Hazardous chemicals: psychological dimensions of the health sequelae of a community exposure in Texas

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Abstract

Study objective – A chemical spill from an oil refinery exposed the local community to more than 40 000 lb of highly toxic and corrosive hydrofluoric acid. A community based symptom prevalence study found an association between exposure and physical symptoms: the psychological impact of the disaster and its potential effect on the reporting of physical symptoms is examined here.

Design – The study used a population based survey design consisting of two phases: phase I, the exposure phase, and, phase II, the symptom prevalence phase.

Subjects – In phase I, information indicative of exposure was collected on 10 811 individuals in a door to door survey of a geographically defined area. In phase II, symptom prevalence information was gathered through in-person interviews with 2509 subjects selected from the phase I census in a sampling scheme that balanced across the exposure categories with regard to age, gender, and predisposition. The refusal rate in both phases was <5%.

Measurement and main results – Stepwise logistic regression analyses were used to assess the relative predictive importance of psychological variables and hydrofluoric acid exposure in explaining the reported physical symptoms two years after the disaster. The findings show a linear relationship between the level of hydrofluoric acid exposure and the degree of psychological stress two years after the accident. High exposure had a long term (more than two years) impact on physical health for some self reported symptoms, even after controlling for the psychological impact. Some physical symptom reports, however, were better explained by psychological status than by exposure to hydrofluoric acid. The physical symptoms for which exposure was the major predictor were those for which the biological plausibility of a relationship with hydrofluoric acid exposure was direct.

Conclusions – Measures of psychological status should be included in symptom studies of health sequelae to man-made disasters so that the physical effects of exposure can be more accurately assessed.

its high solubility in water and the capability of concentrated HF solutions to absorb water with a release of heat. These properties mean that it can cause severe burns to the skin and eyes as well as pulmonary damage, which may not be painful or visible for several hours after the initial exposure.¹ Once absorbed, HF has some direct and indirect systemic toxic effects which occur as a result of the rise of the fluoride concentration in the blood (direct), and the concomitant lowering of calcium and magnesium in blood, skin, and other organs (indirect). Considerable local and systemic toxicity may occur from hydrofluoric acid by all routes of exposure.² Published literature on toxicity of fluoride has mainly dealt with chronic (low dose, long term) exposure.³⁻⁵

Acute exposures to HF have been primarily investigated in occupational settings. Pulmonary oedema and death within a couple of hours of inhaling HF have been reported.⁶⁻⁸ A case of pulmonary injury manifesting several days after exposure and death in four weeks has also been reported.⁹ Respiratory symptoms may persist for months to years after inhalation injury.⁹ Exposure of the eye to HF produces more extensive damage than that of other acids in similar concentrations.² Dermal exposure causes severe skin burns and intense pain, the onset of which may be delayed for hours. Severe burns can progress to ulceration and tissue loss, which, in extreme cases, may result in scarring and permanent disability.^{10,11} There are also reports of systemic fluoride toxicity from acute HF exposure: Tepperman,¹² for example, reports a fatality resulting from a severe facial burn, which produced acute systemic fluoride poisoning. Other reports of systemic toxicity from acute exposures include systemic acidosis, hypocalcaemia and hypomagnesaemia,¹³ and histological myocardial damage.¹⁴

On October 30, 1987, the convection section of the HF alkylation heater was dropped during an attempted crane lift at the Marathon Oil refineries in Texas City, Texas. Two relief valves were sheared off a storage tank and over 40 000 lb of anhydrous HF and 200-300 barrels of isobutane were released into the atmosphere, forming a huge cloud that drifted over residential areas of the community. Residents (approximately 200 blocks) were evacuated for 48 hours. After the spill, about 1000 people were seen at the emergency department of the two area hospitals; 95 were considered sick enough to be admitted to hospital. The Texas City episode was the first substantial acute HF exposure involving an entire community.

A population based symptom survey was

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Anhydrous hydrogen fluoride (HF) is a highly irritating and corrosive substance because of

conducted to evaluate the accident's impact on the health of the community. Details of the methods and findings with regard to short term and long term physical symptoms have been published.¹⁵ The principle findings with regard to physical symptoms can be summarised as follows: (i) the prevalence of severe individual physical symptoms (and the prevalence of severe symptoms in an organ/function system) in the month after the spill increased in relation to exposure in a dose-response manner; (ii) the continuing prevalence of severe individual symptoms (and prevalence of severe symptoms in an organ/function system) two years after the spill was also related to the degree of exposure; (iii) the reported prevalence of severe symptoms two years after the spill was considerably lower than the prevalence in the month after the spill in each exposure category, and the improvement was most substantial for the highly exposed group; and (iv) symptoms like skin burns and blistering were mostly short term, even in the highly exposed individuals, whereas problems related to breathing were reported to be still severe two years after the spill by 20 to 30% of the individuals in the highly exposed group. Thus, Dayal *et al*¹⁵ showed that exposure produced short and long term adverse physical symptoms in the community.

Disasters have also been shown to have long term psychological effects,¹⁶⁻¹⁹ and people with psychological problems or stress tend to report more symptoms of any kind.²⁰ Thus, the long term psychological impact of the accident could potentially account for the higher frequency of physical symptoms in the exposed groups. We examine here the interrelationships of the physical and psychological dimensions of the health sequelae of the community exposure to HF in Texas City. The relative predictive value of the psychological variables and HF exposure in explaining physical symptoms is ascertained through multivariate analyses.

Methods

The population based epidemiological study comprised two phases. Phase I, the exposure study, was a door to door survey of 10 811 individuals in 339 city blocks conducted almost a year after the spill to obtain a census of individuals who had come into contact with the chemical and to assign a measure of exposure to each person in the list. We adopted a multipronged approach as we recognised that there would be uncertainty associated with any single measure. Data were gathered on the whereabouts of each person at 15 minute intervals for the two hours after the release, a respondent reported level of exposure, and, for the 48 hour period afterwards, an assessment was made of the severity of the three acute symptoms considered pathognomonic – burning or irritation of the throat, burning or irritation of eyes, and coughing or difficulty breathing. In addition, predisposition to lung problems was designated for individuals with a pre-existing pulmonary condition or those who smoked two

or more packets of cigarettes per day at the time of the spill.

A mathematical model was used to predict isodensity curves of HF concentrations at various locations at specific times. The model predicted concentrations on a 400 point grid, and this grid was used to draw concentration isopleths for each of the first two hours and for the two hour average. A cumulative exposure index was produced by relating the whereabouts data to projected concentration levels. The model predicted exposure index and the other two indicators exhibited very poor correlation, even when ranks were used. To gain further insight, the location of isodensity curves was compared to the residence of the patients admitted to hospital, and the residence location of those considered to have been heavily exposed by the two highly correlated indicators. It was significant that the cluster of patients admitted to hospital (objectively known to be highly exposed) conformed to the cluster of individuals designated as heavily exposed by the self reports, and neither the hospitalised cluster nor the cluster of designated heavily exposed individuals was consistent with the areas identified by the models as areas of high exposure. These observations suggested the severe limitations of the mathematical modelling approach in defining individual doses from a brief exposure. In fact, the lack of detailed meteorological data and the acute nature of the exposure made the mathematical modelling approach inadmissible.

The selected method of exposure assessment in this study was the combination of the overall reported level and the data on severity of the three pathognomonic acute symptoms associated with the exposure. The questions on acute symptoms were omitted for individuals for whom exposure was reported as 'none' or as 'don't know'. For others, the information on acute symptoms was summarised into – none reported, none severe, one severe, two severe, and all three severe. The data on the reported level of exposure and severe acute symptoms were combined according to the schema presented in the figure, to yield the following exposure categories: high, moderate, mild, none, not well defined, and unknown. Later, the 'mild' and 'moderate' categories were merged to create an 'intermediate' exposure category. It should be noted that pathognomonic symptoms reported at mild or moderate levels did not enter the final designation of an individual's exposure category. Overall, 6.7% were determined to have been heavily exposed, and 51.3% reported no exposure.

Phase II, the symptom prevalence survey, was conducted approximately two years after the accident and consisted of face to face interviews with 2509 people. This included all highly exposed individuals from the exposure study and a sample of controls from the census. The simple random sampling of controls was restricted in a way to produce balance across the exposure categories with regard to age, gender, and predisposition. Complete data were collected from 1994 of the 2509 in-

NA = not applicable
X = unknown
? = not well defined
I = none (no exposure)
II = mild exposure
III = moderate exposure
IV = high exposure

		Reported overall level of exposure					
		Unknown whether exposed	None	Mild	Moderate	Severe	Exposed but severity unknown
Severity of three pathognomonic acute systems	Not asked	X	I	NA	NA	NA	NA
	None reported	NA	NA	I	?	?	I
	None severe	NA	NA	II	II	?	II
	One severe	NA	NA	II	III	III	III
	Two severe	NA	NA	III	III	IV	IV
	All three severe	NA	NA	?	IV	IV	IV

Designation of exposure categories based on combinations of reported overall level of exposure versus the severity of three characteristic acute symptoms.

dividuals sampled, the completion rates being 78%, 80%, and 80% for the high, intermediate, and no exposure groups respectively.

The symptom prevalence questionnaire included items on the presence and severity of 40 physical symptoms in the month after the spill, and, for the initially reported symptoms, their presence and severity in the past month. The 40 physical symptoms were grouped into nine organ/function systems – throat, stomach, chest, skin, nose, breathing, eye, problems waking up at night, and miscellaneous (dizziness, trouble concentrating, tingling or numbness). Based on the known chemical properties of HF, some of these symptom groups were more likely to be causally related to a physical exposure than others.

A list of 33 psychological symptoms (see Appendix) was used to assess the psychological effect in the week preceding the interview in subjects 17 years of age or older. The list was derived from the Brief Symptom Inventory (BSI) of 53 symptoms, which is a version of SCL-90,²¹ shortened by deleting four constructs that were unlikely to result from an acute event, that is obsessive-compulsive, interpersonal sensitivity, phobic anxiety, and psychoticism. Thus, the selected constructs represented by the 33 symptoms include: somatisation, depression, anxiety, hostility, and paranoia. The correlations between the SCL-90 and BSI for the nine constructs range from 0.92 to 0.99.²² The severity of each symptom was recorded as none, a little bit, quite a bit, a whole lot, and don't know, and responses from 'none' to 'a whole lot' were coded 0 to 3. After the authors' recommendations,²² a summary psychological score ranging from 0 to 99 was created for each respondent by adding the intensity values of perceived distress from

each symptom. Individuals with more than six 'don't knows' were excluded from analysis; up to six 'don't knows' were normalised into the known responses by weighting the score by a factor reflecting the proportion of symptoms with a known intensity. Summary construct scores were similarly generated for each of the five constructs.

So that time frames for the physical and psychological symptoms were comparable, only long term physical symptoms (that is, symptoms reported to continue in the month preceding the interview) are considered in this paper. Contingency table analyses were conducted to discern associations. Measures of association are presented in terms of the Gamma statistic, which is appropriate for ordinal data with ties. Multivariate analyses used a stepwise logistic regression procedure. The magnitude of the standardised coefficient associated with a factor was taken to be an indicator of its importance in predicting the outcome – that is, a severe individual symptom or a severe symptom in an organ/function system. The goodness of fit of the final model was assessed using a χ^2 test that compared the observed and expected decile distributions.²³ As such, a small χ^2 statistic, and, correspondingly a large p value was indicative of a large p value was indicative of a good agreement between the observed outcomes and those predicted by the final model.

Separate logistic regression analyses were run for each of the nine organ/function systems. The dichotomous dependent variable in these analyses was the report of a severe symptom in the system, or not. Explanatory factors offered in the model included: exposure entered as two design (dummy) variables to describe the three levels (none, intermediate, high); age entered as a continuous variable; total psychological score entered as a continuous variable; gender entered as a categorical variable; predisposition entered as a categorical variable; and the two terms describing the interaction between the psychological score and exposure. To enter the model, a variable had to be significant at a level of $p=0.05$. Since the main issue in this article was the relative explanatory importance of psychological status *versus* the exposure, however, these factors were forced into the model. In subsequent logistic regression analyses, instead of the total psychological score, summary scores for individual constructs were used as continuous variables. As would be expected, somatisation dominated as a predictor. In fact, no other psychological construct was selected in the models. Since we wished to examine other psychological determinants of long term health effects, we then conducted analyses in which somatisation was not offered. This decision was not therefore a *statistical* decision. Finally, analyses with the total psychological score as well as the four individual construct scores were repeated for selected individual physical symptoms. The individual symptoms chosen for these analyses represented an array of physical effects ranging from those that offered the most direct biological plausibility for a causal association with the exposure (that

Table 1 Psychological symptom score in relation to exposure category

Symptom score	Exposure category			Combined sample (n = 1343) (%)
	None (n = 472) (%)	Intermediate (n = 465) (%)	High (n = 406) (%)	
0	29.03	14.62	10.59	18.5
1–5	34.53	23.66	13.05	24.2
6–15	21.19	29.03	24.63	25.0
16–99	15.25	32.69	51.72	32.3

Gamma = 0.428

is, phlegm, shortness of breath) to those for which such a plausibility, if any, will be quite indirect (that is, diarrhoea, headaches, trouble concentrating).

The presentation in this paper is restricted to the symptom prevalence survey data on the sample from the three exposure categories: none, intermediate, high. Since the psychological symptom data were collected only on persons 17 years of age and older, the sample is limited to the 1343 individuals on whom data on both physical and psychological variables were available.

Results

The association between the psychological symptom score and the exposure is presented in table 1. A value of 0 on the psychological score means no distress at all, whereas a score of 99 signifies that all psychological symptoms were reported at the most severe level. The ordinal categories were created by examining the distribution of the score for the entire

sample, ensuring adequate numbers in each category. The proportion of individuals with a higher psychological score increased with exposure. The Gamma measure of association was 0.428 (p = 0.02).

Table 2 presents the results of stepwise logistic regression analyses for the various organ/function systems' symptoms. The psychological score X exposure interaction term did not enter the final model for any of the nine systems. Similarly, gender was not a predictor of a severe symptom in any organ/function system. Age entered the final model for all systems except the constellation of symptoms related to stomach and skin, and a positive estimated coefficient indicated that there was a higher probability of a severe symptom in those systems among older people after adjustment had been made for all the other factors offered in the model. High HF exposure was the most important predictor of a severe symptom in all organ/function systems. Intermediate exposure was at least as important a predictor of a continuing severe physical symptom as the psychological score for those organ/function systems most likely directly related to the exposure, that is, throat, skin, nose, breathing, and eyes. The total psychological score was a relatively important predictor of a severe symptom for organ/function systems less likely to have a direct relationship to the exposure, that is, stomach, chest, problems that wake one up at night, and the miscellaneous problems.

Table 3 presents the predictors of selected individual symptoms. The psychological score

Table 2 Predictors of severe physical symptoms in organ/function systems with total psychological score*

Organ/function system†	p value for goodness of fit	Predictors entering the model‡	β	SE (β)	p	Standardised estimate
Throat	0.1246	Exposure (inter)	0.91	0.249	0.0003	0.24
		Exposure (high)	1.84	0.241	0.0001	0.47
		Psych score	0.02	0.004	0.0001	0.15
		Age	0.01	0.004	0.0233	0.10
Stomach	0.8047	Exposure (inter)	0.55	0.393	0.1596	0.14
		Exposure (high)	1.55	0.363	0.0001	0.39
		Psych score	0.04	0.005	0.0001	0.37
		Age	0.02	0.006	0.0001	0.23
Chest	0.4394	Exposure (inter)	0.75	0.339	0.0279	0.20
		Exposure (high)	1.84	0.318	0.0001	0.47
		Psych score	0.04	0.005	0.0001	0.34
		Age	0.02	0.006	0.0001	0.23
Skin	0.1272	Exposure (inter)	0.69	0.304	0.0233	0.18
		Exposure (high)	1.83	0.282	0.0001	0.46
		Psych score	0.02	0.004	0.0001	0.19
		Age	0.01	0.005	0.0009	0.22
Nose	0.3750	Exposure (inter)	0.85	0.255	0.0001	0.22
		Exposure (high)	1.56	0.249	0.0001	0.40
		Psych score	0.02	0.004	0.0001	0.20
		Age	0.01	0.005	0.0029	0.13
Breathing	0.0194	Exposure (inter)	0.86	0.198	0.0001	0.23
		Exposure (high)	1.69	0.196	0.0001	0.43
		Psych score	0.03	0.004	0.0001	0.25
		Age	0.01	0.004	0.0002	0.14
Eye	0.6869	Exposure (inter)	0.91	0.226	0.0001	0.24
		Exposure (high)	2.06	0.218	0.0001	0.52
		Psych score	0.03	0.004	0.0001	0.25
		Age	0.01	0.004	0.0192	0.09
Wake up	0.4593	Exposure (inter)	0.56	0.215	0.0092	0.15
		Exposure (high)	1.51	0.207	0.0001	0.38
		Psych score	0.03	0.004	0.0001	0.32
		Age	0.01	0.004	0.0006	0.14
		Predisposition	0.37	0.167	0.0257	0.09
Miscellaneous	0.0884	Exposure (inter)	1.49	0.348	0.0001	0.39
		Exposure (high)	2.12	0.341	0.0001	0.54
		Psych score	0.05	0.005	0.0001	0.48
		Age	0.03	0.005	0.0001	0.29

* Results based on stepwise logistic regression analysis.
† The dichotomous outcome is at least one symptom rated as severe in the organ/function system continuing two years past the spill.
‡ The factors, Exposure (inter), Exposure (high), and Psych score, were forced into the model. The other independent variables offered in models were Age, Gender, Predisposition, Exposure (inter) × Psych score, and Exposure (high) × Psych score and they were selected stepwise at the 0.05 level.

Table 3 Predictors of severe individual symptoms with total psychological score*

Symptom†	p value for the goodness of fit	Predictors entering the model‡	$\hat{\beta}$	SE ($\hat{\beta}$)	p	Standardised estimate
Phlegm	0.1120	Exposure (inter)	0.52	0.279	0.0642	0.14
		Exposure (high)	1.50	0.263	0.0001	0.38
		Psych score	0.01	0.005	0.0411	0.09
		Age	0.01	0.005	0.0138	0.12
Diarrhoea	0.6144	Exposure (inter)	-0.43	0.561	0.4407	-0.11
		Exposure (high)	2.32	0.549	0.0001	0.59
		Psych score	0.06	0.011	0.0001	0.55
		Exposure (high) x Psych score	-0.05	0.014	0.0005	-0.40
Shortness of breath	0.6806	Exposure (inter.)	0.59	0.337	0.0806	0.15
		Exposure (high)	2.07	0.307	0.0001	0.52
		Psych score	0.03	0.005	0.0001	0.25
		Age	0.02	0.006	0.0001	0.21
		Predisposition	0.75	0.204	0.0002	0.18
Headaches	0.3003	Exposure (inter)	0.43	0.252	0.0895	0.11
		Exposure (high)	1.49	0.236	0.0001	0.38
		Psych score	0.03	0.004	0.0001	0.30
		Gender	0.44	0.178	0.0136	0.12
Trouble concentrating	0.7480	Exposure (inter)	1.00	0.488	0.0400	0.26
		Exposure (high)	1.17	0.481	0.0152	0.30
		Psych score	0.06	0.006	0.0001	0.61
		Age	0.03	0.008	0.0002	0.29

* Results are based on stepwise logistic regression analysis.
† The dichotomous outcome is severe symptom continuing two years past the spill.
‡ The factors, Exposures (inter), Exposure (high), and Psych score, were forced into models. The other independent variables offered in models were age, gender, predisposition, exposure (inter) × Psych score, and Exposure (high) × Psych score; and they were selected stepwise at the 0.05 level.

X exposure interaction term entered the model only for diarrhoea. Gender entered the final prediction model for headache as females have a higher probability of reporting a severe headache than males. High HF exposure was the most important predictor of symptoms of phlegm and shortness of breath. For diarrhoea

and headaches, the high HF exposure and psychological status seemed to be of roughly equal importance. However, the total psychological score was the prominent predictor of the symptom of trouble in concentrating. Results of logistic regression analyses in which individual psychological constructs were

Table 4 Predictors of severe physical symptoms in organ function systems with individual psychological construct scores*

Organ function system†	p value for the goodness of fit	Predictors entering the model‡	$\hat{\beta}$	SE ($\hat{\beta}$)	p	Standardised estimate
Throat	0.4033	Exposure (inter)	0.94	0.249	0.0002	0.25
		Exposure (high)	1.91	0.239	0.0001	0.48
		Anxiety	0.14	0.028	0.0001	0.28
		Hostility	-0.13	0.040	0.0011	-0.20
		Predisposition	0.38	0.179	0.0332	0.09
Stomach	0.4493	Exposure (inter)	0.62	0.391	0.1108	0.16
		Exposure (high)	1.68	0.359	0.0001	0.43
		Anxiety	0.17	0.023	0.0001	0.33
Chest	0.2526	Exposure (inter)	0.80	0.338	0.0174	0.21
		Exposure (high)	1.96	0.314	0.0001	0.50
		Anxiety	0.15	0.022	0.0001	0.30
		Age	0.02	0.006	0.0001	0.23
Skin	0.2302	Exposure (inter)	0.72	0.30	0.0181	0.19
		Exposure (high)	1.88	0.28	0.0001	0.48
		Anxiety	0.09	0.02	0.0001	0.18
Nose	0.2500	Exposure (inter)	0.87	0.254	0.0006	0.23
		Exposure (high)	1.60	0.246	0.0001	0.41
		Anxiety	0.10	0.020	0.0001	0.20
		Age	0.01	0.005	0.0044	0.13
Breathing	0.0257	Exposure (inter)	0.91	0.197	0.0001	0.24
		Exposure (high)	1.77	0.194	0.0001	0.45
		Anxiety	0.12	0.018	0.0001	0.23
		Age	0.01	0.004	0.0004	0.13
Eye	0.9117	Exposure (inter)	0.97	0.226	0.0001	0.25
		Exposure (high)	2.16	0.217	0.0001	0.55
		Anxiety	0.11	0.019	0.0001	0.22
		Age	0.01	0.004	0.0355	0.09
Wake up	0.1609	Predisposition	0.33	0.166	0.0464	0.08
		Exposure (inter)	0.64	0.213	0.0025	0.17
		Exposure (high)	1.65	0.204	0.0001	0.42
		Anxiety	0.13	0.019	0.0001	0.26
		Age	0.01	0.004	0.0012	0.13
Miscellaneous	0.5541	Predisposition	0.38	0.165	0.0199	0.09
		Exposure (inter)	1.56	0.344	0.0001	0.41
		Exposure (high)	2.28	0.336	0.0001	0.58
		Anxiety	0.21	0.022	0.0001	0.42
		Age	0.03	0.005	0.0001	0.27

* Results are based on stepwise logistic regression analysis.
† The dichotomous outcome is at least one severe symptom in the organ/function system continuing two years past the spill.
‡ The design variables, Exposure (inter) and Exposure (high), were forced into models. The other independent variables offered in models were scores of Anxiety, Depression, Hostility and Paranoid, as well as Age, Gender, and Predisposition and they were selected stepwise at the 0.05 level.

Table 5 Predictors of severe individual symptoms with individual psychological construct scores*

Organ/function system†	p value for the goodness of fit	Predictors entering the model‡	β	SE (β)	p	Standardised estimate
Phlegm	0.8531	Exposure (inter)	0.53	0.279	0.0562	0.14
		Exposure (high)	1.54	0.260	0.0001	0.39
		Anxiety	0.13	0.031	0.0001	0.25
		Hostility	-0.15	0.048	0.0021	-0.22
		Predisposition	0.41	0.204	0.0468	0.10
Diarrhoea	0.4529	Exposure (inter)	-0.08	0.532	0.8782	-0.02
		Exposure (high)	1.32	0.444	0.0030	0.33
		Anxiety	0.24	0.045	0.0001	0.47
		Hostility	-0.25	0.078	0.0016	-0.38
Shortness of breath	0.7061	Exposure (inter)	0.64	0.336	0.0581	0.17
		Exposure (high)	2.17	0.304	0.0001	0.55
		Anxiety	0.10	0.022	0.0001	0.22
		Age	0.02	0.006	0.0001	0.21
		Predisposition	0.76	0.203	0.0002	0.18
Headaches	0.4627	Exposure (inter)	0.51	0.250	0.0426	0.13
		Exposure (high)	1.61	0.233	0.0001	0.41
		Anxiety	0.13	0.020	0.0001	0.25
		Gender	0.45	0.177	0.0119	0.12
Trouble concentrating	0.6494	Exposure (inter)	1.02	0.484	0.0344	0.27
		Exposure (high)	1.31	0.472	0.0056	0.33
		Anxiety	0.30	0.028	0.0001	0.59
		Age	0.03	0.008	0.0006	0.27
		Gender	-0.55	0.279	0.0495	-0.15

* Results are based on stepwise logistic regression analysis.
† The dichotomous outcome is severe symptom continuing two years past the spill.
‡ The design variables, Exposure (inter) and Exposure (high), were forced into models. The other independent variables offered in models were scores of Anxiety, Depression, Hostility and Paranoid, as well as Age, Gender, and Predisposition and they were selected stepwise at the 0.05 level.

offered in the model showed that somatisation dominated the prediction as an indicator of psychological status. This was to be expected since the symptoms in the somatisation construct were most closely like the physical symptoms (see Appendix).

Analyses reported in tables 4 and 5 examine the relationship between physical symptoms and other dimensions of psychological status, that is, anxiety, depression, hostility, and paranoia. Anxiety was the best psychological indicator in predicting severe physical symptoms. The constructs depression and paranoia did not enter the final model in any of the nine organ/function systems. Analyses in table 5 show that anxiety was more prominent in explaining a severe response in diarrhoea and trouble concentrating than was the high HF exposure.

Discussion

Disasters can have both physical and psychological effects in those exposed.^{16-19 24} The results presented here, in conjunction with those presented in Dayal *et al*,¹⁵ support the psycho-biological paradigm of health sequelae of a disaster involving a community exposure to HF. Based on self reported information, we found that high exposure to a chemical release disaster had a long term (more than two years) impact on physical health which could not be explained by psychological status. The extent to which the effect of the psychological status varied across symptoms, however, was noteworthy. For those organ/function systems more likely to be directly related to the HF exposure (skin, breathing (by inhalation), throat), the impact of psychological variables was much less pronounced than that of the high HF exposure. For these systems, however, the effect of the intermediate level of exposure was comparable with that of psychological distress. The psychological status was weighted more

heavily among those physical symptom groups (stomach, wake up, miscellaneous) more often associated with psychological stress. This pattern of response tends to reinforce the idea that some of the symptom reports were not psychological in aetiology, while others had a substantial psychological status component.

The list of symptoms used to assess psychological status came from the validated BSI. We retained in its entirety a subset of symptoms associated with five constructs. This is a reasonable way of obtaining an instrument of manageable length when interest is limited to a subset of constructs. The consistency and interpretability of findings affirm the appropriateness of the symptom list. The published reports on the psychological effects of environmental stress indicate little uniformity over the instruments used.²⁵ For instance, Horwitz and Stefanko²⁶ adapted the SCL-90 for their study of the psychological effects of living near a toxic waste landfill by adding questions to the somatisation subscale, using a demoralisation subscale from another instrument, and modifying it in other ways to reduce the number of items so as to keep the total survey to a reasonable length. Given the variety of contexts in which psychological status needs to be measured and the pressing extrascientific considerations, investigators have to devise instruments to assess psychological variables. The lack of uniformity makes it difficult to compare findings and interpretations, except at the conceptual level.

There are inherent issues of direction of causality when inferences are drawn from a cross sectional survey, especially if a questionnaire is used to assess both exposure and health at the same time.²⁷ Flanders *et al*²⁷ suggested that a 'checkmark' pattern - that is, an inconsistent pattern in which disease prevalence is highest in the designated exposed group, but is smaller in the internal than in the external control group, must be investigated

carefully for the true direction of causality. Environmental studies do not typically include additional control groups; the Texas City study did not include one either. The control group came from the same neighborhoods as those with high HF exposure, thereby controlling for baseline physical and psychological symptoms. The observed associations in the present study were always consistent with a strong dose response, the primary criterion for causality in Flanders *et al.*²⁷ Moreover, the exposure and outcome assessments were not done at the same time: the two were separated by approximately one year and used different methods for collecting the information.

The findings in this report are based on a symptom prevalence study which relies on self report. Symptom reports are known to be limited by methodological considerations of reliability, differential recall bias,^{28,29} behavioral sensitisation,³⁰⁻³² and validity.³³ Reproducibility is a good indicator of reliability. In interview-reinterview of a 10% subsample, the agreement in data on severe symptoms was over 85%. Differential recall bias and behavioural sensitisation are closely related concepts dealing with the phenomenon of cases (exposed) recalling and reporting events differently from controls (unexposed). This occurs in many studies because the two groups come from different populations and, therefore, do not share the life disturbing experience. However, in this study, it was possible to obtain an internal unexposed group from the same community because of two factors: (1) the HF plume dispersal did not cover the entire town, and (2) many people at the same time of the release were not at home in the area affected by the HF cloud, and, conversely, some people were going home from work through the cloud and were exposed even though their homes were not in the affected area. Since the cases and controls in the Texas City study came from the same community and, therefore, had comparable background effects from living in the chronically exposed community, and had partially comparable experiences of the HF release as a disrupter of their lives, the effect of differential recall bias and behavioural sensitisation should have been minimised.

Compensation neurosis is the neurotic phenomenon that develops after an accident in people who are insured or who believe that by being ill they may increase their chances of receiving compensation. It is possible that some of the results of our analysis are attributable to compensation neurosis. The following points must be considered, however, in judging the likelihood that this phenomenon may have rendered the findings invalid. In our survey, many people refused to participate because their legal advisors had advised them to do so. A study in which compensation neurosis is an important factor would be expected to yield a high percentage of people reporting high exposure and severe symptoms. Also, data from such a study would be expected to show that a high percentage of highly exposed people continued severe symptoms into the future. In our study, only 6.7% individuals were de-

termined to have been heavily exposed. Moreover, only 20 to 30% of the individuals in the highly exposed group reported continuing severe problems related to breathing two years past the spill. Thus, although it is difficult to dismiss compensation neurosis as a possible confounder, it seems the findings of this study can not be explained by such phenomenon.

Whether the symptoms we selected as indicative of HF exposure were truly pathognomonic of this can be questioned. However, while other severe illnesses could lead to these symptoms, it should be noted that because of the large sample, we were able to balance the three exposure groups in terms of conditions that might predispose to such symptoms – for example, smoking and chronic lung disease. Similarly, it might be suggested that our findings are due to the sort of person who likes to say “yes” answering “yes” to exposure assessment and to outcome assessment symptoms. However, as noted earlier, the exposure and outcome assessments were chronologically separated by approximately one year and used different methods for collecting the information. It should also be noted that the psychological symptoms were not identified as such, and, therefore, there is no reason to believe that the “yes saying” people would answer these questions differently from the others. The pattern of results in which covariance analyses with psychological symptoms minimise the effect of exposure for symptoms often considered psychological, but not for symptoms considered more likely to be directly related to an HF exposure, mitigates against a “yes saying” bias.

In theory, the validity of self reported symptoms can be ascertained by verifying medical records or performing clinical tests on the respondents. However, such an approach in a large community setting is not feasible. We adopted a practical approach to validating the observed association between exposure and reported symptoms by seeking corroboration with the open-ended data on names of medications reported to have been taken by the respondents.³⁴ The medication use for an HF related problem was found to be associated with the exposure level. Moreover, there was a uniformly strong association between system-specific medication use and the severity of symptoms at each level of exposure. These findings provide an indirect measure of validity for symptom reports as well as for exposure.

Inferences from this and an earlier paper¹⁵ hinge on the assignment of individuals to exposure categories. Exposure assessment was partly based on responses to three acute symptoms in the study undertaken one year afterwards, while the outcome assessment was based on short and long term symptom prevalence in the symptom assessment study two years afterwards. Using symptom reports partly to define exposure and assess outcome (even though at different times), complicates the attribution of excess severe symptoms to the true exposure. However, the following points are noteworthy: (i) the three symptoms that were considered in the exposure assessment are

pathognomonic of an acute HF exposure; (ii) the outcome symptoms included far more than three symptoms; (iii) as noted earlier, the three pathognomic symptoms and the 40 outcome symptoms were assessed at different times (a year apart) and in different ways: and, most importantly, (iv) the outcome symptoms reported by individuals placed in the highly exposed category resembled closely those reported by the special group of individuals included in the study who were known to have received relatively higher doses of exposure (that is, the police officers managing the evacuation and the cases admitted to hospital after the accident¹⁵).

Our pattern of psychosocial impact results conforms to that found by others. Several authors found that the primary response to an emergency was the somatisation scale, followed by the anxiety scale,^{18 35} lending validity to the pattern of our findings. A number of studies have shown that higher levels of anxiety are associated with more symptom reporting.^{36 37} Pennebaker²⁰ has interpreted this to mean that highly anxious people are more attentive to symptoms. Schwartz *et al*³⁷ showed that both cognitive and somatic anxiety are correlated with symptom reporting, somatic more so than cognitive. Our findings are consistent with these observations.

The results in table 5 show a positive correlation between anxiety and diarrhoea (as might be expected), but a negative association between hostility and diarrhoea. Several interpretations may be proposed for the negative relation. It is possible that hostile people do not ordinarily report this symptom; that hostile people often have diarrhoea and do not attribute it to an external event; or, that hostile people get more immediate attention for such a symptom, thereby minimising its duration and the memory of it. We know of no empirical evidence which would help select from among these alternatives explanations.

Communities in which studies of health sequelae to a man made disaster are to be conducted may feel that the psychological symptom data may be used against them in a "blame the victim" manner. That is, they may feel that their reported physical problems may be attributed to their psychological stress, thereby exonerating the physical insult from the disaster as the cause. It can be justifiably argued, however, that if no attempt is made to assess the psychological component, the true physical and psychological impact of the exposure may never be known. Collecting data on psychological variables, especially on somatic and cognitive anxiety, seems to be important in future studies of the effects of accidental exposures on the health of a community.

Appendix

LIST OF 33 PSYCHOLOGICAL SYMPTOMS IN THE QUESTIONNAIRE

Anxiety

- Nervousness or shakiness inside (Q1)
- Suddenly scared for no reason (Q9)

- Feeling fearful (Q14)
- Feeling tense (Q23)
- Spells of terror (Q27)
- Feeling so restless you couldn't sit still (Q30)

Depression

- Thoughts of ending your life (Q6)
- Feeling lonely (Q11)
- Feeling blue (Q12)
- Feeling no interest in things (Q13)
- Feeling hopeless about the future (Q21)
- Feelings of worthlessness (Q31)

Hostility

- Feeling easily annoyed or irritated (Q4)
- Temper outbursts that you could not control (Q10)
- Having urges to beat, injure, or harm someone (Q25)
- Having urges to break or smash things (Q26)
- Getting into frequent arguments (Q28)

Paranoia

- Feeling others are to blame for most of your troubles (Q3)
- Feeling that most people can not be trusted (Q7)
- Feeling that you are watched or talked about by others (Q16)
- Others not giving you proper credit for your achievements (Q29)
- Feeling that people will take advantage of you if you let them (Q32)

Somatisation

- Faintness or dizziness (Q2)
- Pains in heart or chest (Q5)
- Nausea or upset stomach (Q15)
- Trouble getting your breath (Q18)
- Hot or cold spells (Q19)
- Numbness or tingling in parts of your body (Q20)
- Feeling weak in parts of your body (Q22)

Miscellaneous

- Poor appetite (Q8)
- Trouble falling asleep (Q17)
- Thoughts of death or dying (Q24)
- Feelings of guilt (Q33)

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