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Running title: Brain Gliomas in a Texas Chemical Plant

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AUG 24 1984

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Neuroepidemiology

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762**Case-Control Study of Gliomas of the Brain
among Workers Employed by a Texas City,
Texas Chemical Plant**

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Key Words. Petrochemicals · Brain tumors · Occupation · Residence

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Abstract. A Texas petrochemical plant had elevated standardized mortality ratios for neoplasms of the brain. A case-control study examined possible associations between gliomas of the brain and job title, departmental employment history, chemical exposure history, geographic location within plant, dates of employment, and residence. The greatest apparent risks were associated with exposure to carbon dioxide, diethyl sulfate, diethylene glycol, ethanol, ethylene, isopropanol, methane, tetraethylene glycol, and vinyl acetate; with first employment in the 1940s or early 1950s, and with residence in La Marque, Tex. No significant differences between cases and controls were apparent in duration of exposure to any of these chemicals.

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Introduction

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In February 1979, the National Institute for Occupational Safety and Health (NIOSH) and OSHA, with the aid of the company management, began an investigation of a cluster of primary brain tumors at a chemicals and plastics plant in Texas City, Tex. *Alexander et al.* [1] have described the characteristics of the brain tumor cases and the methods for case identification. Two retrospective cohort mortality studies of all male hourly workers employed at this plant from 1941 through 1977 have been reported [2, 3]. Findings included an overall standardized mortality ratio [SMR = 100 (observed/expected)] for benign, malignant, and unspecified neoplasms of the brain of 206 ($p < 0.05$). For those who worked more than 20 years at the plant (i.e., who began work before 1957), the SMR was 377 ($p < 0.05$) [2]. No other cancers were found significantly in excess of expected, and the overall SMR was not elevated. We here describe a nested case-control study of primary brain tumor cases among the employees of that plant.

Austin and Schnatter [4] have recently published a parallel study which showed no association between exposures in the plant and brain gliomas. They used deceased employees whose deaths were known to the company as controls for the same cases, employed an unmatched design, and did not include analysis of residence. They were able, however, to use multiple comparison groups; one group excluded controls who had died of other malignancies while another permitted such decedents as controls. Subsets of these groups including only hourly employees permitted further refinement. These two studies are thus different enough to be complementary, not duplicative.

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810 **Methods and Materials**

812 *Case Identification*

813 A total of 23 possible cases were identified: the company documented 12 cases from
H 814 death certificates in their possession; lists of all adult males who were residents of sur-
815 rounding counties and who died of malignant brain tumors between 1950 and 1977 were
816 matched with company employment records, yielding 4 additional cases; another 3 cases
817 became ill and died during the course of the study; and 4 additional deceased cases were
818 found in the course of completing the cohort mortality study. We were able to obtain
819 medical records for 20 of the possible cases and tissue specimens for 10.

820 The Armed Forces Institute of Pathology (AFIP) reviewed the tissue specimens.
821 Where different diagnoses were recorded for the same patient, AFIP reviews were ranked
822 first, autopsy reports second, surgical pathology reports third, diagnosis from the hospital
823 chart fourth, and death certificate diagnosis last; the highest-ranked diagnosis was used for
824 this study.

825 Since gliomas are carcinomas, arising from ectodermal tissue of the neural crest,
H 826 while meningiomas arise from mesodermal embryonic tissue, we followed the recommen-
827 dations of Schoenberg et al. [5], and limited consideration in this study to the 17 gliomas
828 among the 23 former employees with death certificate diagnoses of brain tumor. This
829 eliminated 1 case with a metastatic brain tumor from an unknown site, 1 who had been
830 thought clinically to have a brain tumor but was found at autopsy to have a congenital
831 malformation and no tumor, and 4 meningiomas. A summary of the cases excluded and
832 included is given in table I.

834 *Selection of Control Subjects*

835 For each case, a pool of matched potential controls was drawn from the cohort of all
836 people ever employed at the plant. Matching criteria were: race and sex matched the case;
837 year of birth was within 3 years of the case's; date of first employment at the Texas City
838 plant for the control was before that of the case, but year of first employment at the Texas
839 City plant was not earlier than 3 years before the case's; the date the control was last
840 employed was later than the case's last date of employment; the control, if dead, must not
841 have died of a malignancy. For each case, 6 controls were then drawn by random number
842 from the pool of employees meeting these criteria. No control was used for more than 1
843 case. Some cases and controls had prior experience in refineries or chemical plants, but the
844 information available was, in our judgment, insufficient for analysis.

846 *Data Collection*

H 847 For each case and control, plant personnel completed coding sheets containing demo-
848 graphic data, date of each new job title or department code, job code, department code,
849 date of each layoff, date of final termination (if no longer employed at the plant), and vital
850 status (when known). NIOSH/OSHA researchers independently verified the accuracy of
851 the coding.

852 Plant personnel provided translations for the job and department codes, indicated
853 which department codes formed larger major department groups, and provided a list of
854 chemicals used, produced, or redistributed in each department group. A 'department
855 group' is an operational unit of the plant manufacturing related products and within which
856 employees often remained over fairly long periods. The departmental coding schemes used
857 for accounting purposes within the plant have changed over the years, so a common list
858 tracing the history of each department was prepared.

H 859 Plant engineers were able to characterize the chemical feedstocks, outputs, and inter-
860 mediate products of each department through the years the plant has been in operation.
H 861 Since industrial hygiene data were available only for recent years and for certain com-
862 pounds, we equated the presence of a chemical in a department with potential worker
863 exposure. This assumption was clearly not always accurate, nor were exposures necessarily
864 equal in two departments using the same chemical.

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866 *Analysis*

867 For each job, department, major department group, or chemical exposure common to
868 at least 4 cases, an odds ratio was calculated and tested for possible statistical significance
869 by Mantel and Haenszel's [6] procedure, using the matched data programs of Rothman and
870 Boice [7]. Analyses were conducted for periods less than 15 years before the death of the
871 case, 15 or more years before the death of the case, and any time before the death of the
872 case (a case exposed for greater than 15 years and dying soon after last exposure would be
H 873 counted in all three periods). Since this approach is a multiple-significance testing tech-
H 874 nique which should lead by chance to the finding of approximately one 'statistically signif-
H 875 icant' positive association, using a 90% (two-sided) confidence interval, for every 20 inde-
876 pendent jobs, departments, or exposures considered, it is used here as an exploratory or
877 hypothesis-generating mechanism; the probability values and confidence intervals cited
878 throughout the paper are given only to show relative strength of associations.

879 Only those portions of the controls' work experiences which occurred during the time
880 the corresponding case was employed were considered in this analysis, since the matching
881 criteria selected controls with longer total work histories than the cases'.

H 882 Duration of exposure was examined for chemical exposures for which (a) the associa-
883 tion with brain tumors reached statistical significance in the analyses described above or
H 884 (b) previous reports suggested a possible relationship. For each chemical, cases' and con-
885 trols' median months of potential exposure 15 years or more before death of the case were
886 tabulated and a rank-sum test was performed [8]. Employees with no exposure were
887 excluded.

888 Workers in a department nominally unexposed to a particular chemical could be
889 exposed to toxic airborne vapors or dusts from an adjacent department. To assess this
890 possibility, the years worked by each subject in each department group were tabulated,
891 showing which department groups had about the expected 1:6 ratio of case to control-
892 years, which groups had disproportionately more case-years, and which had fewer. This
893 information was plotted on a map of the plant, which was inspected for clusters.

895 *Non-Work Factors*

896 We considered the possibility that the excess risk at the plant might be a reflection of
897 an excess in the communities around the plant rather than a problem intrinsic to the plant.
898 A case-location service was retained to determine past places of residence for the cases and
899 controls and additional information was obtained through review of medical records
900 retained at the plant. Analyses were conducted for communities in which at least 5 cases
901 had lived, using a division of 'ever lived' versus 'never lived' in the community for periods
902 15 or more years before the death of the case, less than 15 years before the death of the case,
903 and any time before the death of the case. The analysis of residence used all addresses up to
904 the date of the case's death. A two-sided 90% confidence interval was calculated to display
905 the strength of association. Addresses were also plotted on a map, which was inspected for
906 further clues to the epidemiology of this occurrence.

909 *Results*

911 *Demographics*

912 Date of first employment of the control subjects at the Texas City plant
913 averaged 18.0 months before that of the cases, and the control subjects were
H 14 born, on average, 4 months before the respective case, with standard devia-
H 15 tions 14.2 and 24 months, respectively. Only 5 controls meeting the match-
916 ing criteria were available for one of the cases.

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918 *In-Plant Work History*

919 'Operator' was the only job code represented by 4 or more cases: the
N 20 Mantel-Haenszel odds ratio for operators was 0.54, with $\chi^2_{M-H} = 1.84$ (not
N 21 statistically). There was no apparent commonality between the departments
922 in which these operators had worked.

H 23 When analyzed by department codes, only the maintenance depart-
N 24 ment had 4 or more cases; the Mantel-Haenszel odds ratio was 0.32 with
N 25 $\chi^2_{M-H} = 1.37$ (not statistically). Grouping the department codes into major
926 departments yielded no new groups of 4 or more cases.

H 27 When cases and controls were analyzed by potential chemical expo-
928 sures, a new problem became evident: maintenance men moved throughout
929 the plant and were exposed to many different agents in an irregular manner.
H 30 Accordingly, we have examined the data in two ways: in the first, mainte-
931 nance men were considered to have been exposed to every agent in the
932 plant; in the second, they were excluded from analysis. The first method
933 may be closer to reality; indeed, maintenance men may have received
934 higher exposures to toxic chemicals than operators since, in maintenance
935 work, they must open pipes, reaction vessels, and pumps. On the other
936 hand, the assumption of exposure for all maintenance men, whether cases
937 or controls, may tend to obscure an elevated odds ratio that might be
938 present if exact data were available. Of the 505 chemicals reviewed, table II
H 39 lists all chemicals to which at least 4 cases were exposed (excluding main-
940 tenance jobs).

941 Statistics for distribution of 'exposures' among cases and controls are
942 presented in table III. The tables include the chemicals to which 4 or more
943 cases were exposed and which showed the strongest positive association
944 with brain tumors, plus vinyl chloride. Vinyl chloride monomer was
945 included since it has previously been associated with brain tumor excess
946 [9-11].

947 Results of analyses by duration of exposure are summarized in
948 table IV. No statistically significant differences between cases and controls
949 were apparent in duration of exposure to any chemical.

H 50 In the mapping analysis of work locations within the plant, no signifi-
951 cant clustering of areas with proportionately more case-years than control-
952 years was detected. Analysis of work locations of cases and controls within
953 the plant offered no useful clues to the etiology of the tumors.

955 *Residential Data*

956 Addresses could be determined for 16 cases. The remaining case was
957 known to have lived for 15 years in Texas City and in the nearby town of La
958 Marque, but neither exact dates of residence in each community nor street
959 addresses could be determined. Complete listings of at least the community
960 of residence were available for 93 of the 101 controls; partial listings, often
961 inexplicit as to the exact date of moving from one community to another,
962 were available for another 7 controls. No information at all was available
H 63 for the residence of 1 control. In most instances, streets or streets and num-
964 bers could be determined, but there were many instances where informants
965 could no longer remember street addresses of 40 years ago.

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966 Table V shows the distribution of addresses among cases and controls
N 67 (note: some subjects appear in both the 'less than 15 years' and 'greater than
968 15 years' columns). The odds ratio for Texas City differed markedly from 1,
H 69 while that for Galveston is essentially equal to 1. La Marque had an appar-
H 70 ent excess of cases over controls (maximum odds ratio = 5.86). It is a resi-
971 dential community, without heavy industry, and lies southwest of Texas
H 72 City, west of the plant, and north of Galveston. A chemical dump, estab-
973 lished in 1959 and listed by the Environmental Protection Agency as a
H 74 high-priority site for emergency cleanup, is located at the southeast extrem-
975 ity of La Marque. Vinyl chloride levels as high as 161 parts per billion have
976 been measured at the fence line of the dump [12]. Figure 1 shows that the
977 known addresses for the cases who lived in La Marque appear to cluster
978 toward the southern and western parts of the city, not adjacent to either the
979 plant or dump nor downwind from them. Drinking water for La Marque
980 and Texas City comes from deep wells, tapping the same stratum, while
981 water for Galveston comes from the Brazos River. The average length of
982 residence in La Marque (excluding those who never lived there) was 12.4
H 83 years for cases, and 16.3 years for controls; this difference was not statisti-
984 cally significant.

985 Highland Bayou, a slow-moving stream draining into Galveston Bay,
986 runs along the southwestern and southern edge of La Marque, upwind from
987 the community. In view of the large number of publications associating
988 glioblastomas with viral agents [13-20], a mosquito-borne virus seemed an
989 interesting etiological hypothesis, as did kerosene and various insecticides
990 used to control mosquitos during and after World War II.

991 To separate the effects of exposures to chemicals and residence in La
992 Marque, we classified subjects into 4 strata for each chemical according to
H 93 history of exposure to that chemical (exp+ or exp-) and history of La Mar-
994 que residence (LaM+ or LaM-). Each of 3 strata (exp+LaM+, exp-LaM+,
995 and exp+LaM-) was compared to cases and controls who had neither risk
996 factor (exp-LaM-); i.e. three 2x2 tables were analyzed for each chemical
N 97 and the odds ratios were compared, as suggested by Kleinbaum et al. [21].
998 We were unable to maintain the matching in this step, since too many
999 empty cells for use with the Mantel-Haenszel procedure would have
N 00 resulted. Results are shown in table VI. The odds ratios generally are greater
001 for La Marque residence without chemical exposure than for exposure to
002 individual chemicals without La Marque residence and often are quite a bit
003 greater for exposure to both risk factors than for either one alone. During
004 the period longer than 15 years before the death of the case for analyses in
H 05 which maintenance men were excluded, only ethanol and di- and tetraethy-
006 lene glycol show a stronger association with disease than does La Marque
007 residence.

008 In reviewing the death certificates obtained for case-finding, we found
009 that 7 (9.9%) of 71 adult male residents of Galveston County whose death
010 certificates were coded as 'malignant brain tumor' and who died between
011 1949 and 1977 had La Marque addresses on the death certificate. Estimates
012 of La Marque's population over the same period were obtained [22].
013 Weighting the populations of the community and county for the calendar
014 years under consideration yielded crude death rates of 2.00 adult male
015 deaths per 100,000 total person-years at risk in La Marque and 1.63 for the
H 16 remainder of Galveston County. The difference was not statistically signif-
017 icant ($p = 0.33$).

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022 The greatest apparent risks were associated with exposure to carbon
023 dioxide, diethyl sulfate, diethylene glycol, ethanol, ethylene, isopropanol,
024 methane, tetraethylene glycol, and vinyl acetate; with first employment in
H 25 the 1940s or early 1950s; and with residence in La Marque [2]. The chem-
H 26 ical associations found may need further study, but are not convincing evi-
027 dence, particularly in view of *Austin and Schnatter's* [4] negative findings.
028 The association with residence is somewhat stronger.

029 Among the in-plant exposures considered, the relationship between
N 30 gliomas of the brain and carbon dioxide is statistically significant only when
031 all work histories are included regardless of latency. We would expect a
032 carcinogen to show stronger relationships when latency was considered; the
H 33 absence of a latency effect, coupled with the fact that carbon dioxide expo-
034 sures likely to be experienced by workers would have virtually no effect on
035 normal physiologic levels, eliminates CO₂ from further consideration. Its
036 appearance on the list serves to illustrate the pitfalls of multiple significance
H 37 testing mentioned above and to inject a note of caution in forming conclu-
038 sions based on other associations in this report. Methane, with 6 cases
039 potentially exposed (excluding maintenance men), is similarly unlikely to
H 40 be present in amounts capable of increasing exposure markedly over back-
041 ground levels produced by intestinal flora.

042 We were unable to find reports of carcinogenesis or mutagenesis testing
043 on tetraethylene glycol. Diethylene glycol was found to cause bladder stones
044 and tumors in one test using rats [23], but has not been carcinogenic or
045 mutagenic in other experiments [24, 25]. Excluding maintenance men, a
046 total of 4 cases definitely worked in departments where di- or tetraethylene
047 glycol was present. Even if the association were causative, the fraction of
048 cases attributable would be insufficient to explain the observed excess; this
049 positive finding may be the result of multiple significance testing.

050 Diethyl sulfate is considered a carcinogen and has caused brain tumors
051 in experimental animals [26]. With regard to other chemicals, a statistically
052 significant excess of brain tumors was observed in a British isopropanol
053 plant, although the numbers were very small [27]. Several other cancers
054 have been associated with isopropanol exposure, although pure isopropanol
055 is not usually considered carcinogenic [28-30]. Ethylene, like vinyl acetate
056 and vinyl chloride, has an unsaturated two-carbon moiety. Although both
H 57 ethylene and vinyl chloride are metabolized through a highly reactive epox-
058 ide stage which may alkylate organic compounds [31, 32], ethylene is not
059 mutagenic in Ames tests [N_{Josh}, unpubl. data] and was not found to have
H 60 any effect in a 2-year exposure study using rats [33]. There is less informa-
061 tion available on vinyl acetate; it is not mutagenic in bacterial assay [34,
H 62 35]. Information on association with length of exposure, latency, and num-
063 ber of cases who could be attributed to the chemical if it were a brain
H 64 carcinogen does not point clearly toward any of these chemicals but obser-
H 65 vation of other clusters or cohorts might indicate that one of them is danger-
066 ous.

H 67 While some of the associations found could be considered weak evi-
068 dence of carcinogenicity, none was conclusive. There are wide confidence
069 intervals around all of the odds ratios given; therefore, differences between
070 odds ratios should be interpreted cautiously.

071 It is possible that a critical exposure was more general than implied by
072 the department group analysis used here, and that use of in-plant controls
073 constituted over-matching which might have obscured a significant finding.
N 74 We know of no satisfactory way to test this possibility within the confines of
075 the present study.

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H 76 Risk associated with La Marque residence seems greater than that asso-
H 77 ciated with the chemicals studied. La Marque and Texas City share a com-
078 mon water source, but La Marque has a higher ratio of cases to controls
079 than Texas City, therefore a water-borne environmental carcinogen [36]
080 seems unlikely. Since there are no major chemical or other industries
081 upwind from the community, airborne industrial carcinogens do not seem
H 82 to be a likely explanation for the association observed. (The wind is domi-
083 nantly out of the south-southeast.) The cases' shorter average duration of
084 residence in La Marque argues against a causal association with residence.
085 From the comparison of crude death rates for La Marque and Galveston
086 County, La Marque does not appear to be over-represented among brain
087 tumor deaths, but this comparison does not assure that a cohort who lived
088 there in the past, some of whom have moved away, is not a greater risk. A
089 refinery adjoining this plant also appears to have an excess of brain tumors
090 and is under study by NIOSH. Examination of the residence histories of the
091 cases who worked at that refinery showed that only 3 of 8 had lived in La
092 Marque.

093 The type of mosquito which constitutes the greatest problem in the La
094 Marque area has a range of 25-50 miles, so control measures, which relied
095 on DDT and γ -benzene hexachloride until the mid 1960s, have always been
096 countywide and would not appear to explain localization to this area [37].
097 Italian farmers are reported to have higher brain tumor rates than urban
098 workers; a finding which is statistically significant [38]. The clustering of
099 cases near the periphery of the community may be meaningful, but further
100 information is needed to understand it.

101 *Greenwald et al.* [39] have suggested that superior medical care may
102 lead to more frequent diagnoses of brain tumors among employed workers
103 with good medical insurance programs. They presented evidence of more
104 sophisticated diagnostic methods in Eastman Kodak employees with brain
105 tumors. Although it is reasonable to suppose such sophistication would lead
106 to fewer missed diagnoses of brain tumors, their report has not achieved
107 universal acceptance [40, 41] and does not directly assess the question of
108 missed diagnoses in the comparison populations. *Schoenberg et al.* [42]
109 found that differences between incidence rates in Rochester, Minn., where
110 the Mayo Clinic provides virtually all medical care, and in Connecticut
111 were mainly due to better diagnosis at autopsy; most of the excess cases in
112 Rochester were due to meningiomas; and the differences in rates were most
113 pronounced in the older age groups. About 70% of Rochester decedents had
114 autopsies, compared to an estimated 38% in Connecticut; in Rochester,
115 60% of meningiomas were found at autopsy, compared to only 17% of
116 glioblastomas. None of the cases in this series were first diagnosed at
H 17 autopsy and gliomas predominated in this group (85 vs. 40.3% in Roches-
H 18 ter). Our impression, from the medical records examined, is that the diag-
H 19 noses in this case series did not hinge on either multiple or highly sophisti-
H 20 cated tests, but we cannot determine the extent to which diagnostic sensi-
121 tivity bias might be a factor in this cluster.

124 Acknowledgments

125 We wish to thank the Union Carbide Corporation for freely opening their records to
H 126 us and in particular Mr. *Damon Engle*, Plant Manager; Dr. *David Glenn*, Gulf Coast Med-
127 ical Director; Mrs. *Dorothy Heyen*, Director of Personnel Relations; Mr. *Robert Frantz*,
128 Engineer; and Mrs. *Perihan Yalcinkaya*, Industrial Hygienist. We are also indebted to the
129 Texas Bureau of Vital Statistics and to M.D. Anderson Hospital and Tumor Institute for
130 their help in case-finding and vital status ascertainment. Messrs. *Richard Miller*, *Ben Bare*,
131 and *Davis Layne* of the OSHA Houston South Area Office, and Dr. *J. William Lloyd* of the
132 OSHA Headquarters Staff provided invaluable advice throughout the study.

UCC 097489

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N 000 ANI:NNEPI044XA.96

L 001 Table I. Cases from cohort study included in and excluded from case-control study

002	Diagnosis	Included	Excluded
005	Gliomas	17	
007	Glioblastoma multiforme (includes diagnoses of astrocytoma grades III and IV)	14	
010	Thalamic glioblastoma suspected clinically; no tumor in biopsy of abnormal appearing area of brain cortex	1	
013	Pituitary adenocarcinoma suspected clinically; radiotherapy followed by proven glioblastoma 12 years later	1	
016	Astrocytoma grade II	1	
018	Metastatic tumor, unknown primary		1
020	Brain tumor suspected clinically, not found at autopsy		1
022	Meningioma, malignant		3
024	Meningioma, benign		1
026	Subtotal	17	6
029	Total	23	

10

L 034 Table II. Chemicals to which four or more cases were exposed

035	Acetaldehyde	Hydrochloric acid	Nonane(s)
036	Acetic acid	Hydroxypropyl acrylate	Potassium hydroxide
037	Acetone	Isopropanol	
038	Carbon dioxide	Isopropyl acetate	Sodium carbonate
039	Diethanolamine	Isopropyl peroxydicarbonate	Sodium hydroxide
040	Diethyl sulfate	Lubricating oil	Styrene
041	Diethylene glycol	Methylisobutyl ketone	Sulfuric acid
042	Ethanol	Methane	Tetraethylene glycol
043	Ethylene	Methanol	Toluene
044	Ethylene dichloride	Methyl ethyl ketone	Triethylene glycol
045	Ethylene glycol	Monoethanolamine	Vinyl acetate
068			Vinyl chloride

1/2 25

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L 072 Table III. Frequencies of exposure and odds ratios for potential chemical exposures

073 075 077	Chemical	Work period	Maintenance men					
			excluded			counted as exposed ¹		
			E/UE	R _(M-H)	90% CI on R _(M-H)	E/UE	R _(M-H)	90% CI on R _(M-H)
078 V 081								
087	Carbon dioxide	0-14	6/1	4.80	1.42-16.20	12/1	2.88	0.83-10.01
089		15+	5/4	1.35	0.32-5.60	12/3	1.76	0.58-5.35
090		ever	7/4	2.14	0.72-6.35	15/2	3.40	1.01-11.38
109	Diethyl sulfate	0-14	2/5	4.43	0.54-36.20	8/5	1.19	0.45-3.15
111		15+	3/6	4.87	1.05-22.53	9/6	0.75	0.27-2.12
112		ever	4/7	2.10	0.57-7.73	11/6	1.13	0.45-2.81
131	Diethylene glycol	0-14	2/5	(2)*	8.15-°	8/5	1.26	0.48-3.33
133		15+	3/6	(3)*	95.55-°	9/6	1.05	0.36-3.06
134		ever	4/7	(4)*	59.43-°	11/6	1.25	0.48-3.25
153	Ethanol	0-14	2/5	3.34	0.64-17.59	8/5	1.13	0.41-3.89
155		15+	3/6	4.03	0.88-18.46	9/6	0.84	0.30-2.38
156		ever	4/7	2.26	0.67-7.62	11/6	1.19	0.47-3.01
175	Ethylene	0-14	4/3	1.17	0.34-4.04	10/3	1.17	0.36-3.78
177		15+	7/2	4.03	0.88-18.32	13/2	1.69	0.42-6.82
178		ever	7/4	1.32	0.45-3.91	14/3	1.23	0.40-3.74
197	Isopropanol	0-14	5/2	4.91	0.94-25.57	11/2	2.75	0.80-9.46
199		15+	4/5	0.87	0.20-3.95	10/5	0.76	0.25-2.31
200		ever	6/5	1.78	0.45-6.98	13/4	1.73	0.59-5.07
219	Methane	0-14	3/4	1.46	0.39-5.56	29/4	1.38	0.44-4.39
221		15+	6/3	3.08	0.79-12.02	13/2	2.12	0.66-5.32
222		ever	6/5	1.80	0.60-5.43	14/3	2.01	0.66-6.19
241	Tetraethylene glycol	0-14	2/5	3.70	0.57-23.87	8/5	1.24	0.49-3.11
243		15+	3/6	(3)*	20.24-°	9/6	1.19	0.38-3.72
244		ever	4/7	(4)*	3.01-°	11/6	1.58	0.57-4.42
263	Vinyl acetate	0-14	5/2	3.10	0.80-12.05	11/2	2.67	0.85-8.38
265		15+	5/4	2.74	0.57-13.20	11/4	1.89	0.62-5.75
266		ever	6/5	3.30	0.84-12.88	13/4	2.47	0.88-6.94
285	Vinyl chloride	0-14	3/4	1.16	0.29-4.58	9/4	1.05	0.42-2.65
287		15+	3/6	0.87	0.20-3.76	9/6	0.91	0.38-2.16
288		ever	4/7	1.13	0.31-4.04	11/6	1.12	0.49-2.59

N 307 R_(M-H) = Mantel-Haenszel odds ratio estimate; 90% CI = 90% confidence interval; * (N) = infinite odds ratio.
 V 308 based on N tables suitable for analysis; E = exposed; UE = unexposed.

309 ¹ Maintenance employees who also worked in other departments without exposure counted as unexposed.

310 ² 0-14 = work less than 15 years before death of case; 15+ = work 15 or more years before death of case. Cases
 311 with work experience in both the 0- to 14-year and 15+ year time periods are counted in each group.

L 315 Table IV. Median months of exposure to selected chemicals (15 years or more before death
316 of case; employees with no exposure excluded)

317		Time in maintenance department			
		excluded		counted as exposed	
		cases/controls	$-z^1$	cases/controls	z^1
324	Carbon dioxide	44/36	0.30	45.5/39	1.14
325	Diethyl sulfate	7/58	-1.51	50/80	0.11
326	Diethylene glycol	50/61.5	-0.55	65.5/80.5	0.46
327	Ethanol	9/50	0.65	69/36	0.63
328	Ethylene	33/41	-0.62	87/59	0.36
329	Isopropanol	33/91	-1.47	55/57	0.29
330	Methane	19/38	-0.81	36/47	-1.10
331	Tetraethylene glycol	50/61.5	-0.36	81/84	0.77
332	Vinyl acetate	55/60.5	-0.42	63/84	0.35
333	Vinyl chloride	63/59	0.24	88/82	0.80

374 The expected value of the sum is $n_1(n_1 + n_2 + 1)/2$ with variance $= n_1 n_2 (n_1 + n_2 + 1)/12$.

375 $^1[(\text{observed rank-sum}) - (\text{predicted rank-sum})]/(\text{predicted variance})$; $z > 1.96$ implies $p < 0.05$.

L 380 Table V. Distribution among cases and controls of community of residence

381	Community	Work period ¹	Cases lived ever/never	$R_{(M-H)}$	90% CI on $R_{(M-H)}$
383					
389	La Marque	0-14	9/8	3.95	1.60-9.77
391		15+	9/8	4.80	1.61-14.26
392		ever	12/5	5.86	2.25-15.25
402	Texas City	0-14	5/12	0.48	0.16-1.41
404		15+	4/13	0.28	0.09-0.86
405		ever	6/11	0.49	0.19-1.29
415	Galveston	0-14	3/14	0.92	0.32-2.67
417		15+	7/10	0.87	0.36-2.06
418		ever	7/10	0.83	0.36-1.96

428 $R_{(M-H)}$ = Mantel-Haenszel odds ratio estimate; 90% CI = 90% confidence interval.

429 ¹ 0-14 = work less than 15 years before death of case; 15+ = work 15 or more years before death of case.

L 434 Table VI. Unmatched odds ratios for combinations of exposure to selected substances and La Marque resi-
435 dence

436		Time	Maintenance men							
438			excluded				counted as exposed			
439			exp-	Exp+	Exp-	Exp+	Exp-	Exp+	Exp-	Exp+
440			LaM-	LaM-	LaM+	LaM+	LaM-	LaM-	LaM+	LaM+
441			(A)	(B)	(C)	(D)	(A)	(B)	(C)	(D)
464	Carbon dioxide	0-14	1.00	7.11	3.20	32.00 ^a	-	(1.00) ^b	(1.14) ^b	(3.73) ^{a,b}
466		15+	1.00	2.54	4.71	22.00		1.43	5.43	13.82 ^a
467		ever	1.00	3.67	8.57	80.00 ^a	1.00	1.78	2.33	17.50 ^a
483							1.00			
493	Diethyl sulfate	0-14	1.00	4.89 ^a	4.40 ^a	0.00	1.00	1.81	8.40	4.31
495		15+	1.00	3.67 ^a	5.50 ^a	3.67 ^a	1.00	0.36	6.25 ^a	4.17
496		ever	1.00	3.63	24.17 ^a	5.80 ^a	1.00	1.33	12.80 ^a	7.00 ^a
521	Diethylene glycol	0-14	1.00	7.67 ^a	3.83 ^a	0.00	1.00	1.69	5.79	4.91
523		15+	1.00	inf.	3.43	16.00	1.00	0.48	3.75 ^a	7.00 ^a
524		ever	1.00	3.78 ^a	7.56 ^a	17.00 ^a	1.00	0.78	3.50 ^a	8.49 ^a
549	Ethanol	0-14	1.00	4.89 ^a	4.40 ^a	0.00	1.00	1.69	8.10	4.15
551		15+	1.00	7.67 ^a	4.60 ^a	5.11 ^a	1.00	0.38	5.20 ^a	4.67 ^a
552		ever	1.00	4.29 ^a	18.75 ^a	7.50 ^a	1.00	1.33	10.67 ^a	8.62 ^a
577	Ethylene	0-14	1.00	0.72	0.87	8.67	1.00	0.81	2.83	3.40
579		15+	-	(1.00) ^b	(1.08) ^b	(4.88) ^{a,b}	-	(1.00) ^b	(5.90) ^b	(6.74) ^{a,b}
580		ever	1.00	2.05	7.50	30.00 ^a	1.00	1.15	6.00	8.44 ^a
605	Isopropanol	0-14	1.00	6.00	7.50	7.50 ^a	-	(1.00) ^b	(2.22) ^b	(2.78) ^{a,b}
607		15+	1.00	0.56	3.33 ^a	3.00	1.00	0.28	4.67 ^a	3.73
608		ever	1.00	1.64	11.50 ^a	9.20 ^a	1.00	1.02	5.40 ^a	7.59 ^a
633	Methane	0-14	1.00	0.53	0.71	inf.	1.00	0.59	1.22	3.67
635		15+	-	(1.00) ^b	(1.22) ^b	(inf.) ^{a,b}	-	(1.00) ^b	(3.26) ^b	(8.29) ^{a,b}
636		ever	1.00	3.17	9.50 ^a	inf. ^a	1.00	1.78	5.25	14.54 ^a
661	Tetraethylene glycol	0-14	1.00	7.67 ^a	4.60 ^a	0	1.00	1.69	6.75	4.50
663		15+	1.00	7.67 ^a	3.29 ^a	15.33	1.00	0.45	3.63 ^a	6.77 ^a
664		ever	1.00	2.75	8.80 ^a	11.00 ^a	1.00	0.74	3.78	7.56 ^a
689	Vinyl acetate	0-14	1.00	7.11	6.40	16.00 ^a	-	(1.00) ^b	(1.90) ^b	(3.03) ^{a,b}
691		15+	1.00	0.67	0.89	10.67 ^a	1.00	0.38	1.24	7.09 ^a
692		ever	1.00	2.36	7.80	17.33 ^a	1.00	1.27	3.44 ^a	11.63 ^a
717	Vinyl chloride	0-14	1.00	2.67	6.00	0	1.00	2.20	9.00	6.00
719		15+	1.00	0	1.60	4.00 ^a	1.00	0.15 ^a	2.25	4.50 ^a
720		ever	1.00	0.90	13.50 ^a	2.25	1.00	1.20	8.57 ^a	7.50 ^a

745 Maintenance employees who also worked in other departments without exposure counted as unexposed.
746 Except where otherwise indicated, all comparisons are to the unexposed/never lived in La Marque category.
747 Column B may be interpreted as the effect of chemical exposure alone, column C as the effect of La Marque
748 residence alone, and column D as the effect of both. Exp- = never exposed to the chemical; Exp+ = ever
749 exposed to the chemical; LaM- = never lived in La Marque; LaM+ = ever lived in La Marque; inf. = no
750 controls in the category results in infinite odds ratio. Figures in parentheses are odds ratios with reference to
751 never lived in La Marque/exposed.

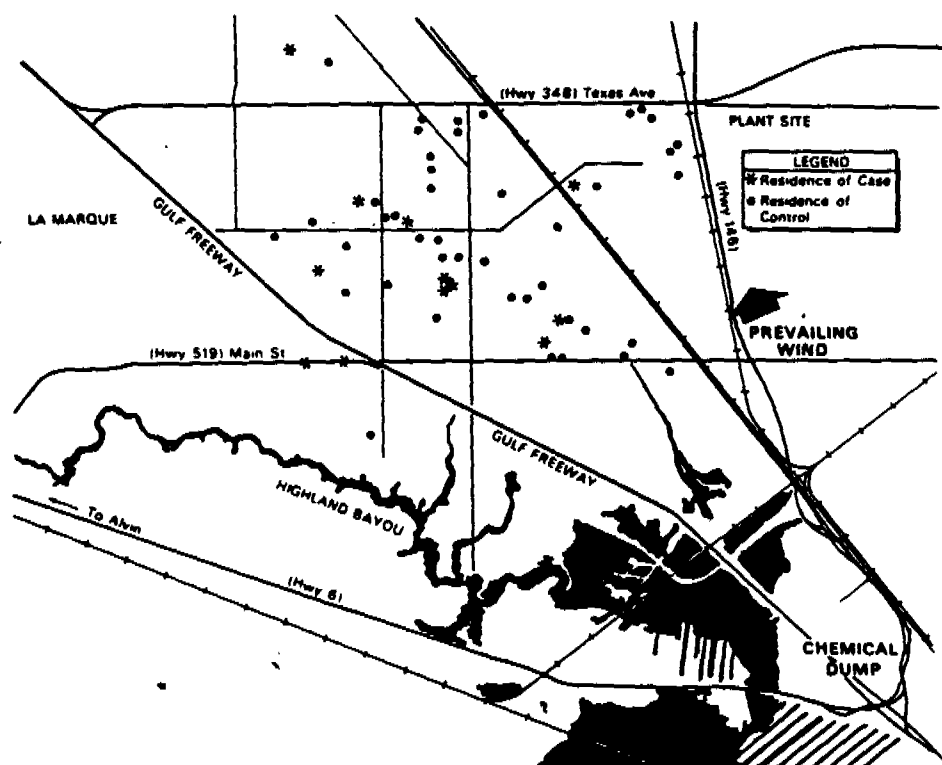
752 ^a Differs from column A; Fisher's exact test, $p < 0.05$.

V 753 ^b No cases in the never lived in La Marque/never exposed category result in infinite odds ratio.

V 757 Fig. 1. Map of La Marque addresses ever held by cases and controls.

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