUP	Number of Deaths										
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+	Total
Death Due To:[1]											
ALL CAUSES (001-999)	2	3	10	12	20	24	27	20	15	20	153
Malignant Neoplasms (140-209)	-	-	-	6	5	10	2	6	2	3	34
Diseases of Circulatory System (390-458)	1	3	5	6	8	9	22	12	7	12	85
Diseases of Respiratory System (460-519)	-	-	1	-	3	-	2	1	2	2	11
Accidents, Poisonings, Violence (800-999)	1	-	2	-	2	1	-	-	1	-	7
Malignant Neoplasms of:											
Intestines, Rectum (152-154)	-	-	-	1	-	1	-	-	-	-	2
Other Digestive Organs (155-159)	-	-	-	1	1	1	-	-	1	-	4
Trachea, Bronchus, Lung (162)	-	-	-	2	4	3	1	-	-	-	10
Prostate (185)	-	-	-	-	-	1	-	2	1	-	4
Urinary Bladder, Kidney (188, 189)	-	-	-	-	-	1	-	-	-	-	1
Lymphatic and Hematopoietic System (200-209)	-	-	-	-	-	2	-	-	-	1	3
PERSON YEARS	1306.5	1334.0	1227.0	1103.0	908.5	631.5	484.0	356.0	213.5	76.5	7640.5

[1] See Footnote 1, Table (5), Appendix V.

APPENDIX VII

Table (4)

Deaths for Selected Causes by Age in the Population at Risk, Ontario/Quebec, Age ≥ 40, 1964-1973

AGE GROUP	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+	Total
	Number of Deaths										
Death Due To:[1]											
ALL CAUSES (001-999)	10	25	51	78	96	116	165	164	127	88	920
Malignant Neoplasms (140-209)	3	8	16	17	26	27	27	23	19	9	175
Diseases of Circulatory System (390-458)	5	10	27	47	54	70	103	103	91	62	572
Diseases of Respiratory System (460-519)	-	1	-	4	4	8	9	14	8	8	56
Accidents, Poisonings, Violence (800-999)	1	4	2	2	3	1	5	5	-	1	24
Malignant Neoplasms of:											
Intestines, Rectum (152-154)	1	-	5	2	4	2	4	6	7	3	34
Other Digestive Organs (155-159)	-	1	3	2	3	3	4	2	2	3	23
Trachea, Bronchus, Lung (162)	1	4	3	1	9	11	6	7	2	-	44
Prostate (185)	-	-	1	-	-	3	3	3	3	2	15
Urinary Bladder, Kidney (188, 189)	-	-	-	2	3	3	2	1	-	-	11
Lymphatic and Hematopoietic System (200-209)	-	-	1	3	2	-	2	-	1	-	9
PERSON YEARS	8544.5	7785.5	6440.0	5546.5	4845.5	4067.0	3190.0	2018.0	1011.0	370.5	43818.5

[1] See Footnote 1, Table (5), Appendix V.

APPENDIX VII

Table (5)

Deaths for Selected Causes by Age in the Population at Risk, Western Provinces, Age ≥ 40, 1964-1973

AGE GROUP	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-	Total
	Number of Deaths										
Death Due To:[1]											
ALL CAUSES (001-999)	8	13	26	43	45	52	52	55	43	24	367
Malignant Neoplasms (140-209)	1	4	7	11	6	11	12	13	10	4	79
Diseases of Circulatory System (390-458)	3	6	11	22	31	34	27	31	31	17	213
Diseases of Respiratory System (460-519)	-	-	-	1	-	2	8	4	3	2	20
Accidents, Poisonings, Violence (800-999)	2	3	3	2	3	-	2	-	-	-	15
Malignant Neoplasms of:											
Intestines, Rectum (152-154)	-	-	1	2	-	1	-	-	1	1	6
Other Digestive Organs (155-159)	-	-	2	-	1	-	1	1	-	1	6
Trachea, Bronchus, Lung (162)	-	-	1	3	4	4	5	6	1	-	24
Prostate (185)	-	-	-	-	-	3	1	-	1	1	6
Urinary Bladder, Kidney (188, 189)	-	1	-	2	-	1	2	-	-	1	7
Lymphatic and Hematopoietic System (200-209)	-	1	-	1	-	2	1	1	4	-	10
PERSON YEARS	6338	5603.5	4625	3689.5	2854.5	2079	1223.5	698.5	393.5	183	27688

[1] See Footnote 1, Table (5), Appendix V.

APPENDIX VII

Table (6)

Deaths for Selected Causes by Age in the Population at Risk,
Other Locations, Age ≥ 40, 1964-1973

AGE GROUP	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+	Total
	Number of Deaths										
Death Due To:[1]											
ALL CAUSES (001-999)	1	2	4	5	7	5	4	8	5	2	43
Malignant Neoplasms (140-209)	-	1	3	-	-	1	-	1	1	-	7
Diseases of Circulatory System (390-458)	-	1	1	5	6	4	4	5	3	1	30
Diseases of Respiratory System (460-519)	1	-	-	-	-	-	-	1	-	-	2
Accidents, Poisonings, Violence (800-999)	-	-	-	-	-	-	-	-	1	-	1
Malignant Neoplasms of:											
Intestines, Rectum (152-154)	-	-	-	-	-	-	-	-	-	-	-
Other Digestive Organs (155-159)	-	-	-	-	-	-	-	-	-	-	-
Trachea, Bronchus, Lung (162)	-	1	1	-	-	-	-	1	1	-	4
Prostate (185)	-	-	-	-	-	-	-	-	-	-	-
Urinary Bladder, Kidney (188, 189)	-	-	-	-	-	-	-	-	-	-	-
Lymphatic and Hematopoietic System (200-209)	-	-	-	-	-	-	-	-	-	-	-
PERSON YEARS	561.5	391	369.5	454	456.5	333	176.5	106	49.5	12.5	2910

[1] See Footnote 1, Table (5), Appendix V.

APPENDIX VII

Table (7)

Deaths for Selected Causes by Age in the Exposed Group
Age ≥ 40, 1964-1973

	Number of Deaths										
AGE GROUP Death Due To:[1]	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+	Total
ALL CAUSES (001-999)	14	28	64	94	123	144	187	184	147	100	1085
Malignant Neoplasms (140-209)	2	8	18	22	25	36	31	35	24	14	215
Diseases of Circulatory System (390-458)	6	13	31	57	70	85	110	109	98	65	644
Diseases of Respiratory System (460-519)	1	1	1	2	6	5	18	18	10	9	71
Accidents, Poisonings, Violence (800-999)	4	4	5	4	8	2	7	5	2	1	42
Malignant Neoplasms of:											
Intestines, Rectum (152-154)	-	-	3	4	3	3	3	5	5	3	29
Other Digestive Organs (155-159)	-	-	2	-	2	3	4	3	3	3	20
Trachea, Bronchus, Lung (162)	1	5	5	5	12	15	10	11	3	-	67
Prostate (185)	-	-	1	-	-	4	1	5	4	3	18
Urinary Bladder, Kidney (188, 189)	-	-	[illegible]	3	2	4	3	1	-	1	14
Lymphatic and Hematopoietic System (200-209)	-	1	1	1	1	3	2	-	3	1	13
PERSON YEARS	9109.5	8785.5	7733.5	6639	5886	4936	3578.5	2220	1172.5	474.5	

[1] See Footnote 1, Table (5), Appendix V.

APPENDIX VII

Table (8)

Deaths for Selected Causes by Age in Non-Exposed Group
Age ≥ 40, 1964-1973

AGE GROUP	Number of Deaths										
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+	Total
Death Due To:[1]											
ALL CAUSES (001-999)	9	15	27	45	45	53	61	63	49	34	401
Malignant Neoplasms (140-209)	3	5	8	12	12	13	10	8	8	2	81
Diseases of Circulatory System (390-458)	3	7	13	23	29	32	46	42	34	27	256
Diseases of Respiratory System (460-519)	-	-	-	4	1	5	1	2	3	3	19
Accidents, Poisonings, Violence (800-999)	1	3	2	-	-	-	-	-	-	-	6
Malignant Neoplasms of:											
Intestines, Rectum (152-154)	1	-	3	1	1	1	1	1	3	1	13
Other Digestive Organs (155-159)	-	1	3	3	3	1	1	-	-	1	13
Trachea, Bronchus, Lung (162)	-	-	-	1	5	3	2	3	1	-	15
Prostate (185)	-	-	-	-	-	3	3	-	1	-	7
Urinary Bladder, Kidney (188, 189)	-	1	-	1	1	1	1	-	-	-	5
Lymphatic and Hematopoietic System (200-209)	-	-	-	3	1	1	1	1	2	-	9
PERSON YEARS	7641	6328.5	4928	4134	3179	2174.5	1495.5	958.5	495	168	

[1] See Footnote 1, Table (5), Appendix V.

APPENDIX VII

Table (9)

Age-Specific Death Rates/10,000 Person Years for Selected Causes in the Non-Exposed Group, Age ≥ 40, 1964-1973

AGE GROUP	Age-Specific Death Rates/10,000 Person Years									
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Death Due To:[1]										
ALL CAUSES (001-999)	11.8	23.7	54.8	108.3	141.6	243.7	407.9	657.3	989.9	2023.8
Malignant Neoplasms (140-209)	3.9	7.9	16.2	28.9	37.7	59.8	66.9	83.5	161.6	119.0
Diseases of Circulatory System (390-458)	3.9	11.1	26.4	55.4	91.2	147.2	307.6	438.2	686.9	1607.1
Diseases of Respiratory System (460-519)	-	-	-	9.6	3.1	23.0	6.7	20.9	60.6	178.6
Accidents, Poisonings, Violence (800-999)	1.3	4.7	4.1	-	-	-	-	-	-	-
Malignant Neoplasms of:										
Intestines, Rectum (152-154)	1.3	-	6.1	2.4	3.1	4.6	6.7	10.4	60.6	59.5
Other Digestive Organs (155-159)	-	1.6	6.1	7.2	9.4	4.6	6.7	-	-	59.5
Trachea, Bronchus, Lung (162)	-	-	-	2.4	15.7	13.8	13.4	31.3	20.2	-
Prostate (185)	-	-	-	-	-	13.8	20.1	-	20.2	-
Urinary Bladder, Kidney (188, 189)	-	1.6	-	2.4	3.1	4.6	6.7	-	-	-
Lymphatic and Hematopoietic System (200-209)	-	-	-	7.2	3.1	4.6	6.7	10.4	40.4	-

[1] See Footnote 1, Table (5), Appendix V

APPENDIX VII

Table (10)

Data for the Calculation of Age-Specific and Age-Adjusted Death Rates by Exposure Group for Specific Causes of Death, Age ≥ 40, 1964-1973

	EXPOSED			NON-EXPOSED			TOTAL
Age Group	40-64	65-79	80+	40-64	65-79	80+	
Person Years	38153.5	10734.5	1647.0	26230.5	4628.5	663.0	82057
Intestinal Cancer (152-154)[1]	10[2] (2.6)[3]	11 (10.2)	8 (48.6)	6 (2.3)	3 (6.5)	4 (60.3)	42
Lung Cancer (162)	28 (7.3)	36 (33.5)	3 (18.2)	6 (2.3)	8 (17.3)	1 (15.1)	82
Lymphatic and Hematopoietic System Cancer (200-209)	4 (1.0)	5 (4.6)	4 (24.2)	4 (1.5)	3 (6.5)	2 (30.2)	22

[1] See Footnote 1, Table (5), Appendix V.

[2] Number of Deaths

[3] Death rate/10,000 person years

APPENDIX VII

Table (11)

Data for the Calculation of Intestinal and Lung Cancer Mortality Rates by Geographic Location for Exposed and Non-Exposed Groups, Age $\geq$ 40, 1964-1973

AGE GROUP	ATLANTIC PROVINCES			ONTARIO/QUEBEC			WESTERN PROVINCES			TOTAL PERSON YEARS
	Person Years	Intestinal Cancer Deaths	Lung Cancer Deaths	Person Years	Intestinal Cancer Deaths	Lung Cancer Deaths	Person Years	Intestinal Cancer Deaths	Lung Cancer Deaths	
EXPOSED										
40-64	4246.0	1	5	19097.5	7	12	12792.5	2	-	36136.0
65-79	1236.5	1	3	6286.0	10	18	2702.0	-	6	10224.5
80+	212	-	-	1001.0	6	2	384.5	2	14	1597.5
NON-EXPOSED										
40-64	1633.0	-	1	14064.5	5	4	10318.0	1	1	26015.5
65-79	235.0	-	1	2989.0	2	4	1299.0	1	1	4523.0
80+	78.0	-	-	380.5	4	2	192.0	-	1	650.5
TOTAL	7640.5	2	10	17434.0	34	42	27688.0	6	23	79147.0

APPENDIX VII

Table (12)

Data for the Calculation of Intestinal and Lung Cancer Mortality Rates by Duration of Employment for Exposed and Non-Exposed Groups, Age $\geq$ 40, 1964-1973

Duration in Years	11-20			21-30			31+			
AGE GROUP	Person Years	Intestinal Cancer Deaths	Lung Cancer Deaths	Person Years	Intestinal Cancer Deaths	Lung Cancer Deaths	Person Years	Intestinal Cancer Deaths	Lung Cancer Deaths	TOTAL PERSON YEARS
EXPOSED										
40-64	8006.5	5	6	19814.0	2	13	9389.5	3	9	37210.0
65-79	1029.5	1	5	3031.5	2	12	6673.5	8	19	10734.5
80+	215.5	-	-	795.0	4	2	635.0	4	2	1645.5
NON-EXPOSED										
40-64	4926.0	-	1	13009.5	4	-	7599.0	2	5	25534.5
65-79	386.5	-	-	895.5	-	4	3346.5	3	4	4628.5
80+	23.5	-	-	215.0	1	-	417.0	3	2	655.5
TOTAL	14587.5	6	12	37760.5	13	30	28060.5	23	41	80408.5

APPENDIX VII

Table (13)

Number of Deaths by Age for Selected Causes
in the Refinery Group, Age ≥ 40, 1964-1973

AGE GROUP	Number of Deaths										
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-80	80-84	85+	Total
Death Due to:[1]											
ALL CAUSES (001-999)	7	17	42	61	85	111	147	142	123	81	816
Malignant Neoplasms (140-209)	1	5	11	16	19	26	26	28	22	10	164
Diseases of Circulatory System (390-458)	3	8	21	36	47	69	82	85	83	53	487
Diseases of Respiratory System (460-519)	-	1	-	-	5	4	17	13	6	8	54
Accidents, Poisonings, Violence (800-999)	2	2	1	2	7	2	6	4	1	-	27
Malignant Neoplasms of:											
Intestines, Rectum (152,153,154)	1	-	3	4	2	3	3	4	6	2	28
Other Digestive Organs (155-159)	-	1	2	-	3	4	4	3	3	1	21
Trachea, Bronchus, Lung (162)	-	3	1	3	8	11	8	7	2	-	43
Prostate (185)	-	-	-	-	-	2	1	5	4	3	15
Urinary Bladder, Kidney (188,189)	-	-	-	1	2	2	3	1	-	1	10
Lymphatic & Hematopoietic System (200-209)	-	-	1	1	-	2	1	-	1	1	7
PERSON YEARS	5789.5	5855.5	5307	4788	4324	3665	2748	1774.5	981.5	371.5	

[1]See Footnote 1, Table (5), Appendix V.

APPENDIX VII

Table (14)

Number of Deaths by Age for Selected Causes in the Non-Refinery Group, Age ≥ 40, 1964-1973

AGE GROUP	Number of Deaths										
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+	Total
Death Due to:[1]											
ALL CAUSES (001-999)	16	26	49	78	83	86	101	105	73	53	670
Malignant Neoplasms (140-209)	4	8	15	18	18	23	15	15	10	6	132
Diseases of Circulatory System (390-458)	6	12	23	44	52	48	74	66	49	39	413
Diseases of Respiratory System (460-519)	1	-	1	6	2	6	2	7	7	4	36
Accidents, Poisonings, Violence (800-999)	3	5	6	2	1	-	1	1	1	1	21
Malignant Neoplasms of:											
Intestines, Rectum (152-154)	-	-	3	1	2	1	1	2	2	2	14
Other Digestive Organs (155-159)	-	-	3	3	2	-	1	-	-	3	12
Trachea, Bronchus, Lung (162)	1	2	4	3	9	7	4	7	2	-	39
Prostate (185)	-	-	1	-	-	5	3	-	1	-	10
Urinary Bladder, Kidney (188,189)	-	1	-	3	1	3	1	-	-	-	9
Lymphatic & Hematopoietic System (200-209)	-	1	-	3	2	2	2	1	4	[illegible]	15
PERSON YEARS	10961	9258.5	7354.5	6005	4741	3445.5	2326	1404	686	271	

[1]See Footnote 1, Table (5), Appendix V

APPENDIX VII

Table (15)

Age-Specific Death Rates/10,000 Person Years
for Selected Causes in the Non-Refinery Group,
Age ≥ 40, 1964-1973

AGE GROUP	Age Specific Death Rates/10,000 Person Years									
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Death Due to:[1]										
ALL CAUSES (001-999)	14.6	28.1	66.6	129.9	175.1	249.6	434.2	747.9	1064.1	1955.7
Malignant Neoplasms (140-209)	3.6	8.6	20.4	30.0	38.0	66.8	64.5	106.8	145.8	221.4
Diseases of Circulatory System (390-458)	5.5	13.0	31.3	73.3	109.7	139.3	318.1	470.1	714.3	1439.1
Diseases of Respiratory System (460-519)	.9	-	1.4	10.0	4.2	17.4	8.6	49.8	102.0	147.6
Accidents, Poisonings, Violence (800-999)	2.7	5.4	8.2	3.3	2.1	-	4.3	7.1	14.6	36.9
Malignant Neoplasms of:										
Intestines, Rectum (152-154)	-	-	4.1	1.7	4.2	2.9	4.3	14.2	29.2	73.8
Other Digestive Organs (155-159)	-	-	4.1	5.0	4.2	-	4.3	-	-	110.7
Trachea, Bronchus, Lung (162)	.9	2.2	5.4	5.0	19.0	20.3	17.2	49.8	29.2	-
Prostate (185)	-	-	1.4	-	-	14.5	12.9	-	14.6	-
Urinary Bladder, Kidney (188,189)	-	1.1	-	5.0	2.1	8.7	4.3	-	-	-
Lymphatic & Hematopoietic System (200-209)	-	1.1	-	5.0	4.2	5.8	8.6	7.1	58.3	-

[1] See Footnote I, Table (5), Appendix V.

APPENDIX VII

Table (16)

Data for the Calculation of Age-Specific and
Age-Adjusted Death Rates by Refinery Group
for Specific Causes of Death, Age ≥ 40, 1964-1973

	Refinery			Non-Refinery			Total
Age Group	40-64	65-79	80+	40-64	65-79	80+	
Person Years	26,064.0	8,187.5	1,353.0	38,320.0	7,715.5	957.0	82,057.0
Intestinal Cancer (152-154)[1]	10[2] (3.8)[3]	10 (12.0)	8 (59.0)	6 (1.6)	4 (5.6)	4 (42.0)	42
Other Digestive Organ Cancer (155-159)	6 (2.3)	11 (13.4)	4 (30.0)	8 (2.1)	1 (1.3)	3 (31.0)	33
Total	16 (6.1)	21 (23.0)	12 (89.0)	14 (3.6)	5 (7.0)	7 (73.0)	75

1. See Footnote 1, Table (5), Appendix V.
2. Number of deaths.
3. Death rate/10,000 person years.

APPENDIX VII

Table (17)

Data for Calculating Mortality Rates for Intestinal Cancer[1] by Geographic Location for Refinery and Non-Refinery Groups, Age ≥ 40, 1964-1973

Age Group (in years)	Atlantic Provinces				Ontario/Quebec				Western Provinces			
	Deaths	Person Years	Rate	Exp[2]	Deaths	Person Years	Rate	Exp[2]	Deaths	Person Years	Rate	Exp[2]
Refinery												
40-64	2	2730	.00073	45.4	7	15336.5	.00046	28.6	2	7823.5	.00026	37.3
65-79	-	1019.5	-	-	9	5183.5	.00174	25.7	-	1956.0	-	-
80+	-	186	-	-	6	877.5	.00684	15.4	2	284.5	.00703	15.8
Total	2	3935.5		45.4	22	21397.5		69.7	4	10064		53.1
Non-Refinery												
40-64	-	3149	-	-	5	17825.5	.00028	17.4	1	15287	.000065	4.0
65-79	-	452	-	-	3	4091	.00073	10.7	-	2045	-	-
80+	-	104	-	-	4	504	.00794	17.8	1	292	.00342	7.7
Total		3705			12	22420.5		45.9	2	17624		11.7

1. ICDA 8th Revision 153,154.

2. Deaths that would be expected to occur if the total employee population at risk in these provinces experienced these rates.

APPENDIX VII

Table (18)

Data for Calculating Mortality Rates for Total Intestinal Cancer and Other Digestive Organ Cancer[1] by Geographic Location for Refinery and Non-Refinery Groups

Age Group (in years)	Atlantic Provinces			Ontario/Quebec			Western Provinces		
	Deaths	Rate	Exp[2]	Deaths	Rate	Exp[2]	Deaths	Rate	Exp[2]
Refinery									
40-64	2	.00073	45.4	11	.00072	44.7	4	.00051	31.7
65-79	1	.00196	28.9	18	.00347	51.2	1	.00051	7.5
80+	1	.00538	12.1	8	.00912	20.5	3	.01054	23.7
Total	4		86.4	37		116.4	8		62.9
Non-Refinery									
40-64	2	.00064	39.8	10	.00056	34.8	2	.00013	8.1
65-79	-	-		3	.00073	10.8	1	.00049	7.2
80+	-	-		7	.01389	31.2	1	.00342	7.7
Total	2		39.8	20		76.8	4		23.0

1. ICDA 8th Revision 153-159.
2. See Footnote 2, Table (17), this Appendix.

APPENDIX VIII

Numbers of Employees and Person Years for the Total Population at Risk and Subgroups Used in the Calculations of Rates Presented in the Text Tables

APPENDIX VII

Table (20)

Data for Calculating Total Intestinal and Other Digestive Organ Cancer[1] Mortality Rates by Duration of Employment for Refinery and Non-Refinery Groups, Age ≥ 40, 1964-1973

Duration of Employment	11-20		21-30		31+		Total Person Years
Age Group	Person Years	Total Digestive Cancer Deaths	Person Years	Total Digestive Cancer Deaths	Person Years	Total Digestive Cancer Deaths	
Refinery							
40-64	3758.5	5	13312.0	5	8624.0	6	25694.5
65-79	517.5	1	2019.5	6	5650.5	14	8187.5
80+	166.0	-	588.0	7	599.0	5	1353.0
Non-Refinery							
40-64	9174.0	1	19511.5	7	8364.5	6	37050.0
65-79	898.5	-	1907.5	-	4369.5	5	7175.5
80+	73.0	-	422.0	3	453.0	4	948.0
Total	14587.5	7	37760.5	28	28060.5	40	80408.5

1. See Footnote 1, Table (18), this Appendix.

APPENDIX VII

Table (21)

Data for Calculating Intestinal and Lung Cancer[1] Mortality Rates by Refinery and Exposure Groups, Age ≥ 40, 1964-1973

Age Group	Refinery Exposed (N=4920) Person Years	Cancer Deaths Intestinal	Cancer Deaths Lung	Refinery Non-Exposed (N=314) Person Years	Cancer Deaths Intestinal	Cancer Deaths Lung	Moderately Exposed (N=2202) Person Years	Cancer Deaths Intestinal	Cancer Deaths Lung
40-64	2[illegible]49.5	9	5	1361.5	1	-	9022.0	-	1
65-79	7458.0	10	25	487.5	-	1	1100.5	-	1
80+	1251.5	7	2	69.5	-	-	187.0	1	-

Age Group	Non-Refinery Exposed (N=3692) Person Years	Cancer Deaths Intestinal	Cancer Deaths Lung	Non-Refinery Non-Exposed (N=3904) Person Years	Cancer Deaths Intestinal	Cancer Deaths Lung	Total Person Years
40-64	15405.0	1	13	15783.5	5	5	64384
65-79	3276.5	1	11	3040.0	3	6	15363
80+	395.5	1	1	406.0	3	1	2310

1. ICDA 8th Revision, Intestinal Cancer (153,154); Lung Cancer (162).

APPENDIX VII

Table (22)

Age-Adjusted[1] Intestinal and Lung Cancer Death[2] Rates per 10,000 Person Years for Exposure Subgroups, Age ≥ 40, 1964-1973

Expected[3] Cancer Deaths

Age Group	Refinery Exposed Intestinal	Refinery Exposed Lung	Refinery Non-Exposed Intestinal	Refinery Non-Exposed Lung	Moderately Exposed Intestinal	Moderately Exposed Lung	Non-Refinery Exposed Intestinal	Non-Refinery Exposed Lung	Non-Refinery Non-Exposed Intestinal	Non-Refinery Non-Exposed Lung
40-64	25.8	42.5	47.0	-	-	7.1	3.9	54.1	20.6	20.6
65-79	20.6	51.5	-	31.5	-	14.0	4.6	51.6	15.2	30.3
80+	12.9	3.7	-	-	12.4	-	5.8	5.8	17.1	5.7
Total Expected Deaths	59.3	97.7	47.0	31.5	12.4	21.1	14.3	111.5	52.9	56.6
Age-adjusted rates/10,000 person years	7.2	11.9	5.7	3.8	1.5	2.6	1.7	13.6	6.4	6.9

1. Direct adjustment on population at risk, age _ 40.

2. See footnote 1, Table (21), this Appendix.

3. Deaths that would be expected to occur in the total population at risk, if the experience had been the same as that in each group.

Appendix VII

Table (23)

Deaths Due to Selected Causes by Age and Job Description, Age ≥ 40, 1964-1973

Death Due to:	Age Group	Services Custodial (10)[2]	Mechanic Boiler Maker Pipefitter (07,37)	Operator Processor (03,11)	Office Workers (25,45)	Engineers (52,62)	Clerks Marketing (36,66)	Utilities Building Boilerhouse (02)	Garage Route Salesmen (09,33)	Packaging Shipping (06,26)
Intestinal Cancer (153,154)	40-64	-	6	4	5	-	-	-	-	-
	65-79	3	5	1	3	-	1	-	1	-
	80+	-	2	2	3	-	1	2	1	-
Other Digestive System (155-159)	40-64	-	2	-	4	4	1	-	4	-
	65-79	-	5	3	-	-	-	-	-	-
	80+	1	1	2	1	-	-	-	1	-
Lung (162)	40-64	-	8	3	4	-	4	1	6	-
	65-79	1	9	5	7	1	5	4	1	2
	80+	-	-	2	1	-	-	-	-	3
Lymphatic Hematopoietic System (200-209)	40-64	-	-	2	2	1	-	-	-	-
	65-79	1	-	1	2	-	2	-	-	2
	80+	-	1	1	1	-	-	-	-	1

1. See footnote 1, Table (5), Appendix V.

2. Numbers in brackets refer to Job Codes.

APPENDIX VIII

Numbers of Employees and Person Years for the Total Population at Risk and Subgroups Used in the Calculations of Rates Presented in the Text Tables

Appendix VIII

Table (1)

Numbers of Employees and Person Years of Observation
by Age for the Population at Risk and Subgroups, All Ages,
1964-1973

Age Group	Population At Risk		Refinery		Non-Refinery		Exposed		Non-Exposed	
	Number	Person Years	Number	Person Years	Number	Person Years	Number	Person Years	Number	Person Years
Total	15,032	120636.5	5,731	46713.0	9,301	73923.5	8,612	69089.5	6,420	51547.0
<40	4,325	38579.5	1,216	11108.5	3,109	27471.0	2,089	18554.5	2,543	20025.0
40-64	7,562	64384.0	2,820	26064.0	4,742	38320.0	4,326	38153.5	2,947	26230.5
65-79	2,480	15363.0	1,296	8187.5	1,184	7175.5	1,737	10733.5	743	4628.5
80+	665	2310.0	399	1353.0	266	957.0	466	1647.0	187	663.0
≥40	10,707	82057.0	4,515	35604.5	6,192	46452.5	6,523	50534.0	3,877	31522.0
40-44	1,686	16750.5	489	5789.5	1,197	10961.0	887	9109.5	510	7641.0
45-49	1,777	15114.0	624	5855.5	1,153	9258.5	970	8785.5	807	6328.5
50-54	1,610	12661.5	629	5307.0	981	7354.5	936	7733.5	674	4928.0
55-59	1,339	10793.0	574	4788.0	765	6005.0	857	6639.0	482	4154.0
60-64	1,150	9065.0	504	4324.0	646	4741.0	676	5886.0	474	3179.0
65-69	1,019	7110.5	512	3665.0	507	3446.0	702	4936.0	317	2174.5
70-74	847	5074.0	469	2748.0	378	2326.0	611	3578.5	236	1495.5
75-79	614	3178.5	315	1774.5	299	1404.0	424	2220.0	190	958.5
80-84	404	1667.5	242	981.5	162	686.0	285	1172.5	119	495.0
85+	261	642.5	157	371.5	104	271.0	181	474.5	68	168.0

Appendix VIII

Table (2)

Person Years by Geographic Location

for the Population at Risk and Subgroups, All Ages,

1964-1973

Age Group	Population at Risk	Refinery	Non-Refinery	Exposed	Non-Exposed
			Atlantic Provinces		
	(1,200)[1]	(568)	(632)	(841)	(359)
<40	2,591.5	1,034.0	1,557.5	1,590.5	1,001.0
40-64	5,879.0	2,730.0	3,149.0	4,246.0	1,633.0
65-79	1,471.5	1,019.5	452.0	1,236.5	235.0
80+	290.0	186.0	104.0	212.0	78.0
≥40	7,640.5	3,935.5	3,705.0	5,694.5	1,946.0
Total	10,232.0	4,969.5	5,262.5	7,285.0	2,947.0
			Ontario/Quebec		
	(7,951)	(3,552)	(4,399)	(4,406)	(3,545)
<40	20,856.0	7,127.0	13,729.0	9,767.0	11,089.0
40-64	33,162.0	15,336.5	17,825.5	19,097.5	14,064.5
65-79	9,275.0	5,183.5	4,091.5	6,286.0	2,989.0
80+	1,381.5	877.5	504.0	1,001.0	380.5
≥40	43,818.5	21,397.5	22,421.0	26,384.5	17,434.0
Total	64,674.5	28,524.5	36,150.0	36,151.5	28,523.0
			Western Provinces		
	(5,287)	(1,558)	(3,729)	(2,819)	(2,468)
<40	13,741.0	2,783.5	10,957.5	5,887.0	7,854.0
40-64	23,110.5	7,823.5	15,287.0	12,792.5	10,318.0
65-79	4,001.0	1,956.0	2,045.0	2,702.0	1,299.0
80+	576.5	284.5	292.0	384.5	192.0
≥40	27,688.0	10,064.0	17,624.0	15,879.0	11,809.0
Total	41,429.0	12,847.5	28,581.5	21,766.0	19,663.0

Age Group	Population at Risk	Refinery	Other Non-Refinery	Exposed	Non-Exposed
	(594)	(53)	(541)	(546)	(48)
<40	1,391.0	164.0	1,227.0	1,310.0	81.0
40-64	2,232.5	174.0	2,058.5	2,017.5	215.0
65-79	615.5	28.5	587.0	510.0	105.5
80+	62.0	5.0	58.0	49.5	12.5
≥40	2,910.0	207.5	2,702.5	2,577.0	333.0
Total	4,301.0	371.5	3,929.5	3,887.0	414.0

1. Numbers in brackets refer to number of employees in each group.

Appendix VIII

Table (3)

Person Years by Job Description, Age ≥ 40,

1964-1973

Age Group	Services Custodial Watchman	Mechanics Boilermakers Pipefitters	Operators Processors Etc.	Office Workers	Engineers	Clerks Marketing Plant	Utilities Bldg Trades Boilerhouse	Garage Workers, Route Salesmen	Packaging Shipping
	(10)[1]	(07,37)	(03,11)	(25,45)	(52,62)	(36,66)	(02)	(09,19)	(06,26)
40-44	59.0	1,821.5	1,782.0	4,316.0	1,490.0	755.0	192.0	1,475.0	512.5
45-49	105.0	1,890.0	1,873.5	3,618.0	1,215.5	848.5	192.5	1,326.0	611.0
50-54	152.5	1,702.0	1,616.0	3,033.0	779.5	797.0	189.0	1,041.5	641.0
55-59	189.0	1,505.5	1,399.0	2,689.0	504.5	677.0	205.0	667.5	661.5
60-64	191.0	1,478.5	1,250.5	2,095.5	254.0	622.0	243.5	419.5	653.0
65-69	200.5	1,330.0	1,038.5	1,498.5	123.0	466.5	236.0	298.5	526.0
70-74	170.5	1,098.0	739.5	1,012.0	81.5	320.5	153.5	257.0	324.5
75-79	102.5	709.5	421.5	604.0	60.5	207.0	122.0	195.5	157.0
80-84	50.5	334.0	218.0	320.5	[illegible]	115.0	104.0	114.0	58.0
85+	11.5	93.0	79.0	124.5	13.0	49.0	64.0	48.5	33.0
Total Person-Years	1,232.0	12,022.0	10,417.5	19,308.0	4,599.0	4,857.5	1,701.5	5,843.0	4,177.5
Total No. of Employees	156	1,496	1,303	2,546	625	609	226	807	494

1. Numbers in brackets represent job code numbers which refer to the job description (Job Title). See Appendix III for more details of Job Titles.

Appendix VIII

Table (4)

Person Years by Age and Duration

of Employment for Refinery and Exposure Groups, Age ≥ 40,

1964-1973

Person Years

Age Group	Refinery			Non-Refinery			
	11-20[1]	21-30	31+	11-20	21-30	31+	Total
	(686)[2]	(2,014)	(1,679)	(1,671)	(2,661)	(1,465)	
40-64	3,758.5	13,312.0	8,624.0	9,174.0	19,511.5	8,364.5	62,744.5
65-79	517.5	2,019.5	5,650.5	898.5	1,907.5	4,369.5	15,363.0
80+	166.0	588.0	599.0	73.0	422.0	453.0	2,301.0
Total	4,442.0	15,919.5	14,873.5	10,145.5	21,841.0	13,187.0	80,408.5

	Exposed			Non-Exposed			
	(1,399)	(2,915)	(1,894)	(958)	(1,760)	(1,250)	
40-64	8,006.5	19,814.0	9,389.5	4,926.0	13,009.5	7,599.0	62,744.5
65-79	1,029.5	3,031.5	6,673.5	386.5	895.5	3,346.5	15,363.0
80+	215.5	795.0	635.0	23.5	215.0	417.0	2,301.0
Total	9,251.5	23,640.5	16,698.0	5,372.0	14,120.0	11,362.5	80,408.5

1. Duration of employment, in years.

2. See footnote 1, Table (2), this Appendix.

Appendix VIII

Table (5)

Person Years by Age and Adjusted Duration of Employment for Refinery and Exposure Groups, Age $\geq$ 40, 1963-1974

Person Years

Age Group	Refinery			Non-Refinery		
	11-20[1]	21-30	31+	11-20	21-30	31+
40-64	8,974.0	11,652.5	4,916.0	15,246.0	15,559.0	5,218.0
65-79	642.5	2,026.5	5,556.0	1,360.5	3,083.0	6,279.0
80+	166.0	588.0	599.0	215.5	795.0	635.0
Total	9,782.5	14,267.0	11,071.0	16,822.0	19,437.0	12,132.0

1. See footnote 1, Table (4) this Appendix.

Appendix IX

Cases of Intestinal Cancer Deaths Showing

Job Descriptions

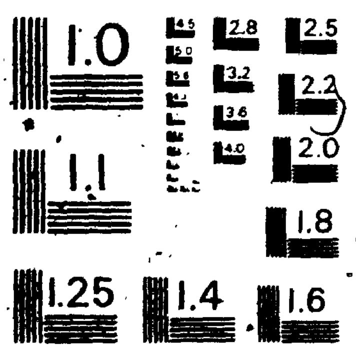
Case No.	Geographic Location	Age (Years)	Years in Service	Job Description	Exposure Category[1]
1	Ontario	87	29	Insulator	E
2	Ontario	57	18	Operator	E
3	Quebec	70	40	Mechanic (Tin)	E
4	British Columbia	85	35	Head Pumpman	E
5	Ontario	77	36	Still Cleaner	E
6	Quebec	75	37	Field Supervisor	*
7	Ontario	83	34	Clay Plant	E
8	Ontario	69	36	Mechanic-Pipefitter	E
9	Nova Scotia	57	26	Operator	E
10	Ontario	65	27	Watchman	*
11	Ontario	80	30	Mechanic-Welder	E
12	Quebec	61	42	Mechanic	E
13	British Columbia	80	35	Shift Foreman	*
14	Ontario	74	26	Plant Protection	*
15	Ontario	74	41	Mechanic (Supervisor)	E
16	Nova Scotia	68	39	Mechanic-Welder	E
17	Quebec	76	38	Mechanic-Pipefitter	E
18	Quebec	50	16	Mechanic-Building	E
19	Ontario	60	35	Sr. Clerk Dispatcher	NE
20	Ontario	83	32	Mechanic-Pipefitter	E
21	Ontario	80	29	Boilerhouse	E
22	Manitoba	59	20	Mechanic-Pipefitter	E
23	Manitoba	52	19	Mechanic-Pipefitter	E
24	Ontario	76	14	Garage	E
25	Ontario	59	19	Operator	E
26	Ontario	54	25	Operator	E

27	Ontario	40	22	General Clerk-Business Services	NE
28	Quebec	64	36	Mechanic	E
29	Ontario	78	37	Warehouse Foreman	E
30	Ontario	86	25	Marketing Plant	E
31	Ontario	54	30	Title Not Listed	-
32	Ontario	53	34	Systems Analyst	NE
33	Ontario	63	26	Landman	NE
34	Saskatchewan	58	27	Sales Representative	NE
35	Quebec	54	35	Supervisor-Office Sales	NE
36	Alberta	68	37	Sales Representative	NE
37	Quebec	86	48	Office	NE
38	Ontario	80	35	Office	NE
39	Ontario	70	33	Office Manager	NE
40	Ontario	79	32	Credit Clerk	NE
41	Ontario	83	34	Treasurer	NE
42	Ontario	80	24	Refinery-Manager	*

1. E - Exposed
   NE - Non-Exposed

Workers, likely to have had 'exposed' jobs earlier in their careers but categorized as 'non-exposed' by job description, have been identified by (*).

3 OF/DE 3



PY RESOLUTION TEST CHART

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APPENDIX X

Computer Program for Calculating Person Years and Standard Mortality Ratios

```
      PROGRAM SMR(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     1  TAPE1,TAPE2,TAPE3)
      REAL TEMP(6)
      REAL SMRTAB(16,6),CAUSE(2,3)
       INTEGER ICARD(80)

      REAL TABLE(16)

      DATA TABLE/20.0,25.0,30.0,35.0,40.0,45.0,50.0,
     1 55.0,60.0,65.0,70.0,75.0,80.0,85.0,1000.0,0.0/
       DATA              FILE/0.0/,IUPPER/19/,IRANGE/5/,CAUSE/6*0.0/
        DATA INUMCAU  /3/


C               TAPE1=READ INPUT DATA
C               TAPE2=WRITE DATA FILE (MANYEARS FILE)

C               1ST READ THE ASDR RATES PER 1000

      IUNIT=2
 1    REWIND IUNIT
      ICOUNT=0

      DO 2 I=1,16
 2    SMRTAB(I,1)=TABLE(I)
      DO 3 I=1,16
      DO 3 J=2,6
 3    SMRTAB(I,J)=0.0
      ZERO=0.0
      IDTHCNT=0
 6990 FORMAT(1H1,*            STANDARD MORTALITY STUDIES*///)
      READ(5,5000)ICARD
 5000  FORMAT(80A1)
      IF(EOF(5))30,50
 30   STOP
```

```
40      IF(IUNIT.EQ.2)GO TO 49
         FILL=OLDCD
           GO TO 54
49      WRITE(6,7000)
7000    FORMAT(1H1,*  ADDING A NEW POPULATION TO MANYEARS FILE*////)

C                  PICK UP OLD MANYRS FILE AND DETERMINE NEW FILE #

        OLDCD=0.0
41      READ(IUNIT)CODE,COD2
        IF(EOF(2))45,42
42      IF(CODE.LT.0.0)OLDCD=ABS(CODE)
        WRITE(3)CODE,COD2
        IF(FILL.EQ.-3.0)WRITE(6,7006)CODE,COD2
        GO TO 41
45      OLDCD=OLDCD+1.0
        CODE=-OLDCD
        WRITE(6,7002)OLDCD
7002    FORMAT(///1H ,*CODE NUMBER ASSIGNED....*,F7.0///)
        WRITE(3)CODE,ZERO
        IF(FILL.LE.-2.0)WRITE(6,7006)CODE,ZERO
        GO TO 100
50      CONTINUE
         IF(ICARD(1).EQ.1H*)GO TO 7750
         WRITE(6,7751)ICARD
         GO TO 1
7751     FORMAT(1H1,*CAUSE OF DEATH CARD EXPECTED HERE*////////
     1      1H ,80A1)
7750     BACKSPACE 5
         READ(5,7760)FILE,IUPPER,IRANGE,CAUSE
7760     FORMAT(1X,F2.0,I2,I2,2X,6F3.0)
         IF(CAUSE(2,1).LE.0.0) CAUSE(2,1)=1000.0
        IF(FILL.EQ.0.0)GO TO 40
        IF(FILL.LE.-2.0)GO TO 40
        IF(FILL.GT.0.0)GO TO 54
```

```
C                LIST OUT MANYEARS FILE
        WRITE(6,7004)
7004    FORMAT(1H1,30X,*MANYEARS FILE*///)
51      READ(IUNIT)CODE,COD2
        IF(EOF(2))1,53
53      WRITE(6,7006)CODE,COD2
7006    FORMAT(1H ,F10.0,F13.3)
        GO TO 51
54      CONTINUE
C                FILL  UP SMR TABLE FOR THIS POPULATION
55      READ(IUNIT)CODE,COD2
        IF(EOF(2))58,57
57      IF(FILE.NE.-CODE)GO TO 55
        GO TO 60
58      WRITE(6,7204)FILE
        GO TO 1
7204    FORMAT(////*1 FILE # *,F5.0,*  DOES NOT EXIST*///)
60      READ(IUNIT)CODE,COD2
        IF(CODE.EQ.0.0)GO TO 65
        I=IFIX(CODE)
         DO 63 IXY=1,INUMCAU
         IF(COD2 .LT. CAUSE(1,IXY))GO TO 63
         IF(COD2.GT.CAUSE(2,IXY))GO TO 63
         SMRTAB(I,5)=SMRTAB(I,5) + 1.0
         GO TO 60
63       CONTINUE
        GO TO 60
65      ICOUNT=IFIX(COD2)
        DO 70 I=1,16
70      READ(IUNIT)CODE,SMRTAB(I,2)
        GO TO 3000
```

```
C                READ A SUBJECT
100     CONTINUE
C                DEBUGGING OUTPUT
C       WRITE(6,9950)(SMRTAB(I,2),I=1,15)
9950    FORMAT(1H0,15F7.2)
        READ(1,5020)ID,[illegible]TAGE,YRSSER,ISTATUS,TERMYR,TERMMTH,DEATHYR,
      1  DEATHMH,DATAYRTAGE,YRBORN,YRBGEM,AGBGEM,RKAUSE
5020    FORMAT(I6,F2.0,F3.0,1A1,4F2.0,F4.0,F3.0,2F4.0,F2.0,F3.0)
        IF(EOF(1))110,150
C                WRITE OUT END OF DEATH CAUSES MARKER
110     COUNT=FLOAT(ICOUNT)
        WRITE(3)ZERO,COUNT
        IF(FILL.LE.-2.0)WRITE(6,7006)ZERO,COUNT
C                WRITE OUT MANYEARS TABLE
        SMRTAB(16,2)=0.0
        DO 120 I=1,15
        WRITE(3)SMRTAB(I,1),SMRTAB(I,2)
        IF(FILL.LE.-2)WRITE(6,7006)SMRTAB(I,1),SMRTAB(I,2)
120     SMRTAB(16,2)=SMRTAB(16,2) + SMRTAB(I,2)
        WRITE(3)SMRTAB(16,1),SMRTAB(16,2)
        IF(FILL.LE.-2)WRITE(6,7006)SMRTAB(16,1),SMRTAB(16,2)
        WRITE(6,7008)IDTHCNT,ICOUNT
7008    FORMAT(1H1,I8,*  DEATHS AMONGST*,I6,* SUBJECTS*/7X)
        FRM=SMRTAB(1,1)-1.0
        WRITE(6,7168)FRM,SMRTAB(1,2)
        DO 130 I=2,14
```

```
      FRM=SMRTAB(I-1,1)
      TOOO=SMRTAB(I,1) - 1.0
  130 WRITE(6,7170)FRM,TOOO,SMRTAB(I,2)
      FRM=TOOO+1.0
      WRITE(6,7172)FRM,SMRTAB(15,2)
      WRITE(6,7190)SMRTAB(16,2)
      FILE=OLDCD
      IUNIT=3
      GO TO 3000
C             YRBGEM=31 DEC....CHANGE TO 1 JANUARY
  150 CONTINUE
      YRBGEM=YRBGEM + 1
      ENDMTH=12.0
      ENDYEAR=DATAYR
      ENDAGE=AGE
  200 BEGYEAR=1964.0
C             GET HIS AGE AT STARTING DATE(1 JANUARY)
      BEGAGE=ENDAGE-ENDYEAR+1963.0
      IF(YRBGEM .LE. 1964.0)GO TO 230
      DIFF=YRBGEM - 1964.0
      BEGYEAR=YRBGEM
      BEGAGE=BEGAGE+DIFF
  230 SLRV=ENDYEAR-BEGYEAR+1
      IF((ISTATUS.NE.1HD).AND.(ISTATUS.NE.1HZ))GO TO 232
      SLRV=SLRV-0.5
      ENDMTH=DEATHMH
      IF(ENDMTH.LE.0)ENDMTH=6.0
      GO TO 233
  232 IF(ISTATUS.NE.1HT)GO TO 233
      SLRV=SLRV-0.5
      ENDMTH=TERMMTH
```

```
      IF(ENDMTH.LE.0)ENDMTH=6.0
233   IF((SERV .GT. 0).AND.(SERV .LE. 10))GO TO 235
      WRITE(6,7009)ID,SERV
      GO TO 100
7009  FORMAT(1H ,*ID NUMBER *,I7,* DISCARDED..YEARS SERVICE = *,
     1   F8.0)
235   BLGMTH=1.0
C             CHECK AGE VALID
      IF(BEGAGE .GT. 0) GO TO 250
      WRITE(6,7030)ID,BEGAGE
7030  FORMAT(1H ,*ID NUMBER *,I8,* DISCARDED..AGEBEGEMPL = *,F8.0)
      GO TO 100
250   ICOUNT=ICOUNT + 1
      BLGDAY=1.0
C             FIND AGE GROUP SUBJECT BEGAN WORKING IN
259   I=1
260   IF(BEGAGE .LT. SMRTAB(I,1))GO TO 270
      I=I+1
      GO TO 260
C             CALC # OF YEARS HE WORKED IN THIS 1ST GROUP
C             AND SO RECORD
270   YRS=SMRTAB(I,1) - BEGAGE - 0.5
280   IF(YRS.GT.SERV)YRS=SERV
      IF(YRS.LE.0)GO TO 550
      SMRTAB(I,2)=SMRTAB(I,2) + YRS
C             NOW PROCESS NEXT AGE GROUP THIS SUBJECT
C             AFTER DECREMENTING NUMBER OF YEARS YET TO ACCOUNT FOR
```

```
      SLRV=SLRV-YRS
      YRS=5.0
      I=I+1
      GO TO 280
550   CONTINUE
C              IF HE DIED DURING THIS 10 YR PERIOD, ADD HIM TO
C              APPROPRIATE AGE GROUP. THEN GO FOR NEXT SUBJECT.

      IF((ISTATUS .NE. 1HD).AND.(ISTATUS .NE. 1HZ))GO TO 100
      I=1
555   IF(AGE .LT. SMRTAB(I,1))GO TO 560
      I=I+1
      GO TO 555
560   CONTINUE
C              ADD CAUSE OF DEATH AND TABLE POSITION TO MANYEARS FILE

      IDTHCNT=IDTHCNT+1
      Z=FLOAT(I)
      WRITE(3)Z,RKAUSE
      IF(FILE.LE.-2.0)WRITE(6,7006)Z,RKAUSE
       DO 6363 IXY=1,INUMCAU
       IF(RKAUSE .LT. CAUSE(1,IXY))GO TO 6363
       IF(RKAUSE.GT.CAUSE(2,IXY))GO TO 6363
       SMRTAB(I,5)=SMRTAB(I,5) + 1.0
       GO TO 100
6363     CONTINUE
      GO TO 100
3000   CONTINUE
       READ(5,5000)ICARD
       IF(EOF(5)) 30,3003
3003   CONTINUE
       BACKSPACE 5
       IF(ICARD(1).NE.1H$)GO TO 1
       READ(5,7780)(SMRTAB(I,3),I=1,15)
7780   FORMAT(1X,15F4.1)
```

```
C                CALC EXPECTED DEATHS
3008      WRITE(6,6890)
          IUPPER=((IUPPER-19)/5)+1
          IF(IUPPER.LT.0)IUPPER=1
          IF(IUPPER.GT.13)IUPPER=13
          IF(IUPPER.LE.1)GO TO 3014
          SMRTAB(1,1)=SMRTAB(IUPPER,1)
          DO 3010 J=2,6
          TEMP(J)=0.0
          DO 3010 I=1,IUPPER
3010      TEMP(J)=TEMP(J)+SMRTAB(I,J)
          DO 3012 I=2,6
          IF(I.EQ.3)GO TO 3012
          SMRTAB(1,I)=TEMP(I)
3012      CONTINUE
3014      CONTINUE
          ISTLIM=13-IUPPER+1
          IF(IRANGE.LT.9)IRANGE=5
          ISTEP=IRANGE/5
          IF(ISTEP.GT.ISTLIM)ISTEP=ISTLIM
          NUMRNG=1
          IST=IUPPER+1
3019      CONTINUE
          IEND=IST+ISTEP-1
          NUMRNG=NUMRNG+1
          IF(IEND.GE.15)GO TO 3030
          SMRTAB(NUMRNG,1)=SMRTAB(IEND,1)
          DO 3020 J=2,6
          TEMP(J)=0.0
          DO 3020 I=IST,IEND
3020      TEMP(J)=TEMP(J)+SMRTAB(I,J)
          DO 3025 I=2,6
          IF(I.EQ.3)GO TO 3025
```

```
      SMRTAB(NUMRNG,I)=TEMP(I)
3025  CONTINUE
      IST=IEND+1
      GO TO 3019
3030  SMRTAB(NUMRNG,I)=SMRTAB(IST,I)
      DO 3035 J=2,6
      TEMP(J)=0.0
      DO 3035 I=IST,15
3035  TEMP(J)=TEMP(J)+SMRTAB(I,J)
      DO 3040 I=2,6
      IF(I.EQ.3)GO TO 3040
      SMRTAB(NUMRNG,I)=TEMP(I)
3040  CONTINUE
3048  CONTINUE
      DO 3050 I=1,NUMRNG
3050  SMRTAB(I,4)=(SMRTAB(I,2)*SMRTAB(I,3))/1000.0
C            NOW CALC SMRIS IN PERCENTS,
C            1ST SUM UP OBSYRS, DEATHS, AND EXPECTED DEATHS
      DO 3100 I=1,NUMRNG
      SMRTAB(16,4)=SMRTAB(16,4) + SMRTAB(I,4)
      SMRTAB(16,5)=SMRTAB(16,5) + SMRTAB(I,5)
      IF(SMRTAB(I,4).EQ.0.0) GO TO 3100
      SMRTAB(I,6)=(SMRTAB(I,5)/SMRTAB(I,4))*100.0
3100  CONTINUE
      SMRTAB(16,6)=(SMRTAB(16,5)/SMRTAB(16,4))*100.0
C            PRINT OUT STATS
      WRITE(6,7100)ICOUNT,FILE
7100  FORMAT(///1H ,I10,* RECORDS, POPULATION CODE  *,F5.0///)
      WRITE(6,7150)CAUSE(1,I),CAUSE(2,I)
7150  FORMAT(1H ,18X,*AGE GROUP*,8X,*MANYEARS  ASDR(RATES *
     1  *PER 1000)  DEATHS EXPECTED  DEATHS OBSERVED  SMR-PERCENT*/
     1 1H ,18X,* FROM    TO  *,13X,
```

```
     1         *CAUSES  *,F5.0,* TO*,F7.0)
               IF(INUMCAU   .LE. 1) GO TO 8968
               DO 4453 J= 2,INUMCAU
               IF(CAUSE(1,J).LE.0) GO TO 8968
               WRITE(6,7151)CAUSE(1,J),CAUSE(2,J)
  7151         FORMAT(1H ,52X,F5.0,3X,F7.0)
  4453         CONTINUE
  8968        FRM=SMRTAB(1,1) - 1.00
               WRITE(6,7895)
  7895         FORMAT(///)
              WRITE(6,7168)FRM,(SMRTAB(1,J),J=2,6)
  7168        FORMAT(1H ,15X,F6.0,* OR UNDER*,F10.2,F15.2,F22.3,
     1          F16.3,F15.5)
              ITEMP=NUMPNG - 1
              DO 3200 I=2,ITEMP
              FRM=SMRTAB(I-1,1)
              TODD=SMRTAB(I,1) - 1.0
  3200        WRITE(6,7170)FRM,TODD,(SMRTAB(I,J),J=2,6)
  7170        FORMAT(1H ,18X,2F6.0,F10.2,F15.2,F22.3,F16.3,F15.5)
              FRM=TODD+1.0
              WRITE(6,7172)FRM,(SMRTAB(NUMPNG,J),J=2,6)

  7172        FORMAT(1H ,15X,F6.0,* OR OVER *,F10.2,F15.2,F22.3,F16.3,
     1          F15.5)
              WRITE(6,7190)SMRTAB(16,2),(SMRTAB(16,J),J=4,6)
  7190        FORMAT(//* TOTALS*,18X,F16.2,15X,F22.3,F16.3,F15.5)
              GO TO 1
              END
```

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