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Cancer Downwind from Sour Gas Refineries: The Perception and the Reality of an Epidemic

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A rural population in southwestern Alberta, Canada, living downwind from natural gas refineries, has expressed concerns about an excess of adverse health outcomes over the last 25 years. This has escalated to the point of causing a prominent sociopolitical controversy within the province. As part of a large field epidemiologic study undertaken during the summer of 1985 to investigate possible health effects, a residential cohort study was carried out to study cancer incidence. The cohort was defined as all those individuals who resided in the area in 1970. A total of 30,175 person-years of risk within Alberta were experienced by this cohort from 1970 to 1984. The incident cancers during this period were enumerated by computerized record linkage with the Alberta Cancer Registry. Age- and sex-standardized incidence ratios, based on expected rates from three prespecified demographically similar, nonmetropolitan Southern Alberta populations, were 1.05, 1.09, and 1.03, respectively, none of which was significantly different from unity. Although they do not address the issue of etiologic association, these data can provide considerable reassurance to a community that was convinced it had experienced an epidemic of cancer.

Introduction

Concerns about the impact of acid-forming emissions have evolved into one of the most significant North American environmental issues over the past two decades. Potential direct or indirect human health effects of these substances are the subject of considerable current interest.

In no locality has this concern been more acute than in a rural area of southwestern Alberta, Canada, situated downwind from two natural gas refineries that emit primarily sulfur compounds, including hydrogen sulfide, (H_2S). Since operation of these sour gas plants began in 1957, concerns about their health effects have been repeatedly voiced by residents and have escalated to the point of causing a prominent sociopolitical controversy within the province (*1*). The reported adverse health effects have included excess cancer incidence, increased numbers of adverse reproductive outcomes and birth defects, excess mortality, contamination with certain heavy metals, and a variety of symptoms such as headache, fatigue, and pruritus. With regard to cancer, a committee of concerned citizens polled the area and compiled a list of approximately 45 past and present residents who had been diagnosed with various types of cancer.

In 1983, the Alberta government together with a consortium of industrial representatives created the Acid Deposition Research Program (ADRP) to sponsor scientific investigation into the questions surrounding acid-forming emissions. As part of this program, we undertook a comprehensive field study known as the Medical Diagnostic Review (MDR) to evaluate the nature and magnitude of long-standing health effects among the residents of the index area (IA) and to determine whether adverse health effects were occurring more frequently than expected. We describe here the results of our investigation pertaining to the incidence of cancer in this area.

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Materials and Methods

Objectives

The area of concern, henceforth called the index area (IA), is a rural area lying to the southeast of the town of Pincher Creek, to the east of the foothills of the Rocky Mountains, and just north of the Montana border (Fig. 1). The area consists primarily of ranchland surrounding five small communities. The boundaries of the IA were delineated in advance by officials of the ADRP, based primarily on the plume patterns of the emissions from the refinery stacks. The IA did not correspond to any single political or geographic jurisdiction and intersected three different municipal districts. The fundamental objective of the cancer study was not to establish an etiologic association between sour gas and cancer but rather to determine empirically whether residents of the IA had experienced a higher than expected incidence of cancer. In prior meetings with concerned residents (Community Advisory Board), it became apparent that no specific cancer site was of particular concern; rather, there was the impression among concerned residents that the cancer incidence was generally elevated. For this reason, we declared in advance that the all site cancer incidence rate would be the primary variable of interest in the cancer study. However, we also planned to carry out secondary analyses involving specific cancer sites although the lower statistical power for these subanalyses and the problem of multiple comparisons were acknowledged in advance.

We defined the index area 1970 Cohort Sample (IACS) to consist of all individuals that could be identified who were resident in the IA anytime during the calendar year 1970, and we based the present investigation on the subsequent cancer experience from 1970 to 1984 of this sample. The choice of this period offered three advantages: it consisted of three 5-year periods, 1970 to 1974, 1975 to 1979, and 1980 to 1984, for which there were national census data readily available (1971, 1976, 1981); it terminated in the last year (1984) for which complete cancer registry information was available at the time of the study; and records of the Alberta Cancer Registry were of greater quality for this period than for the preceding years.

The major objective of the cancer component of the MDR was to determine whether the incidence of cancer (as registered by the Alberta Cancer Registry) during the period January 1, 1970, to December 31, 1984, among all individuals in the IACS was higher than that which should be expected in sociodemographically similar populations in Southern Alberta during the same period.

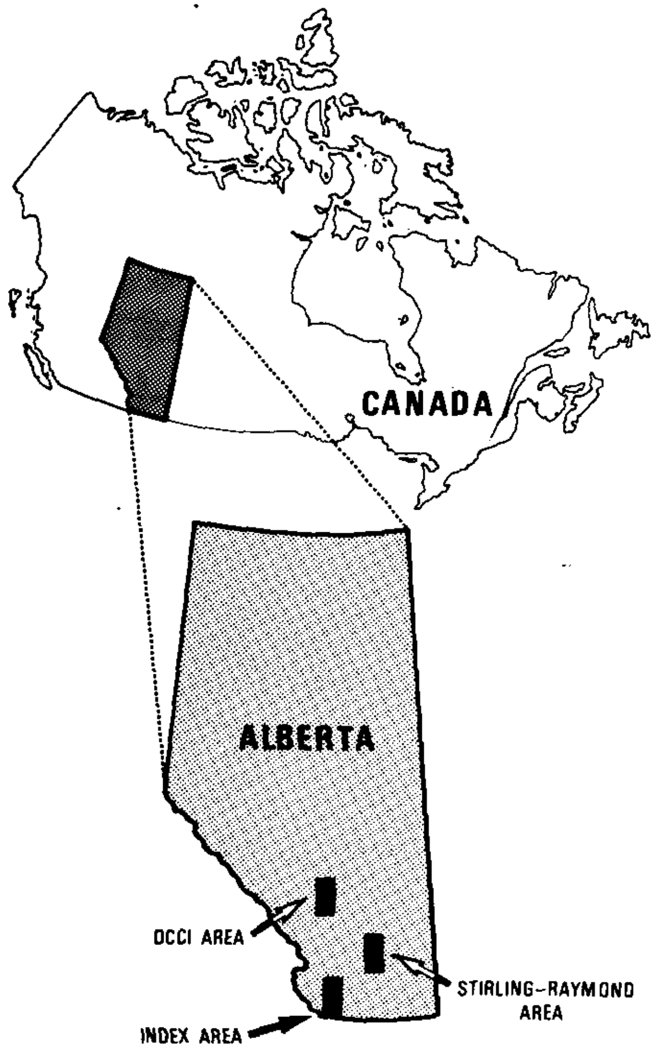

FIGURE 1. Map of the province of Alberta, Canada showing the approximate size and location of the index area within the southwest corner of the province. The regions marked DCCI and Stirling-Raymond correspond to referent areas RP2 and RP3.

Cohort Enumeration

For convenience, the IACS was divided into two parts. The first subgroup, the resident group (RG), was defined to consist of all members of the IACS who were still resident in the IA during the summer of 1985. The second subgroup, the outmigrant group (OG), was defined to consist of the remainder of the IACS, and thus included all individuals who had migrated out of the area since 1970, as well as all those who had died since 1970. These two groups (RG and OG) were enumerated separately as described below.

A major component of the MDR involved a comparative health survey of current residents of the IA, which was carried out during the summer of 1985, and which forms the basis of separate reports (*2,3*). In preparation, all 2328 current residents of the IA were enumerated during June–July 1985, of whom 2157 (93%) subsequently participated in the survey. Based on residential histories, those participants who resided in the area during 1970 were identified, and in this way, the RG was enumerated.

The enumeration of the OG subgroup was a more complex task. This was achieved through a series of steps including a title search of each quarter section of land within the IA going back to the year 1957 and a survey of all current residents ascertaining all friends, relatives, or previous occupants of their dwelling, who had lived within the IA in the past. Information concerning outmigrants was also solicited from interested individuals and from the Community Advisory Board. Then a telephone survey of the entire IA was carried out to review and update outmigrant information. The lists compiled through the described processes were then reviewed by Outmigrant Review Panels, long-time residents of the IA. Any name who was identified by only one previous source and whose existence could not be confirmed by these panels was excluded. The edited outmigrant file was then manually linked to the mortality file of the Alberta Bureau of Vital Statistics to confirm vital status and exact year of death. For reasons of confidentiality, cause of death information was not available to us.

Each record was assigned a certainty code that reflected the overall quality and consistency of the information. The certainty code was 1 when exact agreement from all sources was obtained; 2 when discrepancies existed that did not affect person-years of risk; and 3 when discrepancies existed that did affect person-years of risk. In the latter situations, we adopted the *a priori* policy that the data which gave rise to a lower total person-years of risk would be chosen. All members of the RG were assigned codes of 1 since they were interviewed personally about their residential history.

Person-years of life within Alberta were classified by age group, sex, and 5-year time interval. The age grouping (< 20, 20–34, 35–44, 45–54, 55–64, 65–69, ≥ 70) was that in routine use at the Alberta Cancer Registry and was specified prior to the analysis. Person-years were calculated in the conventional manner for each age group, sex, and 5-year interval. As is customary, one-half year of risk was assessed for the initial or final year of residence for those who were born or entered the area in 1970, or who died or left the area prior to 1985.

Enumeration of Observed Cancers

The definitive source for identification of a cancer in the IACS was the Alberta Cancer Registry. A computerized record linkage was performed between the computerized listings of the RG and OG, and the files of the Alberta Cancer Registry. This linkage was performed twice, the first time using surname and the second time where applicable, using maiden name. Two manual searches were then done to confirm true matches based on name, maiden name (if applicable), month and year of birth, and place of residence (if known). All self-reported cancers were linked manually and the attending physician and hospital were contacted if the report was not confirmed by the Registry.

Referent Populations

Three referent populations were chosen. Referent population 1 (RP1) consisted of all of rural Southern Alberta obtained by excluding the metropolitan areas of Calgary, Lethbridge, and Medicine Hat from a census of Southern Alberta. The two other referent populations were census division 6 (RP2) and census division 2 (RP3), with their metropolitan areas excluded. The referent populations were chosen without any knowledge of cancer incidence rates to approximate the control areas for the comparative health survey known as Didsbury-Crossfield-Carstairs-Irricana (DCCI) and Stirling-Raymond (Fig. 1). Age group, sex, and 5-year interval-specific cancer incidence rates for the referent populations were calculated by the Alberta Cancer Registry.

Statistical Analysis

Expected cancers were derived by applying the appropriate age group, sex, and 5-year interval-specific cancer rates to the corresponding age group, sex, and 5-year interval-specific person-years of risk of the IACS. The significance of the resulting standardized incidence ratios (SIR) was tested by computing 95% confidence intervals around them using methods described by Ederer and Mantel (*4*). *A priori* sample size calculations were based on an estimate of 2000 people in the IACS with an expected 30,000 person-years of observation. Approximately 102 incident cancers were expected (*5*), yielding greater than 90% power (*6*) to detect elevations in relative risk of 1.2 or more using a one-sided test with a confidence level of 0.05.

Results

As seen in Table 1, there were a total of 2164 members of the IACS (1126 male and 1038 female). The age distribution of the IACS in the year 1970 is displayed in Table 1 as are the person-years of risk. Totals of 15,585 and 14,590 person-years of risk were experienced by the IACS males and females, respectively. The proportions of these person-years of risk with certainty codes of 1 in males and females were 93.7% and 90.1%, respectively.

Table 2 presents the cancer incidence rates for males in the three reference populations categorized by age group and by time interval. As a summary measure, the age-standardized incidence rates, adjusted to the 1976 Alberta male population, are presented in the last three rows of Table 3. These standardized rates indicate that incidence of cancer is remarkably similar among the three reference populations and that cancer incidence rates have risen with time in each of these three populations. An analogous set of rates were calculated for females and are shown in Table 3.

As seen in Table 4, a total of 123 incident cancers were identified as having occurred within the IACS during the period 1970 to 1984. Among the RG, a total of 35 cancers were identified, 17 in the males and 18 in the females. These 35 incident cancers occurred in 34 members of the RG; there was 1 individual in the RG with 2 incident cancers. Of the 35 incident cancers, 20 were nonmelanotic skin cancers; the remaining 15 were distributed among the various types of malignancies (Table 4). It is noteworthy that only 29 of these 35 cancers were reported by the RG member at the time of his or her visit to the comparative health survey. An additional 6 cancers, not reported by the individual, were identified solely through linkage with the Alberta Cancer Registry. In 5 of 6 of these unreported cancers, the diagnosis was nonmelanotic skin cancer; the sixth was a cancer of the bladder.

A total of 88 incident cancers were identified in the OG, 54 in the males and 34 in the females. These 88 cancers occurred in 75 members of the OG; there were 64 individuals with 1 incident cancer, 10 individuals with 2 incident cancers, and 1 individual with 4

Table 1. Person-years of risk experienced by the index area 1970 cohort sample by sex, age group, and time interval.

Age group	n^a (sex)	1970–74	1975–79	1980–84	Total
< 20	459 (M)	2028.5	1346.5	699.0	4074.0
	469 (F)	2077.0	1333.5	644.5	4055.0
20–34	224 (M)	1238.5	1534.0	1646.5	4419.0
	182 (F)	1021.0	1406.5	1686.0	4113.5
35–44	117 (M)	543.5	546.5	652.0	1742.0
	121 (F)	563.0	483.0	543.0	1589.0
45–54	129 (M)	638.0	541.5	506.0	1685.5
	123 (F)	637.0	629.0	527.5	1793.5
55–64	110 (M)	586.0	634.5	584.0	1804.5
	80 (F)	431.0	526.0	606.0	1563.0
65–69	34 (M)	172.0	284.0	357.5	813.5
	24 (F)	130.5	209.5	276.0	616.0
70+	53 (M)	287.5	345.0	414.0	1046.5
	39 (F)	221.5	275.5	363.0	860.0
Total	1126	5494.0	5232.0	4859.0	15,585.0
	1038	5081.0	4863.0	4646.0	14,590.0

[a]Number of persons in age group in 1970. Note that individuals not only move across the table with time, but also may move down the table into higher age groups as they age.

Table 2. Cancer incidence rates per 100,000 for males by age group and time interval for three reference populations.

Age group	Population[a]	1970–74	1975–79	1980–84
< 20	RP1	14.31	13.39	12.32
	RP2	10.41	12.43	13.79
	RP3	9.55	12.91	7.03
20–34	RP1	28.23	39.99	45.58
	RP2	37.60	26.25	67.26
	RP3	22.86	46.09	44.01
35–44	RP1	111.00	106.67	106.47
	RP2	102.94	112.09	116.50
	RP3	103.38	103.90	88.61
45–54	RP1	316.38	342.31	310.30
	RP2	277.06	305.14	324.61
	RP3	287.58	302.04	316.60
55–64	RP1	781.21	893.02	1056.69
	RP2	763.36	858.45	979.92
	RP3	835.98	814.07	1014.35
65–69	RP1	1438.71	1779.14	1700.70
	RP2	1257.86	1522.73	1732.62
	RP3	1703.70	1972.22	1804.88
70+	RP1	2256.31	2774.65	3262.74
	RP2	2218.62	2921.50	3379.31
	RP3	2497.92	3229.63	3412.97
Age standardized rates	RP1	250.87	295.66	325.02
	RP2	239.39	266.15	334.43
	RP3	265.43	312.47	327.59

[a](RP1) Southern Alberta excluding Calgary, Lethbridge, and Medicine Hat; (RP2) census division 6 excluding Calgary; (RP3) census division 2 excluding Lethbridge.

incident cancers. Of the 88 cancers in the OG, a total of 25 were nonmelanotic skin cancers; the remaining 63 cancers were distributed among the various other categories.

Table 5 presents observed and expected numbers of cancers for the IACS males and females. The primary standardized incidence ratio analysis is presented in the bottom panel of this table. There were a total of 78

Table 3. Cancer incidence rates per 100,000 for females by age group and time interval for three reference populations.

Age group	Population[a]	1970–74	1975–79	1980–84
< 20	RP1	7.95	14.04	10.93
	RP2	6.78	13.46	12.14
	RP3	8.11	11.93	7.47
20–34	RP1	50.58	58.78	49.85
	RP2	60.99	51.41	44.79
	RP3	60.68	55.61	47.30
35–44	RP1	190.58	183.07	212.03
	RP2	190.87	142.41	182.02
	RP3	136.17	206.19	219.93
45–54	RP1	402.30	409.04	470.70
	RP2	394.62	326.38	469.88
	RP3	404.40	431.03	435.73
55–64	RP1	788.85	781.31	856.05
	RP2	699.45	738.04	785.28
	RP3	722.06	820.78	894.12
65–69	RP1	1063.39	1121.62	1172.32
	RP2	904.35	834.36	1148.33
	RP3	1088.00	1371.43	915.66
70+	RP1	1456.84	1759.12	1967.91
	RP2	1390.48	1523.08	2068.97
	RP3	1504.59	1723.08	1821.78
Age standardized rates	RP1	242.06	263.25	287.07
	RP2	229.05	224.95	282.19
	RP3	237.16	274.21	270.69

[a](RP1) Southern Alberta excluding Calgary, Lethbridge, and Medicine Hat; (RP2) census division 6 excluding Calgary; (RP3) census division 2 excluding Lethbridge.

Table 4. Incident cancers among the index area 1970 cohort sample during 1970–1984.

	Resident group		Outmigrant group		
Type (ICD-9)	Male	Female	Male	Female	Total
Gastrointestinal (150.0–150.9)	1	2	10	5	18
Breast (174.0–175.9)	0	3	0	6	9
Respiratory (160.0–165.9)	0	0	4	2	6
Kidney, bladder, prostate (185.0–189.9)	4	1	17	3	25
Gynecologic (179.0–171.9)	0	0	0	1	1
Lip, oral, pharynx (140–149.9)	2	0	3	0	5
Bone, soft tissue (170.0–171.9)	0	0	0	1	1
Lymphoid, leukemia (200.0–208.9)	0	0	0	1	1
Melanoma (172.0–172.9)	0	1	0	1	2
Other (190.0–199.9)	0	0	3	3	6
Skin (nonmelanoma) (173.0–173.9)	10	10	17	8	45
Total	17	18	54	34	123

Table 5. Standardized incidence ratios excluding nonmelanotic skin cancer for the index area 1970 cohort sample relative to the three reference populations.

Population	Observed	Expected, RP1[a]	Expected, RP2[b]	Expected, RP3[c]
Males	45	49.6	49.6	52.7
Females	33	36.3	34.2	35.1
Total	78	85.9	83.8	87.7
Standardized incidence ratio (95% CI)		0.91 (0.97, 1.26)	0.93 (0.68, 1.29)	0.89 (0.65, 1.23)

[a]Southern Alberta excluding Calgary, Lethbridge, and Medicine Hat.
[b]Census division 6 excluding Calgary.
[c]Census division 2 excluding Lethbridge.

incident cancers in the IACS excluding nonmelanotic skin cancer. Based on the three referent populations, the expected numbers of cancers were 85.9, 83.8, and 87.8, respectively. These data give rise to standardized incidence ratios of 0.91, 0.93, and 0.89, respectively. The 95% confidence intervals provided for each SIR indicate that they are not statistically significantly different from unity.

The preceding analysis excluded nonmelanotic skin cancers in both the observed and expected totals. We conducted a second standardized incidence ratio analysis in which these cancers were included. The results are presented in Table 6. With the inclusion of nonmelanotic skin cancers, there were a total of 123 malignancies in the IACS. Based on the three reference populations, there were 117.3, 113.1, and 119.5 such cancers expected in the cohort. The resulting SIRs were 1.05, 1.09, and 1.03, none of which was significantly different from unity (Table 6). Because these results indicate no unusual incidence of cancer in the IACS, post hoc power calculations were carried out. Given approximately 120 expected cancers (based on reference rates) and using a confidence level of $\alpha = 0.05$, the power was 0.83 (or 0.73) to detect a hypothetical SIR as low as 1.25 with a one (or two-sided) test. Under the same conditions, the power to detect an SIR of 1.5 or greater with either a one or two-sided test was greater than 0.99.

As a secondary analysis, we compared observed and expected cases for specific cancer sites. This analysis revealed no statistically significant deviations between observed and expected numbers for any site. Several specific results are worthy of note. We had expected a paucity of respiratory cancers (larynx, trachea, bronchus, lung) based on the fact that 67% of participants in the health survey over age 15 reported that they had never smoked. Indeed, there were 6 observed cases of respiratory cancer, whereas 12.1 cases were expected based on general Alberta rates, yielding a nonsignificantly reduced SIR of 0.50 (0.20, 1.24). We observed 45 nonmelanotic skin cancers in the IACS, whereas there were 31.4, 29.3, and 31.7 such cancers expected based on rates from the three reference populations, yielding SIRs of 1.43, 1.54, and 1.42, respectively. These SIRs were not statistically significantly elevated. The only other nontrivial excess of observed over expected numbers of cases we detected was for prostate cancer, where 10.8 cases were expected based on general Alberta rates, and 19 cases were observed. These data yield an SIR of 1.76 (0.84, 4.38).

To test the effect of inaccuracies in our enumeration, we carried out a secondary SIR analysis restricted to those having the most reliable information (i.e., a certainty code of 1). Based on expected rates from RP1, the SIR was 0.91 (0.69, 1.23). Similarly, we carried out a secondary analysis restricted to those individuals with maximal durations of exposure, that is from 1957 to 1970. The latter analysis gave rise to an SIR or 1.07 (0.81, 1.42); the numbers of expected and observed cancers were 105.3 and 113, respectively.

Discussion

In summary, we detected no excess in cancer incidence in the index area 1970 cohort during the observation period. The data suggest that the overall

Table 6. Standardized incidence ratios including nonmelanotic skin cancer for the index area 1970 cohort sample relative to the three reference populations.

Population	Observed	Expected, RP1[a]	Expected, RP2[b]	Expected, RP3[c]
Males	71	69.1	68.2	72.3
Females	52	48.2	44.9	47.2
Total	123	117.3	113.1	119.5
Standardized incidence ratio (95% CI)		1.05 (0.81, 1.36)	1.09 (0.84, 1.41)	1.03 (0.80, 1.33)

[a]Southern Alberta excluding Calgary, Lethbridge, and Medicine Hat.
[b]Census division 6 excluding Calgary.
[c]Census division 2 excluding Lethbridge.

cancer experience of this cohort during the period 1970 to 1984 was remarkably similar to that which should have been expected based on any of the three reference populations chosen from within Southern Alberta.

A fundamental issue concerns the enumeration of the OG and the accuracy of the person-years of risk estimate. Because this was an irregularly defined rural area to which census data could not be meaningfully applied, there is no gold standard against which to assess the enumeration. However, we feel it is accurate for several reasons. Only outmigrants who were identified by two independent sources were used in the analysis. Our outmigrant enumeration gives rise to a total of 2164 members of the IACS. Given the 1985 population count of the IA of 2328 and given an elapsed interval of 15 years during which virtually no new housing was built in the area, we believe the total of 2164 represents a realistic estimate for the population of the IA in 1970. If anything, our enumeration process may have slightly biased the OG toward those more likely rather than less likely to develop cancer, as those who developed cancer may be more likely to be recalled by their friends and relatives by virtue of this event. As well, the policy in outmigrant enumeration was such that if any error was introduced, it was that person-years of risk and hence numbers of expected cancers would be lowered, and standardized incidence ratios would be elevated, favoring the likelihood of finding an elevated incidence in the IA. Finally, when only those individuals with certainty codes of 1 were included in the analysis, there was no significant change in the results. Based on these observations, we conclude that inaccuracy of information in the outmigrant group is unlikely to have obscured any real increase in cancer incidence.

Refining of sour gas that contains H_2S results in the production of sulfur dioxide (SO_2) and, through processing, results in the conversion of H_2S and SO_2 to elemental sulfur. It appears, unfortunately, that virtually all available information about the toxic effects of H_2S is derived from the study of acute occupational exposures. A recent critical review found no studies that considered the toxicity of chronic low dose exposure to H_2S in humans, and the carcinogenic effects of such exposures were thought to be unlikely (*7*). Data in humans suggesting SO_2 exposure can result in lung cancer (*8,9*) are far from conclusive, and animal data suggesting that SO_2 may be a cancer promoting agent or a cocarcinogen (*10,11*) have received considerable criticism (*12*).

Air quality surveys have measured levels of aromatic and polyaromatic hydrocarbons, as well as nitrous oxides associated with sour gas refining (*13*). Recent Environmental Protection Agency documents examining exposures and risk assessments for 16 major polluting polyaromatic hydrocarbons provide evidence for carcinogenicity, as well as cocarcinogenicity or initiation, for several of these substances (*14*). Long-term exposure to nitrogen dioxide (NO_2) has not been shown to cause malignancies (*9*). Combustion of fossil fuels are said to release several radioactive species, including radon gas, but the small amount of information available suggests that the amount of exposure in these areas is not appreciable relative to natural background levels (*15*).

Petroleum workers have been reported to be at elevated risk for various cancers involving the gastrointestinal tract, brain, skin, leukemia, and multiple myeloma, but these findings have been inconsistent (*16–19*). The only environmental study was an ecological study in California that compared exposure to air emissions produced by the petroleum and chemical industries with average annual cancer incidence (*20*). Associations were found with a number of cancer sites including the buccal cavity and pharynx in both sexes and in stomach, lung, prostate, kidney, and ureters in men only. The pertinence of these findings is unclear, however, in the face of numerous criticisms, which include short latency periods, inadequate control of potential confounding variables, and the ecological fallacy. In particular, the consistently higher rates in men raise suspicion of occupational and lifestyle factors, rather than any environmental etiology. In summary, the biologic plausibility of the relationship between sour gas refining and carcinogenesis remains unclear.

Only the overall cancer experience of the IACS was specified in the primary hypothesis test in this study. This decision was made because of the lack of biologically plausible evidence, the lack of community concern about any one cancer site, the lack of adequate power to investigate specific sites, and the potential for the multiple comparisons problem. We did detect a nonsignificant increase in skin cancer and a nonsignificant decrease in respiratory cancer, which could be chance findings or could be related to the increased sunlight exposure and lower smoking rates in this community. With regard to the excess of prostate cancer observed, given that this was not statistically significant, given the number of site-specific comparisons made, and given the lack of any evidence concerning a sour gas etiology, to conclude that this is anything but a chance observation would be extremely tenuous.

It is not surprising that our study provided negative results given the lack of prior evidence for an etiologic association between exposure to sour gas emissions and an elevation in the all-site cancer incidence. Nevertheless, it was critical that the investigation be carried out. While biologic plausibility is an important consideration in studies of etiology, we found that prior discussions of biologic implausibility did little to allay this group's anxiety about a perceived health risk. In this instance, we believe the most effective way to address this fear was an empirical investigation of whether the local health experience has been different from what would have been expected based on the experience of fellow citizens in nearby communities. This appears to be a type of information that the public can readily interpret. For this reason, the cancer cohort study reported here was designed not to study any etiologic association, but to investigate empirically the cancer experience of a residential cohort. These data were presented to this community by the investigating team and government officials in a public forum; the results proved very compelling to a community gripped with fear about a long-standing epidemic of cancer. The demonstration to this population that it has indeed experienced a number of cancers but that they occurred with no greater frequency to them than to their peers in neighboring areas has provided considerable reassurance. Such empirical investigations, if negative, can do much to allay fears of an environmental threat; if positive, they might point the way for more focused etiologic studies. These methods may be amenable to other environmental controversies.

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REFERENCES

1. Alberta Environment. Environmental Views. November/December 7 (6): 4–33 (1984).
2. Spitzer, W. O., Dales, R., Schechter, M. T., Steinmetz, N., and Tousignant, P. The Southwest Alberta Medical Diagnostic Review, Volumes I and II. Report to the Acid Deposition Research Programme of the Government of Alberta, June 1986.
3. Spitzer, W. O., Dales, R., Schechter, M. T., Tousignant, P., and Hutcheon, M. Subjective fears and objective data: An epidemiologic study of environment health concerns. Plenary presentation at the Association of American Physicians Annual Meeting, San Diego, May 1987. 35 (3): 643(A) (1987).
4. Ederer, F., and Mantel, N. Confidence limits of the ratio of two Poisson variables. Am. J. Epidemiol. 100: 165–167 (1974).
5. Cancer Registration in Alberta. Edmonton: Provincial Cancer Hospitals Board, 1978.
6. Beaumont, J. J. and Breslow, N. E. Power considerations in epidemiologic studies of vinyl chloride workers. Am. J. Epidemiol. 114: 725–734 (1981).
7. Beauchamp, R. O., Bus,. J. S., Popp, J. A. Borieko, C. J., and Andjelkovich, D. A. A critical review of the literature on hydrogen sulphide toxicity. CRC Crit. Rev. Toxicol. 13: 25–96 (1984).
8. Shapiro, R. Genetic effects of bisulphite (sulphur dioxide). Mutat. Res. 39: 149–175 (1977).
9. Von Nieding, G. Possible mutagenic properties and carcinogenic action of the irritant gaseous pollutants NO_2, O_3, and SO_2. Environ. Health Perspect. 22: 91–92 (1978).
10. Laskin, S., Kushner, M., and Drew, R. T. Studies in pulmonary carcinogenesis. In: Inhalation Carcinogenesis, AEC Symposium Series No. 18 (M. G. Hanna, Jr., P. Nettesheim, and J. R. Golberg, Eds.), U.S. Atomic Energy Commission Division of Technical Information, Oak Ridge, TN, 1970, pp. 321–350.
11. Laskin, S., Kuschner, M., Sellakumar, A., and Katz, G. B. Combined carcinogen-irritant animal inhalation studies. In: Air Pollution and the Lung (E. F. Aaronsen, A. Ben-David, and M. A. Klinberg, Eds.) Wiley and Sons, New York, 1976, pp. 190–213.
12. Mehlman, M. A. Current toxicological information as the basis for sulfur oxide standards. Environ. Health Perspect. 52: 261–266 (1983).
13. Sciex, T. M. Final Report to Alberta Environment: Air Quality Surveys in Alberta Using the TA6A™ 3000 Mobile Laboratory. Contract No. 156.1, February 1982.
14. AD Little Inc. Exposure and risk assessment for benzo(a) pyrene and other polycyclic aromatic hydrocarbons, Vols. I-IV. Prepared for the Environmental Protection Agency, July 1982.
15. Natusch, D. F. S. Potentially carcinogenic species emitted to the atmosphere by fossil-fueled power plants. Environ. Health Perspect. 22: 79–90 (1978).
16. Hanis, N. M., Stavraky, K. M., and Fowler, J. L. Cancer mortality in oil refinery workers. J. Occup. Med. 21: 167–174 (1979).
17. Thomas, T. L., Decouffle, P., and Moure-Erasa, R. Mortality among workers employed in petroleum refining and petrochemical plants. J. Occup. Med. 22: 97–103 (1980).
18. Theriault, G., and Goulet, L. A. Mortality study of oil refinery workers. J. Occup. Med. 22: 367–370 (1979).
19. Gottlieb, M. S. Lung cancer and the petroleum industry in Louisiana. J. Occup. Med. 22: 384–388 (1980).
20. Kaldor, J., Harris, J., Glazer, E., Glaser, S., Neutra, R., Mayberry, R., Nelson, V., Robinson, L., and Reed, D. Statistical association between cancer incidence and major-cause mortality, and estimated residential exposure to air emissions from petroleum and chemical plants. Environ. Health Perspect. 54: 319–332 (1984).
21. Bako, G., Smith, E. S. O., Hanson, J., and Dewar, R. The geographical distribution of high cadmium concentrations in the environment and prostate cancer in Alberta. Can. J. Publ. Health 73: 92–94 (1982).
22. Hill, G. B., and Fincham, S. The Etiology of Cancer of the Prostate in Alberta. Final Report to the National Health Research Development Programme of Health and Welfare Canada. Project no. 6609-1177-53, July 1985.