Mortality Among Workers Employed in Petroleum Refining and Petrochemical Plants

Terry L. Thomas, M.S.; Pierre Decoufle, Sc.D.; and Rafael Moure-Eraso, M.S.

The cause-specific mortality experience of 3,705 members of the Oil, Chemical and Atomic Workers International Union was examined to determine if there were unusual patterns of fatal disease that may be indicative of hazardous agents in the work environment. Deaths among active Union members that were reported by locals in Texas between 1947 and 1977 were identified through membership records, and proportionate mortality was analyzed in several broad industrial categories. PMRs for cancers of the liver and biliary passages, pancreas, lung and skin were elevated among refinery and petrochemical Plant workers; however, risks did not increase with length of membership. Increased relative frequencies of stomach cancer, cancer of the brain, leukemia and multiple myeloma were confined to white males in the same category who had been Union members for 10 or more years. Excess deaths from stomach cancer and brain cancer were found among white male members employed at one specific oil refinery and petrochemical plant. Observed numbers of deaths from cancer of the stomach were greater than expected among whites and nonwhites, and an elevated PMR for lung cancer among nonwhites was found at an additional plant. Findings suggest that workers in this industry may be at increased risk of certain cancers and indicate areas for further investigation.

Several studies have indicated the need for further evaluation of cancer risks among persons employed in petroleum refineries and petrochemical plants. In a recent study of cancer mortality by county, high rates of cancers of the lung, nasal cavity and sinuses, and skin were found among male residents of counties where the petroleum industry is heavily concentrated.[1] Early studies indicated increased risk of scrotal cancer among wax pressmen in a refinery[2] and cancer of the larynx and nasal sinuses among workers engaged in the manufacture of isopropyl alcohol.[3] Although no increased cancer risks have been found in more recent studies of U.S. refinery workers,[5,6] a Canadian study has reported elevated risks of esophageal, stomach, and lung cancer among workers exposed to crude petroleum and its products.[7]

The opportunity to evaluate cancer risks among a large group of workers employed in petroleum refineries, petrochemical plants and related industries arose when officials of the Oil, Chemical, and Atomic Workers International Union (OCAW) invited the National Cancer Institute to review data sources within the Union that might be useful for a epidemiologic study. The present report examines the cause-specific mortality experience of Union members to determine if there was an unusual pattern indicative of hazardous agents in the work environment. The purpose of this study is to point out areas for further investigation.

Materials and Methods

In considering what kind of study design might be possible, a retrospective cohort study was deemed not feasible because of limitations in the Union's record-keeping system. Since records of deaths among active Union members are maintained by the Membership Department, we decided to examine the relative frequency of specific causes of death as a preliminary means of obtaining an estimate of site-specific cancer risks in various broad industrial categories within the petroleum refining, petrochemical, and related industries.

Because of the heavy concentration of the petroleum industry in the state of Texas, and the large OCAW

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Table 6. — Mortality for Selected Cancer Sites in White Male Texas OCAW Members in Category 2 by Length of Union Membership.

Revision, ICD)	Length of Membership: < 10 Years (N = 578) O*	E†	PMR	E‡	PCMR	E§	TPMR	10 + Years (N = 1124) O'	E†	PMR	E‡	PCMR	E§	TPMR
Liver and biliary passages (8th 155, 156)	5	24	208	26	190	27	184	7	46	152	68	103	57	122
Pancreas (157)	15	44	3.38¶	53	2.81¶	52	2.89¶	14	125	112	167	084	124	1.13
Lung (162, 163)	35	21 7	1.61¶	24 3	1.44¶	25 9	1 35	95	74 3	1281	91 1	104	76 6	124¶
Skin (172. 173)	6	23	2561	27	223	34	179	8	49	165	62	129	63	126

*O = Observed deaths
†E = Expected deaths based on proportionate mortality for U.S. white males
‡E = Expected deaths based on proportionate cancer mortality for U.S. white males
§E = Expected deaths based on proportionate mortality for Texas white males
(Statistically significant at the 0.05 level

relative frequencies of specific causes of death, excesses for one or more causes will automatically force others to be in deficit, In addition, whenever multiple comparisons are made, a certain number of differences will be statistically significant based on chance alone. Despite its limitations, a PMR analysis is useful as a preliminary, hypothesis-generating step.

Results

Distribution of study subjects by industrial category is shown in Table 1. Most of the decedents were classified into Category 2. Only 55 decedents worked for companies that could not be classified.

Since the study group is comprised entirely of workers who were active Union members at the time of death, less than 1% were age 65 or older; however, over half of the 3,105 decedents were *50* or older (Table 2).

Table 3 indicates that 62% of the whites and 57% of the nonwhites died 10 or more years after initiation into the Union. A substantial number (> 25%) were members for 20 or more years prior to death.

PMRs for major causes of death are shown in Table 4, by race, for each industrial category that had at least 100 deaths. Among whites, the relative frequency of cancer deaths is elevated only in Category 2. Ratios for heart disease are elevated in both racial groups and in each industrial category. Observed numbers of deaths from respiratory and digestive disease are lower than expected in each category and exceptionally low among whites in Category 4. An increased relative frequency of motor vehicle accidents is seen among whites in Categories 1 and 3 and among nonwhites. Non-motor vehicle accidental deaths are elevated in each category except 3.

Site-specific cancer mortality is shown in Table 5 for each of the industrial categories in which there were at least 100 total deaths. Most interesting are results for the petroleum refinery and petrochemical plant category (Category 2). Among whites, observed numbers of deaths are significantly greater than expected for cancers of the digestive and respiratory systems, skin, and brain. A non-significant excess of respiratory cancer deaths appears in the crude oil and gas extraction category (Category 1). No other site/category combination is associated with unusual mortality, although the numbers of deaths are small in many instances. Observed numbers of deaths from digestive and respiratory cancer are greater than expected for nonwhites. Further analyses of cancer risks a limited to decedents employed in petroleum refine and petrochemical plants (Category 2).

If occupational exposure contributes to cancer risk, generally expect risk to increase with increasing durati of exposure, or, in this case, with length of member Specific cancer sites that were associated with increas relative frequencies in Category 2 were examined w respect to length of membership. Not all cancer sites w elevated PMRs in the petroleum refinery a petrochemical category show a positive gradient. Table shows cancer sites for which risk among members in t category does not increase with length of membersh The elevated PMR for cancer of the pancreas is confin to members initiated less than IO years prior to dea Observed numbers of deaths from cancers of the liv lung, and skin are greater than expected regardless length of time between initiation and death. PCMRs co puted for each of these sites show essentially the sa pattern for the < 10 year membership group; howev ratios are smaller for decedents who were members for or more years. Results using Texas white males as a co parison group vary little from the expected values bas on the total U.S. males for each site except skin. TPM for skin cancer are much lower than PMRs but rem elevated.

Table 7 shows cancer sites for which risk increases w length of membership for white males in the petroleu refinery and petrochemical plant category. An increase relative frequency of stomach cancer is confined t members who joined the Union *20* or more years prior t death. There were four deaths from multiple myeloma i the same length-of-membership group and only 1.3 we expected Deaths from leukemia and from cancers of t brain and central nervous system seem to cluster amo males who were Union members for 10 or more yea Although an increased relative frequency of kidn cancer deaths is not present in the total group, there is significant excess of deaths among members who were i itiated at least 20 years prior to death, with seven deat observed and 3 3 expected Expected numbers of deat based on proportionate cancer mortality are higher th those based on proportionate mortality, however, t same trends are present

Table 8 shows cancer sites contributing to the excess shown in Table 5 for nonwhite males Increased relativ

Table 4. — Mortality Experience of Texas OCAW Members by Race and Industrial Category, 1947-1977.

Underlying Cause of Death (8th Revision, ICD)	White Males - Industrial Category															Nonwhite Males - Industrial Category					
	All Categories			1			2			3			4			All Categories			2		
	O*	E†	PMR	O	E	PMR	O	E	PMR	O	E	PMR	O	E	PMR	O	E	PMR	O	E	PMR
Cancer (140-209)	541	463.1	1.17‡	46	50.1	0.92	394	313.6	1.26‡	55	53.4	1.03	24	25.1	0.9	101	79.6	1.27‡	79	62.1	1.27
Circulatory disease (390-458)	1247	1180.0	1.06‡	131	134.1	0.98	839	801.9	1.05	145	126.4	1.15	73	64.2	1.1	235	220.3	1.07	183	172.1	1.06
Arteriosclerotic heart disease (410-413)	1029	845.6	1.22‡	111	93.2	1.19	687	575.7	1.19‡	121	92.6	1.31‡	61	46.8	1.30‡	145	97.7	1.48‡	114	76.4	1.49‡
Vascular lesions of CNS (430-438)	85	120.3	0.71‡	7	14.3	0.49	62	81.7	0.76	6	12.4	0.48	6	6.3	0.96	36	48.2	0.75	27	37.8	0.72
Respiratory disease (460-519)	45	110.6	0.41‡	9	12.3	0.73	27	74.8	0.36‡	7	12.6	0.56	1	6.0	0.17	15	30.3	0.49‡	13	23.1	0.56
Digestive disease (520-577)	92	155.6	0.59‡	11	16.4	0.67	68	104.8	0.65‡	10	18.5	0.54	2	8.5	0.23	19	29.2	0.65	12	21.6	0.56
Accidents, suicide, homicide (800-998)	499	414.7	1.20‡	66	38.7	1.71‡	302	268.1	1.13	70	65.2	1.07	31	22.0	1.41	134	97.8	1.37‡	90	66.1	1.36‡
Motor vehicle accidents (810-827)	161	143.0	1.13	28	13.2	2.12‡	81	90.7	0.89	34	24.5	1.39	18	7.8	2.32‡	45	23.3	1.93‡	29	15.7	1.84‡
Other Accidents (800-807, 830-949)	219	144.1	1.52‡	26	14.1	1.84‡	145	93.9	1.54‡	20	21.3	0.94	17	7.5	2.26‡	41	30.0	1.36	29	21.3	1.36
Suicide (950-959)	91	94.5	0.96	8	8.9	0.90	59	62.2	0.95	14	13.5	1.03	4	5.0	0.80	8	5.5	1.45	7	3.7	1.89
All other causes	139	238.9	0.58‡	16	27.5	0.58	92	158.8	0.58‡	17	28.0	0.61	7	12.2	0.57	38	84.8	0.45‡	32	64.0	0.50‡
All causes	2563	2563.0	1.00	279	279.0	1.00	1722	1722.0	1.00	304	304.0	1.00	138	138.0	1.00	542	542.0	1.00	409	409.0	1.00

*O = Observed deaths
†E = Expected deaths based on proportionate mortality for U.S. males
‡Statistically significant at the 0.01 level

Table 5. — Mortality for Selected Cancer Sites in Texas OCAW Members by Race and Industrial Category.

Site (8th Revision, ICD)	White Males - Industrial Category															Nonwhite Males - Industrial Category					
	All Categories			1			2			3			4			All Categories			2		
	O*	E†	PMR	O	E	PMR	O	E	PMR	O	E	PMR	O	E	PMR	O	E	PMR	O	E	PMR
Digestive organs & peritoneum (150-159)	140	131.3	1.07	9	15.3	0.59	111	89.3	1.24‡	9	13.7	0.66	5	7.0	0.72	34	27.6	1.23	30	21.7	1.38
Respiratory system (160-163)	188	150.8	1.25‡	21	15.6	1.35	130	102.6	1.31‡	18	17.6	1.02	9	8.3	1.08	35	24.9	1.40‡	27	19.5	1.38
Skin (172, 173)	19	10.8	1.76‡	1	1.0	—	14	7.2	1.94‡	3	1.4	—	0	0.6	—	2	0.5	—	2	0.4	—
Genitourinary organs (185-189)	42	40.2	1.04	3	4.6	—	28	27.2	1.03	6	4.5	1.34	4	2.1	—	7	8.3	0.84	6	6.6	0.91
Brain & central nervous system (191, 192)	31	21.3	1.46‡	2	2.2	—	25	14.2	1.76‡	4	2.7	—	0	1.2	—	1	1.4	—	1	1.0	—
Lymphatic & hematopoietic tissue (200-209)	63	54.4	1.16	4	5.5	0.7	44	36.3	1.21	8	7.1	1.13	2	3.0	—	5	6.3	1.11	4	4.8	0.84

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Table 6. — Mortality for Selected Cancer Sites in White Male Texas OCAW Members in Category 2 by Length of Union Membership.

Site (8th Revision, ICD)	Length of Membership: < 10 Years (N = 578) O*	E†	PMR	E‡	PCMR	E§	TPMR	10 + Years (N = 1144) O*	E†	PMR	E‡	PCMR	E§	TPMR
Liver and biliary passages (155, 156)	5	2.4	2.08	2.6	1.90	2.7	1.84	7	4 6	152	6 8	103	5 7	122
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*O = Observed deaths
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relative frequencies of specific causes of death, excesses for one or more causes will automatically force others to be in deficit. In addition, whenever multiple comparisons are made, a certain number of differences will be statistically significant based on chance alone. Despite its limitations, a PMR analysis is useful as a preliminary, hypothesis-generating step.

Results

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Site-specific cancer mortality is shown in Table 5 for each of the industrial categories in which there were at least 100 total deaths. Most interesting are results for the petroleum refinery and petrochemical plant category (Category 2). Among whites, observed numbers of deaths are significantly greater than expected for cancers of the digestive and respiratory systems, skin, and brain. A non-significant excess of respiratory cancer deaths appears in the crude *oil* and gas extraction category (Category 1). No other site/category combination is associated with unusual mortality, although the numbers of deaths are small in many instances. Observed numbers of deaths from digestive and respiratory cancer are greater than expected for nonwhites Further analyses of cancer risks are limited to decedents employed in petroleum refineries and petrochemical plants (Category 2).

If occupational exposure contributes to cancer risk, we generally expect risk to increase with increasing duration of exposure, or, in this case, with length of membership. Specific cancer sites that were associated with increased relative frequencies in Category 2 were examined with respect to length of membership Not all cancer sites with elevated PMRs in the petroleum refinery and petrochemical category show a positive gradient Table 6 shows cancer sites for which risk among members in this category does not increase with length of membership. The elevated PMR for cancer of the pancreas is confined to members initiated less than 10 years prior to death Observed numbers of deaths from cancers of the liver, lung, and skin are greater than expected regardless of length of time between initiation and death PCMRs computed for each of these sites show essentially the same pattern for the < 10 year membership group. however, ratios are smaller for decedents who were members for 10 or more years Results using Texas white males as a comparison group vary little from the expected values based on the total US males for each site except skin TPMRs for skin cancer are much lower than PMRs but remain elevated

Table 7 shows cancer sites for which risk increases with length of membership for white males in the petroleum refinery and petrochemical plant category An increased relative frequency of stomach cancer is confined to members who pined the Union 20 or more years prior to death There were four deaths from multiple myeloma in the same length-of-membership group and only 13 were expected Deaths from leukemia and from cancers of the brain and central nervous system seem to cluster among males who were Union members for 10 or more years. Although an increased relative frequency of kidney cancer deaths is not present in the total group, there is a significant excess of deaths among members who were initiated at least 20 years prior to death, with seven deaths observed and 3 3 expected Expected numbers of deaths based on proportionate cancer mortality are higher than those based on proportionate mortality, however, the same trends are present

Table 8 shows cancer sites contributing to the excesses shown in Table 5 for nonwhite males Increased relative

requencies of cancers of the stomach and lung are seen n both length-of-membership groups shown here. Results of the PCMR analysis are not too different from those of he PMR analysis; however, the estimated risk for lung ancer is reduced.

In order to determine whether the increased risks of pecific cancers among OCAW members employed in etroleum refineries and petrochemical plants were con- ined to employees of particular plants, mortality patterns vere examined in five plants from which at least 100 leaths had been reported.

Plant A is a large petroleum refinery with 421 deaths among whites and 54 deaths among nonwhites. Some Union members employed at this plant are guards; however, most are production workers. The observed number of stomach cancer deaths is significantly greater than expected among whites who died *20* or more years after joining the Union (Table 9). The excess of deaths from cancers of the brain and central nervous system is limited to workers with at least 10 years of membership. Among nonwhites there were one death from stomach cancer and no deaths from cancer of the brain.

Plant B is a petroleum refinery and petrochemical plant that also produces sulfuric acid. Certificates were recovered for 413 deaths reported by the Union local during the study period. Observed numbers of deaths for cancers of the stomach, skin, kidney, and leukemia are greater than expected for whites with 10 or more years of membership (Table 10). Significant excesses of stomach and lung cancer are present among nonwhites. Expected numbers of deaths were not calculated for nonwhites by length of membership because of the small numbers. Brain cancer was not excessive in either racial group.

Significantly increased relative frequencies of brain (5 observed; 1.5 expected) and of lung cancer deaths (22 observed; 11.7 expected) were seen among 198 whites who worked at Plant C, which functions as a refinery and products terminal. Although numbers were very small, we examined mortality patterns by length of membership and found that the brain cancers clustered among males who were members for less than 10 years (all of the decedents in this group with brain tumors were members for nine years) while the lung cancer excess was confined to workers with at least 10 years of membership. No excesses of specific cancers were seen among members who worked in the other two plants that were examined separately.

Discussion

The present study provides an example of the epidemiologic value of data collected routinely for administrative purposes. As pointed out earlier, the primary use of this type of study is as a hypothesis-generating report.

PMRs for some causes of death may appear higher than they should because of lack of information on members who retired or left the Union for other reasons. No conclusions can be drawn with respect to exposure to specific agents; however, categories of industrial processes and individual plants associated with higher than expected risks can be identified. In spite of limitations imposed by the "healthy worker effect" and the lack of exposure information, the finding that risks of stomach

Table 7. — Mortality for Selected Cancer Sites in White Male Texas OCAW Members in Category 2 by Length of Union Membership.

Site (8th Revision, ICD)	Length of Membership															
	< 10 Years (N = 578)						10-19 Years (N = 609)						20 + Years (N = 535)			
	O*	E†	PMR	E§	TPMR	¶	O*	E†	PMR	E§	TPMR	¶	O*	E†	PMR	E§	TPMR	¶
Stomach (151)	7	7.1	0.98	6.0	0.81		9	7.2	1.26	9.2	0.97		14	5.2	2.69	8.1	1.73	
Kidney (189)	1	2.3	—	2.8	—		4	3.1	—	3.9	—		7	3.3	2.14	4.2	1.65	
Brain & central nervous system (191, 192)	7	4.7		5.5			2	5.2	2.30	6.6	1.81		6	4.3	1.40	5.6	1.07	
Leukemia (204-207)	6	5.0		5.8			8	5.0	1.61	6.3	1.27		7	3.9	1.77	5.6	1.25	
Multiple myeloma (203)	0	1.0		1.2			2	1.5	—	1.6	—		4	1.3	—	1.8	—	

*O = Observed deaths
†E = Expected deaths based on proportionate mortality for U.S. white males
‡E = Expected deaths based on proportionate cancer mortality for U.S. white males
§E = Expected deaths based on proportionate mortality for Texas white males
¶Statistically significant at the 0.05 level
—Not calculated

Table 8. — Mortality for Selected Cancer Sites in Nonwhite Male Texas OCAW Members in Category 2 by Length of Union Membership.

Site (8th Revision, ICD)	Length of Membership: < 10 Years (N = 150) O*	E†	PMR	E‡	PCMR	E§	TPMR	10 + Years (N = 259) O*	E†	PMR	E‡	PCMR	E§	TPMR
Stomach (151)	5	2.1	2.421	2.7	1.87	2.2	2.31	12	4.3	2.80¶	6.2	1.92¶	4.6	2.59¶
Lung (162, 163)	7	3.8	1.82	4.7	1.48	4.8	1.46	19	14.1	1.35	16.6	1.14	12.3	1.55

*O = Observed deaths
†E = Expected deaths based on proportionate mortality for U.S. nonwhite males
‡E = Expected deaths based on proportlonate cancer mortality for U.S. nonwhite males
§E = Expected deaths based on proportionate mortality for Texas nonwhite males
¶Statistically significant at the 0.05 level

Tabb 9. — Mortality for Selected Cancer Sites in White Male OCAW Members Employed at Plant A by Length of Union Membership.

Site (8th Revision. ICD)	lLength of Membership: < 10 Years (N = 107) O*	E†	PYR	10-19 Years (N = 177) O	E	PMR	20 + Years (N = 137) O	E	PMR
Stomach (151)	3	1.4	—	1	2.2	—	5	1.3	3.76‡
Brain 8 central nervous system (191, 192)	0	0.8	—	5	1.5	3.32‡	4	1.1	—

'O = Observed deaths
†E = Expected deaths based on proportionate mortality for U.S. white males
‡Statistically significant at the 0.05 level
—Not calculated

Tabla 10. — Mortality for Selected Cancer Sites in OCAW Members Employed at Plant B by Length of Union Membership.

Sir (8th Revision, ICO)	White Males, Length of Membership: < 10 Years (N = 111) O*	E†	PMR	10 + Years (N = 191) O	E	PMR	Nonwhite males (N = 111) O	E	PMR
Stomach (151)	I	1.7	—	6	2.0	2.97‡	7	2.1	3.40‡
Lung (162.163)	5	4.5	1.11	13	12.1	1.08	13	4.4	2.94‡
Skin (172,173)	1	0.4	—	3	0.8	—	0	0.1	—
Kidney (189)	1	0.5	—	3	1.0	—	0	0.3	—
Leukemia (204-207)	3	0.9	—	3	1.5	—	0	0.4	—

*O = Observed deaths
†E = Expected deaths based on proportionate mortality for U S males
$Statistically significant at the 0 05 level
—Not calculated

cancer, cancer of the brain, leukemia, and multiple myeloma increase with longer Union membership among workers in the refinery and petrochemical category strengthens the possibility of an association with occupational factors. Furthermore, essentially the same relationships were seen in a proportionate cancer mortality analysis.

These findings are consistent with reports of an excess of stomach cancer deaths among Canadian petroleum refinery workers,[1] and of an elevated risk of leukemia associated with exposure to benzene and perhaps other petrochemicals.[**14 15] Studies of vinyl chloride workers have shown an increased relative frequency of brain tumors;[16 17 18] however, no association between employment in refineries and petrochemical plants and excess mortality from brain tumors has previously been reported.

Although no positive gradient in risk with length of Union membership was detected for cancers of the pancreas, liver, lung, and skin, further evaluation of these sites should be made. PMR analysis using Texas males as a comparison group does not alter the conclusions; therefore, these findings cannot be explained by high Texas rates. The lack of a gradient raises the possibility that factors other than occupational exposure may be operating; however, occupational factors cannot be completely ruled out because some cancers may have shorter latent periods, depending upon the nature of the exposure.

In addition, this study has highlighted three specific plants in which Union members appear to have increased

risks of certain cancers — of brain cancer at Plants A and C, of stomach cancer at Plants A and B, and of lung cancer at Plants B and C. Further evaluations of mortality among workers at these plants will be made.

Despite limitations in data and in methodology, results of the present study suggest that workers in this industry are at increased risk of certain cancers. Further studies are necessary to support and clarify these findings

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Meaning of Work

For many persons, work is a vital part of the process of coping with life stress. This has two apsects: first, without work, the potential for boredom and meaninglessness is immeasurably increased. Work is often the primary means by which a person feels useful in life and through which significance and personal identity are established. The young adult must find a useful and meaningful place in society, and only in this way does a man or woman develop a firm sense of identity.

Second, work is often a form of coping and a refuge. Consider, for example, how people in grief regard work. Many report that in the process of mourning and reorienting their lives after a major loss, work is not a burden, but the best refuge against constant high levels of distress and depression. One speaks here of "burying one's self in work." Thus, work may provide a psychological haven against problems that otherwise would be insurmountable, or against loneliness and depression. For such people not to work is to be deprived of the only viable means of coping with non-work-related stress.

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