

A Mortality Study of Oil Refinery Workers

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Survival status of 1205 men employed for more than five years in a Canadian oil refinery in East Montreal, from 1928 through 1976, was assessed and death certificates were reviewed. Expected numbers of deaths were estimated based upon age- and cause-specific death rates for the Province of Quebec applied to person-years at work. Oil refinery workers showed a standard mortality ratio lower than expected for all causes of death (SMR = 78.43). Three cancers of the brain were found among young people who died less than 20 years since start of exposure. This was statistically higher than expected. Cancers of the digestive system, though not significantly higher than expected, remained suspect of being associated with work. There is a need to expand this research to other oil refinery workers.

Though processing in an oil refinery is carried out in airtight compartments, the presence of hydrocarbons of all kinds and the possibility of worker exposure to these chemicals at the time of sampling and maintenance raises the possibility that cancers of occupational origin may appear in this environment.

Few epidemiological studies dealing with the health of oil refinery workers have been reported. Mortality rates from genital cancers, lymphomas,¹ cancers of the digestive system and lung cancers^{2,3} were described as conspicuous and appeared to be exposure-related, but their excess was neither large nor statistically significant and could have been a chance occurrence.

Occupations other than those encountered in an oil refinery in which workers were exposed to oil derivatives were associated with the appearance of cancer. Benzopyrene was associated with an increase in lung cancer deaths.^{4,5,6} Benzene was suspected of inducing leukemia.⁷ A high incidence of urinary bladder cancer among workers in the rubber industry led to confirmation of a causal association between exposure to betanaphthylamine and urinary bladder cancer in man.⁸

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This mortality study was carried out in a Canadian oil refinery plant which has been in operation since 1928 and which has had an average work force of 750 men over the years. The purpose of the study was to determine if cancer mortality among oil refinery workers was higher than expected.

Methods

Study Population. — The study population comprised all men who worked at the oil refinery for more than five years between the start of operations in 1928 and December 31, 1975.

Survival Status. — The survival status was determined as of December 31, 1976. The company furnished the name, date of birth, date of employment, work termination date, last known address, the social insurance and unemployment insurance numbers, when known, as well as a classification of workers according to type of work (operation, maintenance, or office work). A detailed service file showing in chronological order the occupations and the departments in which each person worked during his years of employment was made available upon request so that references could be made to it when further details were needed.

People who no longer were in the company's employ were traced through several means: telephone calls, inquiries at the Motor Vehicle Bureau, the Quebec Health Insurance Board, the Pension Board, and the Unemployment Insurance Commission, and circular letters to fellow workers. Persons whose survival status could not be ascertained by a direct personal contact or through their family or friends, even though a current address was found in the registries, were considered lost.

The list of untraced workers was linked to the death certificates filed at the Quebec Population Registry to further increase the number of traced people. Death certificates were consulted and causes of death were recorded according to the 8th Revision of the International Classification of Disease.

Expected Number of Deaths. — A chart of person-years worked was calculated.⁹ A man entered the chart after five years of work in the oil refinery. He remained under observation to the time of his death or December 31,

Table 1.—Distribution of 1205 Oil Refinery Workers According to Survival Status as of December 31, 1976.		
Survival Status	Male Workers	
	No.	%
Alive	907	75
Dead	108	9
Cause known	104	
Cause unknown	4	
Lost to follow-up	190	16
Total	1 205	100

1976, whichever came first. For the years 1928 to 1962, the expected number of deaths was based upon the age- and cause-specific death rates for the Province of Quebec, 1951, while for the years 1963 to 1976, those of 1971 were used.

The influence of time evolved between the start of exposure and the cancer appearance was studied by dividing the population into two subgroups, more than 20 years and less than 20 years of elapsed time between the date of employment and the time of death. Expected numbers of deaths were determined and the standard mortality ratios (SMR) were calculated for each subgroup.

The Bailar-Ederer test for the ratio of a Poisson variable to its expectation was used to test the differences

Table 2.—Distribution of 1205 Oil Refinery Workers According to Survival Status and Birth Date.						
Date of Birth	Alive		Dead		Lost to Follow-up	
	No.	%	No.	%	No.	%
1860-1864	—	—	2	1.9	—	—
1865-1869	2	0.2	5	4.6	—	—
1890-1894	1	0.1	5	4.6	2	1.1
1895-1899	6	0.7	12	11.1	1	0.5
1900-1904	19	2.1	9	8.3	2	1.1
1905-1909	38	4.2	16	16.17	5	2.6
1910-1914	44	4.9	17	15.7	17	8.9
1915-1919	63	6.9	13	12.0	13	6.8
1920-1924	154	17.0	14	13.0	37	19.5
1925-1929	141	15.5	6	5.6	48	25.3
1930-1934	104	4.8	5	4.6	36	18.9
1935-1939	75	8.3	1	0.9	13	6.8
1940-1944	99	10.9	1	0.9	10	5.3
1945-1949	103	11.4	—	—	6	3.2
1950-1954	8	0.9	—	—	—	—
Total	907	100	108	100	190	100

Table 4.—Person-Years Worked by Time Period and Age (1015 Men who Worked for Over 5 Years at the Oil Refinery).													
Time Period	Age												
	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80+
1926-32	—	—	—	—	—	—	—	—	—	—	—	—	—
1933-37	5.0	5.1	6.1	8.6	3.4	5.6	3.9	—	—	—	—	—	—
1938-42	8.6	45.7	85.3	71.5	36.3	21.0	22.1	9.8	1.2	—	—	—	—
1943-47	14.0	67.5	96.4	150.9	109.2	59.5	31.3	27.9	10.1	1.2	—	—	—
1948-52	17.7	179.3	216.9	205.4	221.8	150.8	83.6	33.8	27.7	9.2	1.2	—	—
1953-57	32.3	243.2	448.9	421.0	281.8	241.6	156.8	78.5	31.8	27.8	4.3	—	—
1958-62	15.5	293.2	537.7	716.1	510.5	286.5	237.1	151.9	80.3	29.8	25.3	0.8	—
1963-67	12.1	178.5	560.9	715.4	777.7	511.5	263.0	223.2	145.8	73.4	17.8	14.3	0.8
1968-72	8.2	162.3	281.4	621.7	725.5	774.4	494.8	252.5	205.9	133.9	54.8	9.9	9.1
1973-76	0.8	241.2	338.5	304.4	527.9	581.4	601.1	358.4	179.2	153.6	79.4	32.5	10.3
Total	114.2	1416.6	2572.1	3214.8	3194.1	2632.5	1893.9	1136.0	682.0	428.9	182.8	57.5	20.2

Table 3.—Distribution of 1205 Oil Refinery Workers According to Survival Status and Date of Employment						
Date of Employment	Alive		Dead		Lost to Follow-up	
	No.	%	No.	%	No.	%
1925-1932	19	2.1	17	15.7	3	1.6
1933-1937	27	3.0	18	16.7	8	4.3
1938-1942	46	5.1	20	18.6	16	8.5
1943-1947	142	15.7	31	28.7	26	13.7
1948-1952	232	25.7	12	11.1	59	31.1
1953-1957	135	14.9	5	4.6	36	18.9
1958-1962	99	10.9	2	1.9	22	11.5
1963-1967	95	10.5	3	2.8	13	6.8
1968-1971	142	15.7	0	0	7	3.7
Total	907	100	108	100	190	100

between the observed and the expected numbers of deaths.¹⁰

Results

The Study Population.—Table 1 shows the survival status of the people of the study population. There were 1205 male employees who worked for more than five years at the refinery. Of these, 190 men were considered lost to follow-up. The studied group comprised 1015 men or 84% of the total study population.

Tables 2 and 3 show the distribution of the employees alive, dead or lost to follow-up according to their birth dates and their dates of employment. The distribution of the lost-to-follow-up men according to age and date of employment was similar to that of the regrouped alive and dead men. The lost-to-follow-up group is therefore expected not to generate any bias in the overall result of the study.

Mortality Among Oil Refinery Workers.—There were 108 deaths in the employee population during the 49-year observation period. Ninety-one percent of the deaths (98 men) occurred in the group of employees who were over 40 years of age. The person-years of exposure chart generated from the study cohort is shown in Table 4.

Table 5 shows the observed and expected numbers of deaths and standard mortality ratios according to the time elapsed since start of exposure. Whereas the overall mortality is lower than expected among the refinery workers (SMR=78.43), the SMRs for specific causes, though sometimes differing from 100, were not statistically significant.

When mortality is studied according to whether more than 20 years or less than 20 years have elapsed between

Table 5 — Observed and Expected Number of Deaths and Standard Mortality Ratio (SMR) Among Oil Refinery Workers (1928-1976) According to the Time Elapsed Since Start of Exposure.

Disease Category (ICDA*)	-20 Years Since 1st Expos		+ 20 Years Since 1st Expos		Total	
	Obs/Exp.†	SMR	Obs/Exp.	SMR	Obs/Exp.	SMR
Malignant neoplasms (140-209)	7/8.38	83.73	18/20.18	89.19	25/28.54	89.29
Central nervous system diseases (320-349)	1/0.70	142.86	0/0.69	—	1/0.69	142.86
Cardiovascular diseases (390-458)	12/19.07	62.90	40/42.55	93.98	52/61.63	84.37
Respiratory system diseases (460-519)	3/1.57	—	3/3.29	89.93	6/4.86	121.19
Digestive system diseases (520-577)	0/2.72	—	7/13.90	175.57	7/16.62	151.14
Genitourinary system diseases (580-607)	0/1.27	—	0/1.07	—	0/2.34	—
Accidents and violence (800-999)	12/11.44	104.89	1/5.80	17.18‡	13/17.26	75.31
Others	1/7.77	12.87‡	5/5.73	89.15	6/12.90	51.36
All causes (001-999)	33/52.28	63.11‡	75/86.42	87.60	108/138.70	78.47‡

*International Classification of Diseases, Eighth Revision.

†Expected deaths based on age specific death rates of Quebec males.

‡Statistically significant.

Table 6 — Observed and Expected Number of Deaths Due to Malignant Neoplasms and Standard Mortality Ratio (SMR) Among Oil Refinery Workers According to Time Elapsed Since Start of Exposure.

Disease Category (ICDA*)	-20 Years Since 1st Expos		+ 20 Years Since 1st Expos.		Total	
	Obs/Exp.†	SMR	Obs/Exp.	SMR	Obs/Exp.	SMR
Nose, tongue, oropharynx (140-149)	0/0.21	—	0/0.59	—	0/0.80	—
Digestive system (150-159)	3/3.10	96.77	9/7.12	126.40	12/10.22	117.31
Larynx, lung, pleura (160-163)	0/1.80	—	3/6.68	44.91	3/8.48	35.37
Bone, skin (170-173)	0/0.23	—	1/0.19	526.31	1/0.42	233.09
Kidney, genital (185-189)	0/0.58	—	3/1.97	152.28	3/2.55	117.64
Brain, central nervous system (190-192)	3/0.46	652.17‡	0/0.31	—	3/0.77	389.61
Leukemia, lymphoma (200-209)	1/0.90	111.11	2/1.46	136.98	3/2.36	127.11
Other cancers	0/1.08	—	0/1.67	—	0/2.65	—
All neoplasms (140-209)	7/8.36	83.73	18/20.18	89.19	25/28.54	89.29

*International Classification of Diseases, Eighth Revision.

†Expected deaths based on age specific death rates of Quebec males.

‡Statistically significant.

Table 7. — List of Workers Who Died of Cancer (Among 1015 Men Who Worked for Over 5 Years at the Oil Refinery).

No.	Type of Cancer	Age at Death	Occupation at the Refinery	Time Elapsed Between Starting Work & Death	No. of Years of Service
1	Stomach (151)	51	Maintenance	24	15
2	Stomach (151)	55	Maintenance	33	29
3	Stomach (151)	43	Laboratory	21	21
4	Stomach (151)	50	Office	23	23
5	Rectum (154)	57	Laboratory	13	15
6	Rectum (154)	67	Operations	18	15
7	Pancreas (157)	65	Maintenance	29	23
8	Pancreas (157)	71	Operations	30	8
9	Intestinal (159)	45	Maintenance	14	14
10	Brain (191)	43	Operations	18	6
11	Lung (162)	77	Maintenance and others	25	15
12	Lung (162)	80	Office	42	19
13	Liposarcoma of the legs (170)	79	Maintenance	36	19
14	Prostate (185)	74	Office	24	17
15	Prostate (185)	66	Maintenance	23	19
16	Bladder (188)	51	Maintenance	21	21
17	General lymphoma (200)	68	Maintenance	25	20
18	Myelogenous leukemia (205)	43	Operations	13	13
19	Intestine (153)	72	Operations and office	36	28
20	Brain (192)	41	Maintenance	13	12
21	Lymphosarcoma (200)	56	Office and maintenance	29	29
22	Pancreas (157)	43	Maintenance	25	19
23	Lung (162)	46	Maintenance	20	8
24	Intestinal (153)	73	Office	40	26
25	Brain (191)	41	Maintenance-operations	19	18

the first exposure and the date of death, the "less than 20 years since start of exposure group" has statistically significant lower SMRs for all causes of death and for the category "other diseases" when compared with the Quebec population.

In the "more than 20 years since start of exposure" subgroup, the observed numbers of deaths for all causes do not differ from the expected numbers. The SMR for diseases of the digestive system (520-577) is elevated but not enough to be statistically significant. The SMR for accidents and violence (800-899) is statistically significantly lower than expected when compared with the Quebec population.

Cancer Mortality. — Table 6 shows mortality due to malignant neoplasms. There is no significant difference in the total cancer mortality death rate between the refinery workers and the Quebec population (SMR = 89.29).

Three observations stand out of the detailed study of the various cancer types: (1) Lung cancer was less frequent than expected (3 vs 7.42). (2) Three brain cancers appeared in workers within an interval of less than 20 years since the start of exposure. This was unusual and showed an SMR of 652.17. (3) Though cancers of the digestive system were not statistically higher than expected (12 vs 10.22), an SMR of 117 combined with an elevated number of deaths due to diseases of the digestive system deserve further attention.

Table 7 gives the list of workers who died of cancer by type of cancer, age at death, occupation, time elapsed between start of work and death, and number of years of service. Table 8 gives the distribution of workers who died of cancer by occupational categories. The occupational group "others" includes individuals who worked in more than one of the preceding categories. There is no statistically significant difference in the cancer mortality between the three subgroups: operators, office employees and maintenance workers.

Discussion

The finding of an overall mortality rate for oil refinery workers better than that expected from the general population agrees with what other authors have found in similar occupational mortality studies.^{1,2,11} There seems to be a selective process by which healthy persons constitute the employed portion of the population. This is reinforced by the fact that it is the "less than 20 years since start of exposure group" which showed the lowest standard mortality ratios.

The occupational history of the three young workers who died of brain cancer revealed that one of them was assigned to the fire safety department, the second was a maintenance man in the furnace room, and the third, an operator in the heavy oil unit. No common exposure of these men to a single or a class of chemicals could be identified which would have given clues as to what was associated with the appearance of these cancers.

No obvious reason could account for the low lung cancer death rate among oil refinery workers either. Other authors have described elevated lung cancer rates

Table 8.—Cancer Distribution According to Occupational Categories

Occupational Categories	No of Workers	No of Cancers Observed	No of Cancers Expected*	Obs/Exp
Operators	289	4	5.5	.73
Office employees	169	4	3.8	1.05
Maintenance	321	11	9.9	1.11
Others (more than one of several groups)	227	6	6.0	1.00
Total	1005	25	25	1.00

*Expected numbers based on age adjusted death rates in the study population.

$\chi^2 = 0.55$ D.F. = 3, P = .91.

among workers exposed to hydrocarbons.^{1,2,11} The smoking history of the present workers was not known.

The high number of deaths caused by disease and cancer of the digestive system organs deserves particular attention. It is worth noting that similar observations were made in two previous mortality studies of oil refinery workers.^{1,2} A review of the detailed occupational history of the persons deceased from these diseases did not lead to the identification of a common exposure to a chemical within the refinery. Poorly documented data on the men's alcohol consumption could not account for the five cases of cirrhosis of the liver among seven deaths due to diseases of the digestive system.

The questions raised in this study as to the presence of an association between work in an oil refinery and the development of brain cancers and diseases of the digestive system will only find an answer by extending the study to larger groups of oil refinery workers.

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References

1. Gattley W, Weaver NK, and Tapershaw JR. Mortality study of petroleum refinery workers. The American Petroleum Institute, Washington D.C., Medical Research Report, No. EA-7402, 1974.
2. Hanis N and Stavratsky K. Ten-years mortality study of control group in a petroleum company. Society for Epidemiologic Research Abstracts Am J Epidemiol 106:244, 1974.
3. Weil CS, Smyth HF, and Nale TW. Quest for a suspected industrial carcinogen. AMA Arch Ind Hyg 5:535-547, 1952.
4. Hammond EC, Serikoff IJ, Lawther PL, and Seidman H. Inhalation of benzopyrene and cancer in man. Ann NY Acad Sci 271:116-124, 1976.
5. Doll R, Vessey MP, and Beasley RMP. Mortality of gas-workers. Final report of a prospective study. Br J Ind Med 29:394-401, 1972.
6. Lloyd JW. Long-term mortality study of steelworkers. Respiratory cancer in coke plant workers. J Occup Med 13:53-68, 1971.
7. Vignani EL. Leukemia associated with benzene exposure. Ann NY Acad Sci 271:143-151, 1976.
8. Case RAM and Hocker ME. Tumour of the urinary bladder as an occupational disease in the rubber industry in England and Wales. Br J Prev Soc Med 8:39-50, 1954.
9. Hill ID. Computing man years at risk. Br J Prev Soc Med 26:112-114, 1972.
10. Bailar JC and Ederer F. Significance factors for the ratio of a Poisson variable to its expectation. Biometrics 20:639-643, 1964.
11. Andelkovic D, Taurbee J, and Symons M. Mortality experience in a cohort of rubber workers, 1964-1973. J Occup Med 18:387-394, 1976.