A Follow-up Study of the Community near the McColl Waste Disposal Site

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To assess the effect of interim clean-up measures on the current health of a community, we conducted a follow-up survey of 193 residents living near the McColl waste disposal site and a comparison area located approximately 5 miles from the site. Results from this survey were compared with results from a similar survey conducted 7 years earlier. Odors were detected at least once per week by 32.7% of “high-exposed” respondents in 1988 compared with 68.5% in 1981, but prevalence odds ratios (PORs) comparing symptom reporting between “high-exposed” and comparison-area respondents were greater than that of the 1981 survey for 89% of symptoms. PORs comparing symptom reporting between these two areas were greater than 2.0 for 64% of symptoms assessed in the current survey. Symptoms reported in excess did not represent a single organ system or suggest a mechanism of response. PORs comparing respondents who were very worried about the environment and those reporting no worry were greater than 2.0 for 86% of symptoms. These findings, along with environmental data from the area, suggest that living near the waste disposal site and being very worried about the environment, rather than a toxicologic effect of chemical from the site, explain excess symptom reporting found in this follow-up study.

Introduction

Community concern regarding potential health problems associated with living near hazardous waste disposal sites has resulted in a flurry of health studies over the past decade. The California Department of Health Services (CDHS) has conducted five such studies during the 1980s (I–5). These studies were conducted in response to initial community concern regarding potential health problems associated with residence in the communities containing the waste sites. The findings from these studies have been reassuring in that no serious health conditions have been found that could be attributed to the site in the populations studied. Four of these studies (I–4) and several others conducted outside California (6–9) have documented an increased prevalence of self-reported symptoms associated with exposure to the site. These four California studies and at least two others (6,10) also found an association between concern about the environment and self-reported health problems. This second finding has been suggested in studies of other environmental threats, such as Three Mile Island (TMI) (II), but has only recently begun to receive attention in health surveys of communities residing near waste disposal sites. For the purpose of this study, the term "exposure" refers to surrogate measures such as the relative frequency of detecting odors from the site or to the relative proximity to the waste site rather than measurement of chemical exposure from the site. The term "environmental worry" refers to the reported level of concern or worry about environmental hazards in one's neighborhood (perceived environmental risk), as assessed in this questionnaire survey.

Until the current study was undertaken, no waste-site community had been followed over time to assess the effect of a health survey or interim clean-up measures on the community’s current health. This study was designed as a longitudinal follow-up study at the first of the five sites studied in California (I). The purpose of this study was three-fold: first, to assess community members’ knowledge of the initial health survey conducted 7 years earlier; second, to systematically assess the rate of symptom reporting and odor complaints to determine if health complaints continue in spite of interim remediation measures at the site; and third, to assess the role of symptom reporting bias related to individuals’ concerns about environmental problems and their perception of health risk associated with living in a community with an inactive hazardous waste site. This paper reports the findings from the second and third study objectives. The first study objective is addressed in a separate report (12).
Background

The McColl waste disposal site, located in Fullerton Hills, California, was used between the early 1940s and 1946 for the disposal of acidic refinery sludge, byproducts in the production of aviation fuel. Between 1951 and 1962, drilling mud from oil exploration activities was deposited on the site with the intention of making the site suitable for future development. The site is approximately 20 acres in size and consists of moderate to severe slopes with terraces between slopes. Recorded quantities of waste deposited at the site included refinery waste and drilling mud, resulting in an estimated total of 75,920 cubic yards of waste (13).

By 1962, most of the site was covered with soil. Part of the site was left as open space, and the remainder was developed as part of a private golf course. Residential development began in this area in the 1960s. The area directly surrounding the McColl site to the east and south was subdivided and developed for residential housing in the late 1970s and early 1980s (13). The site is bordered by an oil field to the north and recreational areas to the west. Prevailing winds in the area during the daylight hours blow from the southwest. The wind direction is from the north at night.

In 1978, residents began to complain of odors in their neighborhood and expressed concern about possible health problems associated with the site. In 1981, at the request of the community, the CDHS carried out a health survey of 377 households located in the neighborhood surrounding the site and extending to approximately one-half mile from the site and 242 households in two control areas located approximately 5 miles from the site. Results of this survey showed a higher than expected rate of odor and symptom complaints near the McColl site. The survey found no difference in the patterns of use of medical care or in the occurrence of tumors between the McColl and comparison neighborhoods (1). An environmental survey was conducted concurrently.

Environmental Data

Environmental data collected by several government agencies and private consultants during 1981 and 1982 showed increased levels of airborne hydrocarbons off site, including benzene in the range of 9 to 14 ppb. The major class of compounds identified in the community air was aliphatic hydrocarbons, with total hydrocarbons adding up to 0.6 ppm. Although these levels were above background levels, they were in the range found in many urban areas of the Los Angeles air basin. Specific alkenes, aromatic hydrocarbons, and sulfur-containing hydrocarbons, especially thiophenes and tetrahydrothiophenes, were identified. Sulfur dioxide (SO₂), a known respiratory irritant in sensitive individuals at levels of 100 to 200 ppm, was detected in the McColl community in the range of 0.0 to 21 ppb. The current California ambient air standard for SO₂ is 50 ppb for 24 hr and 500 ppb for 1 hr (1).

An extensive odor survey (14) was conducted at the time of the 1981 health survey, and results were used to divide the McColl study area into five odor zones. These five odor zones were used to classify exposure areas in both the 1981 health survey and in the 1988 follow-up study (Fig. 1).

At the time of the environmental surveys, most of the site was covered with soil. In 1983, a Geotex material cover and 2 ft of clay-augmented soil was placed on the site as an additional measure to contain wastes on site. At the time of the 1988 survey, all of the 12 pits had been covered with soil, and the site was secured with chain-link fencing and a 24-hr-per-day guard (12). Air monitoring conducted by the Environmental Protection Agency (EPA) during field work in the spring of 1987 and January 1988 showed levels of total hydrocarbons on site in the range of 0 to 10 ppm downwind. Sulfur dioxide was occasionally measured on site at levels of 20 ppm for very brief periods during fieldwork, but never reached the “stop-work” level of a sustained 5-min period of 0.5 ppm (15).

Tests of groundwater and tap water in 1981 did not show any contamination by substances found at the McColl site. Sampling of garden soil and run off from the site did not indicate an environmental hazard to the community (1). In 1988, 8 of 40 randomly sampled McColl area households participated in a study of home tap water. In standing water samples (“worse case” estimate) of these 8 homes, none of over 100 semi-volatile and volatile compounds were detected above the laboratory detection limit, with the exception of trihalomethanes, which are usual by-products of chlorination (M. Harnly, personal communication).

Political and Legal Background

In 1982, the McColl site was placed on the National Priority List (NPL), making remediation of the site eligible for funding under Superfund. In 1983, state officials determined that the dump would be excavated. In late 1984, preliminary excavation finally got underway but was blocked when two separate court injunctions were filed by the county which anticipated receiving the waste, pending preparation of an Environmental Impact Report (EIR). Between 1985 and late 1988, the CDHS and EPA prepared an EIR of alternative methods of remediation: excavation and redisposal, on-site containment, or on-site thermal destruction (13). At the time of the current study the final method of remediation had not been determined.

Litigation involving the site has been ongoing since the early 1980s. A second lawsuit involving community residents, this time including over 100 plaintiffs, was in progress at the time of this study.
Methods

In April 1988, a community health workshop was held in Fullerton Hills, at which time the proposed follow-up study was presented to the community. Residents present at the workshop had few questions about the survey and offered no objections to the proposed project.

Sample size calculations were performed specifying the following parameters: alpha of 0.05, beta of 0.20, expected proportion of the exposed group reporting a specific symptom within the past 1 year equal to 0.40 and a 2-fold excess in symptom prevalence rates between exposed and comparison areas (16). A two-to-one ratio of exposed to comparison area respondents was selected in order to allow the stratification of the exposed area into high exposure and low exposure. Based on the 1981 participation rate and the number of adults per household in that survey, 150 households were selected to obtain the desired sample size for this study. The study population consisted of adults currently residing in each sampled household, regardless of whether they participated in the 1981 survey. The study was designed to assess the presence of symptom and odor complaints among the current neighborhood population.

Using the original odor survey exposure classification, the highest three odor zones (zones 3–5 in Fig. 1) containing 92 households, the lowest odor zone (zone 1 in Fig. 1) containing 217 households, and the comparison area (not shown in Fig. 1) containing 242 households were selected from the 5 odor zones to maximize a dose-response between study areas, if one did exist. Using city planning maps to identify housing lots, 50 households were selected by systematic sampling from each of these three strata. These samples were selected by first determining the desired sampling interval, k within each stratum, choosing a random starting number between 1 and k and then selecting every k housing unit from that starting number (17). Participation was solicited from two adults per household.

Telephone numbers were obtained from the following sources: reverse telephone directory, the 1981 household enumeration, mailed request forms and, as a last resort, by visiting the remaining households. All 150 households were sent a letter that described the study as one that would assess environmental conditions in their neighborhood and notified them that an interviewer would call them in the next several weeks for a short telephone interview. The 88 (59%) households not listed in the reverse directory also received a form requesting their telephone number for the purpose of this survey.

The follow-up study interview schedule was a modified version of the 1981 schedule. It was shorter than the 1981 schedule and was administered by trained interviewers, whereas the 1981 survey consisted of a self-administered questionnaire. Several questions were taken directly from the 1981 survey to allow for the comparison of responses between the two time periods. The health-related questions were modified to shorten the interview and included 18 symptoms from the 1981 survey (plus four new symptom inquiries). The current interview schedule assessed the prevalence of symptoms in the past 1 year. The 1981 survey assessed symptoms occurring since moving to one’s current residence, but also asked whether one was “bothered” by the symptom in the past 1 year.

The follow-up study interview schedule also included questions that attempted to measure perceived environmental risk, one question regarding the frequency of odor perception, a general self-health-appraisal question, a list of 22 symptoms, and demographic information. The questions about the 22 symptoms did not ask one to determine whether symptoms were attributed to the waste site.

Two trained CDHS interviewers conducted the 10-min telephone interviews. When necessary, at least seven attempts during both daytime and evening hours were made to contact potential participants by phone. Interviewers began by introducing themselves and the purpose of the study and then attempted to interview the adult who answered the phone. At the end of the first interview, they asked if a second adult resided in the house and if so, requested to conduct a similar interview with him or her. If a second person was unavailable for an interview at that time, the interviewer requested that the first adult not discuss the specific content of the interview with the second adult until the second interview was completed. Non-English speaking adults (n = 21) were considered ineligible for participation and eliminated from the potential study population. Telephone interviews were conducted between July and September 1988. The principal investigator and chief interviewer visited Fullerton Hills in September 1988 and interviewed 18 adults from 30 households that we were unable to contact by telephone.

Analysis

Participants from the 1988 study who also participated in the 1981 survey were identified by matching name (when available), sex, date of birth, and address from both surveys, and responses were stratified by whether or not the respondent participated in the 1981 survey for several analyses. Data from the 1981 survey were compared with data from the 1988 survey for odor detection frequency, self-health-appraisal and one question regarding environmental worry. One-year symptom period prevalence rates from the 1981 survey were determined by an affirmative response to the question of whether the respondent had experienced a specific symptom since moving to their current residence and an affirmative response to whether they had been bothered by the symptom in the past 1 year. Prevalence rate differences and prevalence odds ratios between high-exposure and comparison groups during the 1988 survey and the 1981 survey were compared.

One-year symptom period prevalence rates by exposure area were calculated. Symptom prevalence odds ratios (ratio of odds of symptoms for those in the exposed group versus those in the comparison group) for high exposed versus comparison area, high worry versus low worry, and frequent odor detection versus rare odor detection were calculated. The prevalence odds ratio was chosen as the appropriate measure of association for cross-sectional data (18) and because the alternative ratio measure, the prevalence rate ratio, has a limited upper range of values when assessing highly prevalent conditions (e.g., 50% or greater). It should be noted that the prevalence odds ratio does not estimate the prevalence rate ratio in these situations. The relationship between symptom prevalence, exposure area, and environmental worry was assessed by calculating prevalence odds ratios within the nine possible combinations of the three levels of exposure and three levels of worry. This analysis was conducted to assess for differences in the association between exposure and symptom reporting across varying levels of
environmental worry and environmental worry and symptom reporting across the three exposure areas, also known as "effect modification."

The exposed study area was reclassified into two areas of near equal number of households, based on distance from the site, to assess whether this measure of exposure was more strongly associated with symptom reporting and environmental worry than the original odor zone classification. Because the selection of two adult participants per household introduced the possibility of nonindependent responses within households, analyses were repeated using only the first respondent from each household.

Prevalence odds ratio analyses were conducted using SAS software (19). A small-sample correction factor was used in calculating the prevalence odds ratio when the value in any cell in the two-by-two table equaled zero (20). Multiple linear regression was conducted using SAS software (19) to examine the relationship between the total number of symptoms reported and several measures of exposure while controlling for potential confounding variables.

Results

One hundred ninety-three of 267 (72.3%) eligible adults participated in an interview. The participation rate in the high exposed area, 67.9%, was lower than in the low-exposed or comparison area, which had participation rates of 75.9% and 76.1%, respectively.

Within each group, the distribution of potential confounding variables was examined (Table 1). Overall the groups were quite comparable, but the following differences were noted. The high-exposed had a lower percentage of females and Caucasians. The comparison group had a lower percentage of persons with only a high school education and a lower percentage of persons who had lived in their current residence for more than 5 years.

Table 1. Characteristics of study population by study area.

| Characteristic            | Study area       |          |          |          |
|---------------------------|------------------|----------|----------|----------|
|                           | High exposed (%) | Low exposed (%) | Comparison (%) |
| Sample size               | 57               | 66       | 70       |
| Females, %                | 43.9             | 56.1     | 51.4     |
| Ethnicity                 |                  |          |          |          |
| Caucasian, %              | 61.8             | 67.2     | 79.4     |
| Latino, %                 | 5.5              | 14.1     | 4.4      |
| Asian, %                  | 27.3             | 15.6     | 14.7     |
| Other, %                  | 5.5              | 3.1      | 1.5      |
| Age                       |                  |          |          |          |
| 22–34 years, %            | 14.0             | 10.8     | 17.7     |
| 35–54 years, %            | 70.2             | 64.6     | 64.7     |
| ≥ 55 years, %             | 15.8             | 24.6     | 17.6     |
| Education                 |                  |          |          |          |
| 8–12 years, %             | 19.6             | 24.2     | 7.3      |
| 13–16 years, %            | 48.2             | 60.6     | 63.8     |
| > 16 years, %             | 32.1             | 15.2     | 29.0     |
| Length of residence       |                  |          |          |          |
| 0–2 years                 | 29.4             | 21.0     | 34.3     |
| 3–5 years                 | 2.0              | 9.7      | 11.9     |
| 6–10 years                | 66.7             | 37.1     | 23.9     |
| > 10 years                | 2.0              | 32.3     | 29.9     |
| Current smokers, %        | 8.8              | 18.2     | 15.9     |
| Solvent exposed, %        | 10.5             | 12.1     | 15.7     |
| Pesticide exposed, %      | 5.4              | 7.6      | 7.1      |

Exposure classification was based on odor zones determined by an extensive odor survey conducted in 1982. The reported frequency of odor detection in the current study corresponded to the odor ranking scheme adopted from the earlier survey. When households were reclassified according to geographic distance from the site, similar associations with symptom reporting and environmental worry were observed. Therefore, the analysis is based only on the odor zone classification of exposure. Reclassification of exposure areas by distance from the site resulted in the movement of approximately 20 households between the two exposed areas.

Of the 22 symptoms included in the current study, 21 were reported more frequently by high-exposed than by comparison-area participants (Table 2). Crude prevalence odds ratios comparing symptom reporting between high-exposed and comparison area respondents were greater than 2.0 for 14 of 22 (64%) symptoms (Table 3). Symptoms with prevalence odds ratios of greater than 2.0 were not specific to a single organ system but included those associated with neuropsychological, gastrointestinal, and respiratory effects. Irritant effects, such as skin irritation and throat irritation, were also elevated among exposed persons. However, the largest prevalence odds ratio, 5.95 (95% confidence level, 1.85, 19.16) was for the symptom toothache which was asked to assess reporting bias rather than toxicologic effects.

Exposed area individuals who participated in the 1981 survey reported a higher prevalence of symptoms than those who did not participate in the 1981 survey. Comparison area participants showed the opposite relationship between symptom reporting and participation in the 1981 survey. The magnitude of the difference in symptom rates between 1981 participants and all others varied by specific symptom.

Table 2. One-year symptom period prevalence rates* by study area.

| Symptom                        | High exposed, % | Low exposed, % | Comparison, % |
|--------------------------------|-----------------|----------------|--------------|
| (n = 57)                       | (n = 66)        | (n = 70)       |
| Headache                       | 80.4 (45)       | 54.6 (36)      | 51.4 (36)    |
| Fatigue or tired               | 64.3 (36)       | 47.0 (31)      | 40.0 (28)    |
| Nervousness                    | 62.5 (35)       | 51.5 (34)      | 44.3 (31)    |
| Sinus congestion               | 62.5 (35)       | 51.5 (34)      | 50.7 (35)    |
| Irritated eyes                 | 60.7 (34)       | 47.0 (31)      | 44.9 (31)    |
| Sore throat                    | 48.2 (27)       | 33.3 (22)      | 26.1 (18)    |
| Colds                          | 47.3 (26)       | 33.3 (22)      | 34.8 (24)    |
| Allergies                      | 47.3 (26)       | 37.9 (25)      | 46.4 (32)    |
| Difficulty sleeping            | 42.9 (24)       | 42.4 (28)      | 27.1 (19)    |
| Poor memory                    | 39.3 (22)       | 37.9 (25)      | 28.6 (20)    |
| Nausea                         | 35.7 (20)       | 22.7 (15)      | 10.1 (9)     |
| Stomach pain                   | 35.7 (20)       | 27.3 (18)      | 17.4 (12)    |
| Diarrhea                       | 35.7 (20)       | 21.2 (14)      | 24.6 (17)    |
| Skin irritation                | 32.1 (18)       | 16.7 (11)      | 8.7 (6)      |
| Poor concentration             | 32.1 (18)       | 19.7 (13)      | 14.5 (10)    |
| Toothache                      | 26.8 (15)       | 9.1 (6)        | 5.8 (4)      |
| Loss of appetite               | 25.0 (14)       | 16.7 (11)      | 7.3 (5)      |
| Wheezing                       | 25.0 (14)       | 18.2 (12)      | 7.3 (5)      |
| Dizziness                      | 19.6 (11)       | 13.9 (9)       | 12.9 (9)     |
| Chest pain                     | 17.9 (10)       | 15.2 (10)      | 8.7 (6)      |
| Numbness                       | 17.9 (10)       | 25.8 (17)      | 21.7 (15)    |
| Earaches                       | 16.1 (9)        | 15.2 (19)      | 8.7 (6)      |

*One-year period prevalence per 100 persons.

bNumbers in parentheses are n for the symptom.
Comparison with the 1981 Health Survey

Six symptoms for which the prevalence odds ratio between high-exposed and comparison-area respondents was 2.5 or greater were selected for comparison with prevalence rates from the 1981 survey. Since the wording of the symptom questions and the method of questionnaire administration were different between the two surveys, the symptom prevalence rates between studies are not directly comparable. However, the prevalence rate differences and prevalence odds ratios between exposure groups for the two time periods are informative (Table 4). The difference in symptom rates between persons residing in the high-exposed and comparison areas continue to be elevated in 1988 in spite of interim remediation at the site. In fact, the 1988 survey prevalence odds ratio for these two areas was greater than that of the 1981 survey for all six symptoms presented in Table 4 and for 16 of the 18 (89%) symptoms included in both surveys.

Odor detection “over the past 2 months when at home or in one’s yard” was reported less frequently by persons living in both exposed areas during the 1988 survey than during the 1981 survey (Table 5). The odor frequency distribution for the comparison area was constant between the two time periods with 54.7% and 52.9% reporting never noticing odors in the 1981 and 1988 surveys, respectively. Odors were reported less frequently by both exposure areas in 1988, but the difference over time was greatest for the high-exposed area. There was a smaller difference in the frequency of odor detection between areas in 1988 compared with 1981.

Self-reported health status was significantly associated with exposure group in both the 1988 and 1981 surveys. The health status distribution for the high-exposed and comparison groups was similar between the two time periods. A higher percentage of the low-exposed group reported that they were in excellent health in 1988 (53.0%) than in 1981 (33.3%) (Table 6). In 1981 and 1988, both the exposure groups were more likely to report fair or poor health than the comparison group.
prevalence odds ratios for each of the 22 symptoms included in the survey (Table 8). Each variable was strongly associated with a number of individual symptoms. The symptoms for which area, odor, or worry were the strongest predictors were not symptoms generally associated with a physiologic response to odor, or to stress in the case of the association with environmental worry. For instance, symptoms most frequently associated with unpleasant odors, nausea, and headache (21), were not the symptoms most strongly associated with odor in this analysis. Those symptoms most associated with odor detection in this study, dizziness, wheezing, and skin irritation, are unlikely to be related to any known physiologic response to odor per se, but wheezing and skin irritation could be associated with irritant chemicals if odors were a surrogate for chemical exposure. Similarly, the symptoms most strongly associated with worry, namely, wheezing, earache, and sore throat, are not symptoms classically associated with a physiologic response to stress.

In an attempt to evaluate the association between symptom reporting and the variables worry and exposure, while holding constant the effect of each of these two variables, prevalence odds ratios for nine possible combinations of exposure/worry were calculated for the four most prevalent symptoms. The reference group was comparison-area persons reporting no or little environmental worry (Figs. 2–5). Attention should be directed to the comparison area and low worry categories. There appears to be no association or a negative association between exposure and symptom reporting in the low worry categories, so the relationship between symptoms and exposure is only seen for the worried group. At the same time, the odds ratio of high versus low worry in the comparison area is 1.5 or greater for 2 (50%) of these symptoms, while there is little evidence of a consistent dose–response relationship by level of worry in the comparison area. Because of the small number of observations in each cell (n = 7 for high exposed/low worry category), interpretation of these data is limited, but this suggests effect modification between symptoms and exposure and symptoms and worry.

Table 8. Symptom prevalence odds ratios, high versus no exposure, odor detection, and environmental worry.

| Symptom         | Exposure (n=126) | Odor (n=110) | Worry (n=104) |
|-----------------|-----------------|--------------|---------------|
| Toothaches      | 5.95            | 3.50         | 4.92          |
| Skin irritation | 4.97            | 5.50         | 3.72          |
| Nausea          | 4.92            | 2.95         | 3.37          |
| Wheezing        | 4.28            | 9.80         | 25.28*        |
| Loss of appetite| 4.27            | 4.57         | 3.44          |
| Headache        | 3.86            | 2.25         | 3.44          |
| Poor concentration| 2.78           | 5.13         | 2.96          |
| Fatigue or tired| 2.70            | 3.30         | 1.86          |
| Stomach pain    | 2.64            | 3.68         | 3.16          |
| Sore throat     | 2.64            | 3.84         | 7.07          |
| Chest pain      | 2.28            | 4.79         | 2.31          |
| Nervousness     | 2.10            | 2.00         | 3.67          |
| Difficulty sleeping| 2.01           | 2.44         | 2.40          |
| Earaches        | 2.01            | 4.31         | 13.80*        |
| Irritated eyes  | 1.89            | 2.52         | 2.61          |
| Diarrhea        | 1.70            | 1.93         | 4.36          |
| Colds           | 1.68            | 1.48         | 2.64          |
| Dizziness       | 1.66            | 12.17        | 4.15          |
| Poor memory     | 1.62            | 2.92         | 2.27          |
| Sinus congestion| 1.62            | 1.95         | 5.59          |
| Allergies       | 1.04            | 0.99         | 1.70          |
| Numbness        | 0.78            | 1.62         | 0.72          |

*One cell contained 0 observations, so 0.5 was added to each cell to calculate the prevalence odds ratio.

The results of multiple linear regression analysis evaluating the total number of symptoms reported as the dependent variable (range 0–18) and exposure variables and demographic variables as predictive variables are presented in Table 9. Sex, odor detection frequency, worry, and length of residence were each statistically associated with symptom reporting in this model. The coefficients represent the increase in the total number of symptoms reported per one unit increase in the covariate. For
FIGURE 4. Prevalence odds ratios for fatigue by all combinations of exposure/worry. Reference: comparison-area participants reporting low worry.

FIGURE 5. Prevalence odds ratios for sinus congestion by all combinations of exposure/worry. Reference: comparison-area participants reporting low worry.

e.g., females reported nearly 1.5 more symptoms than males, persons reporting little environmental worry reported 0.70 more symptoms than those reporting no worry. Other covariates that were initially entered into the model but had little impact on the $R^2$ and had very small beta coefficients included age, education, and cigarette smoking.

| Covariates                        | Coefficient | 95% CI  |
|-----------------------------------|-------------|---------|
| Sex (reference = male)            | 1.43        | 0.31, 2.55 |
| Frequency of odor detection (reference = never, 6 levels) | 0.93 | 0.47, 2.05 |
| Environmental worry (reference = none, 4 levels) | 0.70 | 0.13, 1.26 |
| Exposure area (reference = unexposed, 3 levels) | 0.75 | -0.015, 1.31 |
| Length of residence (reference = < 1 year, 16 levels) | 0.17 | 0.04, 1.29 |

The results of analyses conducted with only one participant per household were similar to those using the entire study population. Further effort to assess nonindependence between household respondents was deemed unnecessary.

**Discussion**

The current study assessed symptom reporting, odor complaints, and risk perception in a community that contains an inactive hazardous waste disposal site and a comparable unexposed population. This community was selected for follow-up of an earlier environmental health survey in 1981 to assess whether intervening events had changed symptom reporting. The sample of 150 households was selected from the original 619 households as the minimum number of subjects required to detect a two-fold difference in symptom reporting between the exposed and comparison groups in univariate analysis. The study had limited power to detect small differences in symptom reporting, particularly in stratified analysis.

The overall participation rate, 73%, was somewhat lower than the 1981 survey rate of 84%. The refusal rate in the high-exposed area (20%) was higher than in other areas. Eight persons in both exposed areas refused to participate because they were involved in litigation related to the site. Since potential study participants were not asked whether they refused because of litigation, the total number of refusals related to litigation could not be determined, and it is possible that all nonrespondents were symptomatic litigants, so that symptom rates in the exposed area could have been underestimated. It is also possible that many of the nonrespondents chose not to participate because of being asymptomatic, which would cause a bias in the direction of overestimating symptoms among the exposed. No information regarding nonrespondents was available, and because of the magnitude of differences observed, nonresponse is an unlikely explanation for the differences in symptom rates between areas.

Differences in the demographic characteristics between the exposed and comparison study areas included a lower percentage of participants with less than a high school education and a lower percentage who had lived at their current residence for greater than 5 years among the comparison area. The high-exposed group had a lower percentage of females and Caucasians. The total number of symptoms reported by an individual did not vary by education, but did vary by sex and length of residence, as demonstrated by the multiple linear regression analysis. Controlling for these variables in the analysis did not explain the association between exposure, as measured by reported odor detection frequency and environmental worry and the total number of symptoms reported. Since the high-exposed group
had approximately 8% fewer females than the comparison group, this would have the effect of slightly lessening the difference in symptom rates between these two groups. When the two exposed groups were combined, they had approximately the same proportion of females as the comparison population. The difference in the length of residence between the exposed and comparison groups would have the opposite effect.

The purpose of this part of the McColl follow-up study was twofold. First, to assess the rate of symptom reporting and odor complaints 7 years after the initial 1981 study and after interim remediation measures (e.g., Geotex and clay soil cover, fence around the site) had been implemented. Twenty-one of twenty-two symptoms directly queried were reported more frequently in 1988 by exposed-area participants. The symptoms observed to be (versus toxicologically) most strongly associated with exposure did not represent particular organ systems suggestive of a causal mechanism between exposure and symptoms, but rather suggested what Ozonoff described as a "pan symptom" effect indicative of reporting bias (6). In support of this explanation for the observed excess symptom reporting was the finding that toothache, included as a "dummy" symptom in the survey to test for reporting bias, was reported nearly six times as often by persons residing in the high-exposed area compared with persons in the comparison area. The difference in symptom prevalence rates between the high-exposed and comparison areas in this study was greater than the difference in rates observed in 1981, suggesting that interim clean-up measures and information from the health survey have not reduced the symptoms experienced and/or reported by those living near the site. Findings from the current study suggest that interim clean-up measures have reduced odor detection frequency relative to the frequency reported in 1981, but this reduction was not accompanied by reduced symptom reporting.

Exposed-area individuals reported a similar distribution of worry or concern about the environment in 1981 and 1988. However, the comparison area participants reported considerably more worry in 1988. Considering the increased media coverage of environmental issues over the past decade, it is not surprising that the background rate of environmental worry has increased since 1981. The results suggest that exposed-area participants are either less worried about their immediate environment than they were in 1981 or that their awareness of general environmental issues was already heightened in 1981. In any case, the exposed-area participants continue to report a higher level of worry in 1988.

The second purpose for the study was to assess the role of symptom reporting bias related to individuals' awareness of environmental problems and their perception of health risk associated with living in a community with an inactive hazardous waste site. This type of assessment is essential to any study that is conducted in a politically charged environment and that relies on a subjective outcome measure, such as symptom reporting. This study was designed to elaborate on the measurement of this phenomenon, reporting bias, which has been evaluated in other waste site studies (1,4,6) and which was the objective of a Louisiana waste site study (10).

As the 1981 survey, a dose-response relationship was demonstrated between symptoms and exposure area and symptoms and level of environmental worry in the unstratified analysis. Approximately 60% of the symptoms included in this survey were reported at least twice as often by persons reporting they were very worried versus not worried, resulting in prevalence odds ratios of three or greater. When the association between symptoms and exposure was examined among persons reporting no or little worry, no association was detected. An association between worry and symptoms was detected in the comparison area for two of four symptoms included in this analysis.

Multiple linear regression analysis demonstrated that the frequency of odor detection and the level of environmental worry, but not the exposure group, were significant predictors of the total number of symptoms reported. Although the original exposure group classification was based on odor, individual respondents' frequency of odor detection was a stronger predictor of symptom reporting in this analysis. It should be noted that the question regarding odor detection frequency asked about the odor from petroleum or chemicals in one's yard or home and did not specify that these odors were related to the McColl site. Ten percent of comparison-area respondents reported odors once a week or more frequently. The association between odor detection and symptom reporting suggests that either odors play a causal role in symptom reporting or that reporting odors may be a surrogate for concern or perhaps demonstrate a heightened awareness of stimuli that could include both odors and symptoms. This last explanation is supported by the fact that the symptoms most highly associated with odor detection in this study are not symptoms classically associated with odors.

In spite of the difficulty in determining which particular aspect of perceived risk is most strongly associated with symptom reporting, the findings of this study clearly suggest that symptom reporting is associated with perceived environmental risk. The causal mechanism for this association, if one exists, is uncertain. In fact, one possible explanation for the association between worry and symptom reporting is that experiencing symptoms that one attributes to the waste site then causes worry about the environment. In an attempt to illuminate the direction of the causal relationship between these two factors, respondents who stated they were worried about environmental hazards in their neighborhood were asked what made them worried. Four percent stated they were worried because of personal illness. The majority of individuals gave "risk of future health problems or damage to the environment" as the reason for their worry. In other California studies of waste site communities, approximately 10% of respondents reported personal illness caused their worry (1,3,4). The association between worry and symptom reporting remained when those who were worried related to personal illness were removed from the analysis. This finding suggests that in these studies, worry caused symptom reporting rather than symptoms causing worry.

The current state of knowledge in this area of research limits one to speculating on the role exposure to a waste site and its associated increased risk perception plays in symptom reporting. A number of possible mechanisms have been proposed and include the following: toxicologic properties of chemicals, physiologic response to odors from the site, physiologic response to the stress of living near a waste site, psychosomatic reactions to stress, reporting bias, and confounding variables. It is believed that a combination of these mechanisms characterize the effects
of most community chemical exposures but that several mechanisms are more plausible than others. Data from this follow-up study will be examined in terms of potential mechanisms for excess symptom reporting by individuals residing in communities with waste disposal sites.

Environmental data from 1981 and 1988 do not indicate exposure at acute or chronic toxicologic levels around the site. Airborne chemical exposures were found to be above background levels for total hydrocarbons, but below levels in many areas in the Los Angeles air basin, the location of the site and the community. Levels of all airborne contaminants were found to be orders of magnitude lower than exposures known to cause health effects in occupational settings. The use of occupational standards for community settings where sensitive segments of the population (e.g., children, the elderly, and those with debilitating health conditions) are exposed 24 hr-per-day, 7 days-per-week is probably not appropriate. However, occupational standards and animal toxicity testing can be used as reference values with the appropriate safety factors to assess whether community exposures may cause irritant, neurotoxic or other toxicologic effects.

This follow-up study addresses the question of a physiologic response to odors from the site in a way that was not possible in the initial study. When odor detection frequency was assessed in the follow-up study, odor complaints had been reduced from 1981 levels by approximately 50% in the exposed areas; however, the difference in symptom prevalence between the high-exposed and comparison area increased. Symptoms reported in the 1988 survey covered the previous 1-year period and therefore were not influenced by higher odors from the early 1980s. This finding suggests that a physiologic response to odors is not the sole pathway for symptom reporting in this population. In the current study, odor detection frequency was significantly associated with the total number of symptoms reported in the multiple linear regression analysis, suggesting that odors may trigger symptom experience and/or recognition.

Did exposed members of this study population experience, ascertain, or simply report more symptoms than comparison-area participants? The experience of living in a community with a waste site, especially in an area identified as "high exposed," is undoubtedly stressful. Possible causes of this stress include economic insecurity (e.g., property devaluation), slow action by government agencies, the lack of a quick technological fix to the situation, and uncertainty and conflicting messages about health risks associated with the site. The slow pace of site remediation is likely to cause considerable stress for concerned community members. There is convincing evidence that environmental threats such as hazardous waste sites or other potential manmade technologic disasters are associated with physiologic and psychologic manifestations (22–24). However, it is difficult to assess the mechanisms of either physiologic or psychosomatic responses to the stress of living near a hazardous waste site. Without valid and reliable biochemical markers of stress and the related sequelae, it is impossible to assess to what extent stress explains the excess symptom reporting in the exposed areas.

Reporting bias, a differential ascertainment, recall or reporting of symptoms by exposed compared with unexposed individuals is likely in situations where the media, the public and/or agencies have focused attention on potential health and environmental problems in the area. Roht et al. concluded that reporting bias was the likely explanation for differential symptom reporting in two communities exposed to hazardous waste disposal sites in Louisiana (10). Ozonoff et al. studied a population residing near the Silresim, MA hazardous waste site and concluded that there was evidence of both recall bias and adverse health outcomes (6). The real effect they referred to was the association between exposure area and several symptoms, most notably "bowel complaints" and cough, which could not be explained by worry or other covariates. Baker et al. recently reported findings from the study of the Riverside, California, Stringfellow waste disposal site that suggested an increased perception or recall of health conditions by respondents living near the site (25). The three California waste site studies that attempted to examine reporting bias by measuring environmental worry found that worry was a strong predictor of symptom reporting, but it did not completely explain the differential symptom reporting between exposure areas (1,3,4). Goldman et al. found evidence of recall bias among women reporting birth deformations around the Love Canal waste site (26).

The current study found an association between symptom reporting and environmental worry that varied by study area, indicating effect modification by exposure area. The symptom question in this survey was not designed to differentiate between symptoms attributed to exposure and background factors. A comparison group was included to estimate the prevalence of symptoms related to background factors. When the area-specific prevalence rate for headache (the most prevalent symptom reported by exposed individuals) was examined, it is interesting to note that only 51% of comparison area individuals answered affirmatively to the question "during the past 1 year have you had headaches." Because headaches are such a common occurrence, this lower than expected reported prevalence of headaches in the comparison population may suggest the differential ascertainment and reporting of headaches rather than differential experience of headaches in the exposed area.

Conclusion

This study, the first of its kind to follow a community over time to assess whether a health survey and interim remediation at a waste disposal site affects the community's current health, found that the exposed population continues to experience and/or report significantly more symptoms than the comparison population, 7 years later. This was true whether the exposure area was defined by odor zones or proximity to the site. Paradoxically, exposure, as measured by the perception of odors from the site, has been reduced since the 1981 survey. However, potentially troubling political and legal events have occurred that may have mitigated any positive effects of reduced odors by causing increased psychological stress since strong associations between symptom reporting and exposure area were found only among persons reporting a high level of environmental worry. Conversely, consistent associations between worry and symptom reporting were only found for the exposed study area. Both of these findings demonstrate that exposure (residing in the high odor zones) in the presence of high environmental worry is associated with increased symptom reporting. However, environmental monitoring of community exposure suggested that McColl waste site contaminants were present at levels considerably lower than...
those associated with these symptoms in occupational or experimental settings. Taken together, these findings suggest that the concern and worry associated with living in a community with a waste disposal site, rather than the exposure to chemicals from the site, is responsible for the excess symptom reporting observed in this study. This does not eliminate the possibility that there may be highly sensitive individuals in the community who experience symptoms when exposed to chemicals at the part-per-billion levels found at this waste site, but the presumably rare sensitive persons in the population cannot explain the very large differences in symptom prevalence rates between the populations observed in this study. This study demonstrates the personal and societal cost of the political and social upheaval often involved in hazardous waste disposal clean-up efforts. Community and government collaboration to address the problems created by the generation of hazardous waste has never been more crucial. This response needs to pay increased attention to addressing community stress and concern, as well as engineering controls and remediation.

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