RELATION BETWEEN SUICIDE AND THE ELECTROMAGNETIC FIELD OF OVERHEAD POWER LINES

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• *Laboratory studies have shown that electromagnetic fields similar to those from high-voltage transmission lines can produce biological effects. Surveys of the actual effects of such lines on exposed individuals usually have been hampered by complicating factors tending to blur the data. By means of a new approach, however, correlation has been established between the presence of transmission-line fields and the occurrence of suicides in part of the Midlands of England.*

INTRODUCTION

Since construction of overhead high-voltage (OH-HV) transmission lines began in the 1880's, more than 100,000 miles of such lines have been built in America. Traditionally the only recognized health risk associated with such transmission lines has been electrocution resulting from direct contact.[1] Recent evidence, however, has forced a re-evaluation of that view.

In 1969 the United States Navy proposed to build an antenna, then known as Project Sanguine, that would radiate at a frequency and with a magnetic field similar to those of typical OH-HV lines but with an electric field about six orders of magnitude less intense.[2] In many ensuing studies, Sanguine-strength electromagnetic fields were found capable of producing biological effects in both man and animals.[3] These studies, and other developments,[4] have led to concern over the public-health consequences of the electric and magnetic fields of OH-HV lines.[5] Recently a relation between OH-HV lines and the incidence of childhood cancer was reported.[6]

Both the electric and magnetic fields of OH-HV lines have been calculated.[7] It was found that the field intensities decrease steeply in the immediate vicinity of the lines, but more laterally (100-2000 m) the rate of decrease slows markedly. The dependence of field intensity on distance, line geometry, and operating voltage makes it difficult to identify a class of similarly exposed individuals, and an appropriate control group, to be examined for effects associated with exposure. The situation is further complicated by the fact that many locations are within the zone of influence of more than one OH-HV line. We have developed a novel approach to this problem, involving the use of a digital computer to find the cumulative effect of all OH-HV lines at any chosen point. We applied our method to a study of the locations of suicide deaths in part of the Midlands of England.

In England, the verdict of suicide is reached by the Coroner after a public investigation. Clear evidence is required that the injury was both self-inflicted and intentional. Because of the specificity and reliability of the diagnosis, we chose suicide as the "effect" for study in relation to OH-HV lines. We sought to determine whether there was any correlation between the act of suicide and the power-frequency electromagnetic environment arising from OH-HV lines at the domicile of the victim.

METHODS

The area chosen for study comprised the whole of the County of Shropshire, the Mid-Staffordshire Health District, the Parish of Burntwood in Staffordshire, and the Metropolitan Boroughs of Wolverhampton, Walsall, and Dudley (Fig. 1). Between January, 1969, and mid-October, 1976, a total of 651 suicide verdicts had been reached in this area by the coroner. From records of coroners and police we obtained for each case the following information: date of death, name, age, occupation, sex, address, and method of suicide. Included in the study were only those suicide deaths of individuals who had resided in the study area for more than 14 days, a total of 598. Pertinent statistical data regarding this group are given in Tables I-III.

The addresses of the suicide victims were plotted onto 1:25,000 planimetric maps, a total of 66 maps being required to cover the study area. In a few cases where the deceased had resided in a large building

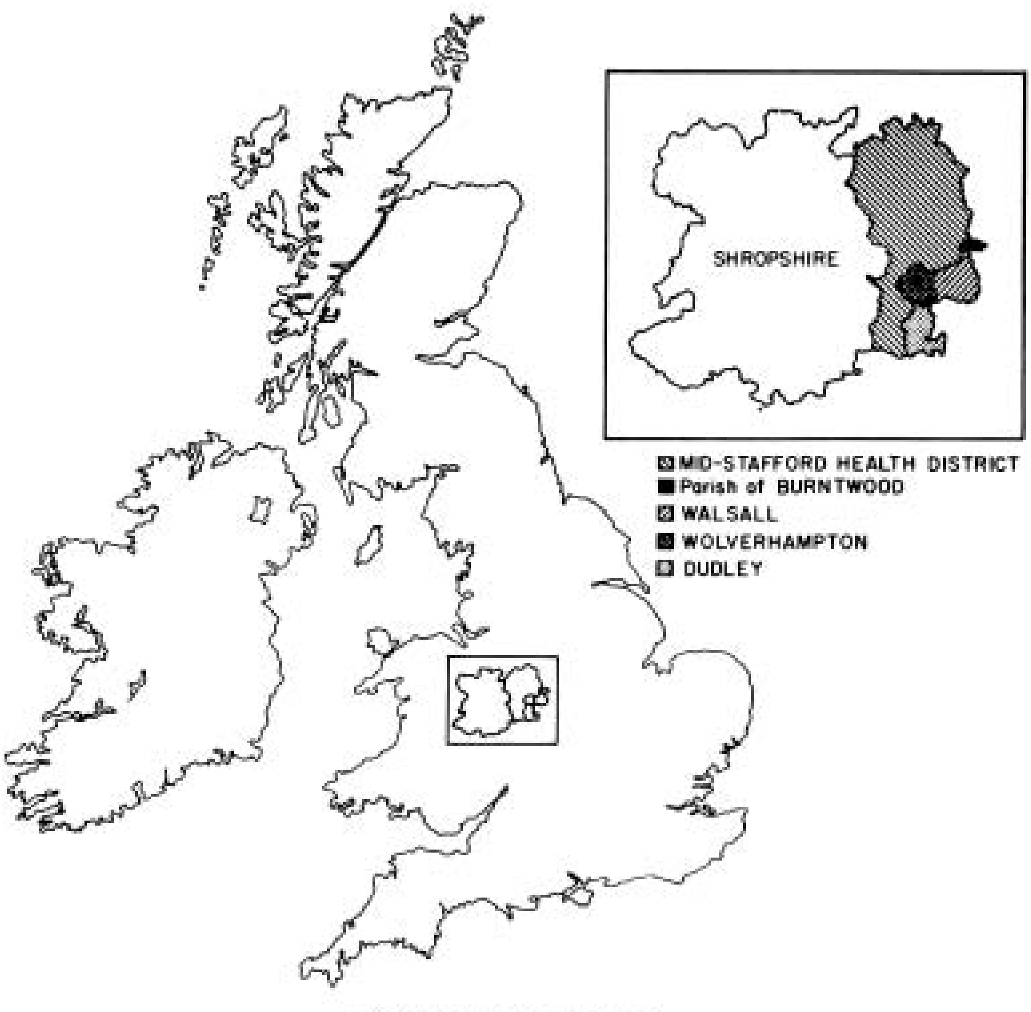

FIGURE 1. Study area (inset).

or group of buildings such as a hospital or military camp, the center point of the complex was plotted. On the same maps we also plotted all OH-HV transmission lines operating at or above 33 kV (Table IV). Multiple circuits, parallel lines, and operating voltage were indicated, using information provided by the utilities operating the lines: the Central Electricity Generating Board (C.E.G.B.), the Midlands Electricity Board (M.E.B.), and the Merseyside & North Wales Electricity Board (MANWEB). Because only two of the suicides would have been less than 18 years old at their next birthday, it was appropriate to use Parliamentary and Local Government Electoral Registers to derive a series of control addresses. Using a table of random numbers, the control addresses were chosen such that they equaled the number of suicide addresses in each geographical area shown in Fig. 1. These control addresses were also plotted, and together with the suicide addresses amounted to one address in every 415 within the study area. Since our aim was to test the hypothesis that the fields of OH-HV lines were related to occurrence of suicide, for every address we computed the total electric and magnetic fields attributable to OH-HV lines.

TABLE I. Resident Suicide Verdicts in Study Area by Year and Sex. (Study period 93½ months.)

Year	Male	Female
1969	45	28
1970	42	28
1971	53	27
1972	43	40
1973	51	34
1974	45	23
1975	44	38
1976 (to mid-Oct.)	42	15
Total	365	233

TABLE II. Resident Suicide Verdicts in Study Area by Age and Sex

Age (years)	Male	Female
15-24	30	16
25-34	34	20
35-44	61	21
45-64	149	103
65 +	90 + 1*	73
Total	365	233

*Age of one individual was not recorded.

The electric and magnetic fields of such transmission lines depend on their geometry as well as their voltage and current. The study area contained 15 different configurations of OH-HV lines, each configuration differing in voltage, current, phase-spacing, number of circuits, or orientation (whether the cables were in a vertical or horizontal plane). For each configuration, the fields at all lateral distances were calculated,[7] with each line assumed to be at its average height and carrying its rated maximum current. The maximum electric field due to each OH-HV line was found for each address, and when the sum was greater than a specific threshold value E_t, that address was included in the analysis. For each address at which the electric field strength met this criterion, the magnetic field strength was also computed.

The average ambient exposure experienced from sources other than OH-HV lines is as low as 0.1 V/m. Therefore with E_t defined as the threshold for additional exposure due to OH-HV lines, separate analyses were performed for $E_t = 0.1$, 0.5, and 1.0 V/m. A computer program was prepared to calculate separately the sums of the maximum electric magnetic field strengths at each address for which the electric field exceeded E_t and to print the results in descending order of magnitude. Thus the data produced

TABLE III. Suicide Rate for Residents of Study Area

Sub-area	Mean population during study period	Number of suicides	Annual suicide rate per million
Shropshire	345,967	209	77.5
Mid-Staffordshire	301,613	89	37.9
Wolverhampton	268,250	110	52.6
Walsall	271,125	102	48.3
Dudley	296,000	88	38.2
Whole Study Area	1,482,955	598	51.8

TABLE IV. Kilometers of OH-HV Lines of 33 kV or Greater in Study Area. (Parallel lines of equivalent voltage are counted as one length.)

Sub-area	275/400 kV (km)	132 kV (km)	33 kV (km)
Shropshire	79.9	82.3	502.2
Mid-Staffordshire	65.2	146.0	164.5
Wolverhampton, Walsall, and Dudley	17.6	49.8	17.8
Total study area	162.7	278.1	684.5

TABLE V. Addresses Included in Analyses Using the Indicated Threshold (E_t). (See also Tables VII-IX.)

E_t (V/m)	Number of addresses *Control*	*Suicide*
1.00	181	158
0.50	267	241
0.10	465	471

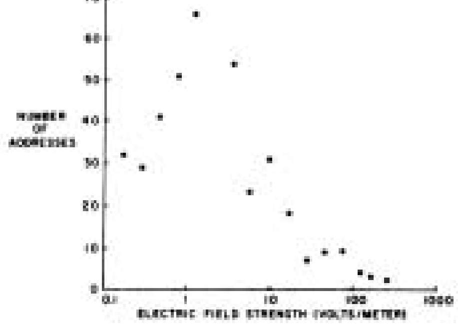

FIGURE 2. Number of addresses vs. electric field strength (V/m). Field was divided into 16 equally spaced increments on logarithmic scale; number of addresses within each increment was plotted. Threshold = 0.1 V/m.

for final analysis consisted of lists of suicide addresses and control addresses arranged in decreasing order of field strength. The total number in each series was a function of E_t.

RESULTS

Table V shows the fraction of the 598 addresses in each series which was retained for the various thresholds. Figure 2 illustrates a typical distribution of addresses. In every case, the addresses were not normally distributed with either electric or magnetic field strength. The data could therefore be evaluated using non-parametric statistics or, following an appropriate partition, by the chi-square test. We used both techniques.

The non-parametric method used was the sign test.[8] With the field strengths in each series numbered consecutively in descending order of magnitude, we counted the number of times correspondingly numbered fields in one series exceeded those in the other. The results are given in Table VI. If the electric or magnetic fields of the OH-HV lines were unrelated to the act of suicide, then $N_{C>S} = N_{S>C}$. But this hypothesis must be incorrect, because the equality does not hold for either electric or magnetic field, regardless of the threshold E_t.

To further test the hypothesis that the suicides were related to the electric and magnetic fields of OH-HV lines, we proceeded as follows. The data were split into ten equal (as nearly as feasible) groups in accordance with Sturges' rule.[9] We assumed as a null hypothesis that the suicide data would fall into 10 groups, with each containing approximately the same number of addresses as the corresponding group in the control series. The field-strength range (analysis was done separately for the electric and magnetic field) of each suicide group was determined by the control data, and the number of suicide addresses that fell into each group was compared to the control data by the chi-square test[8] (Tables VII-IX). In Table IX, for example, the list of electric field strengths for the control addresses (for a threshold of 0.1 V/m) was split into ten groups, each containing 46-47 addresses. This partition uniquely defined ten ranges of electric field strength. N_C is the number of control addresses placed in each group, and N_E is the number of suicide addresses that fell into the range of electric field strengths defined by the corresponding control group. A parallel procedure was followed for the magnetic field—the ten groups of control addresses within each such range were counted. If the electric field or the

TABLE VI. Sign Test for Various Thresholds (E_t). $N_S > _C$ denotes number of times the value in the suicide series exceeded the correspondingly numbered value in the control series; $N_C > _S$, conversely. In each case, $N_S > _C$ was significantly less than $N_C > _S$ ($p < 0.05$, 2-tailed sign test).

E_t (V/m)	Field	$N_S > _C$	$N_C > _S$
0.1	Electric	30	434
	Magnetic	48	417
0.5	Electric	23	218
	Magnetic	17	224
1.0	Electric	32	126
	Magnetic	5	153

TABLE VII. Distribution of Control and Suicide Addresses for E_t = 1.0 V/m. For the electric field, distributions of control (N_C) and suicide (N_E) addresses differ significantly ($p < 0.05$). Any suicide address for which the electric field did not fall within the range defined by the control series was dropped.

Group	N_C	Electric field (V/m)	N_E	Magnetic field (μG)	N_B
1	19	>45.1	12	>1062	11
2	18	15.2-45.1	17	423-1062	20
3	18	8.79-15.1	18	224-422	12
4	18	5.86-8.78	27	127-223	25
5	18	3.84-5.85	16	85.3-126	20
6	18	2.51-3.83	25	60.8-85.2	13
7	18	2.01-2.50	5	41.7-60.7	19
8	18	1.46-2.00	17	32.1-41.6	10
9	18	1.19-1.45	10	21.0-32.0	15
10	18	1.20-1.18	10	8.7-20.9	13
Total addresses	181		157		158

TABLE VIII. Distribution of Suicide and Control Addresses for $E_t = 0.5$ V/m. For both electric field and magnetic field, distributions of control (N_C) and suicide (N_E) addresses differ significantly ($p < 0.05$). Any suicide address for which the electric field did not fall within the range defined by the control series was dropped.

Group	N_C	Electric field (V/m)	N_E	Magnetic field (μG)	N_E
1	26	>32.4	14	≥724	17
2	27	9.48-32.4	30	227-724	27
3	27	5.59-9.47	33	112-226	37
4	27	3.11-5.58	31	73.3-111	22
5	27	2.35-3.10	16	49.4-73.2	13
6	27	1.72-2.34	18	36.8-49.3	28
7	27	1.34-1.71	22	26.5-36.7	21
8	27	0.94-1.33	21	18.6-26.4	24
9	26	0.63-0.93	32	11.0-18.5	27
10	26	0.51-0.62	19	4.5-10.9	24
Total addresses	267		236		240

TABLE IX. Distribution of Suicide and Control Addresses for $E_t = 0.1$ V/m. For both electric field and magnetic field, distributions of control (N_C) and suicide (N_E) addresses differ significantly ($p < 0.05$). Any suicide address for which the electric field did not fall within the range defined by the control series was dropped.

Group	N_C	Electric field (V/m)	N_E	Magnetic field (μG)	N_E
1	46	>11.0	39	>279	40
2	46	5.07-11.0	48	104-279	51
3	46	2.79-5.06	38	62.6-103	31
4	47	1.76-2.78	54	39.7-62.5	56
5	47	1.35-1.75	29	30.6-39.6	38
6	47	1.08-1.34	36	23.8-30.5	45
7	47	0.70-1.07	62	14.3-23.7	45
8	47	0.42-1.06	55	8.5-14.2	58
9	46	0.21-0.41	54	4.3-8.4	44
10	46	0.10-0.20	56	1.6-4.2	63
Total addresses	465		471		471

magnetic field were unrelated to the act of suicide, then the columns N_C and N_E should not differ by the chi-square test. The results show, however, that in both cases the suicide series is significantly different from the control series. The same result was found (Tables VII, VIII) for the other two thresholds (1.0 and 0.5 V/m). The results are presented graphically in Figs. 3-5.

DISCUSSION

The results show that by each of two specific criteria—exposure to total electric

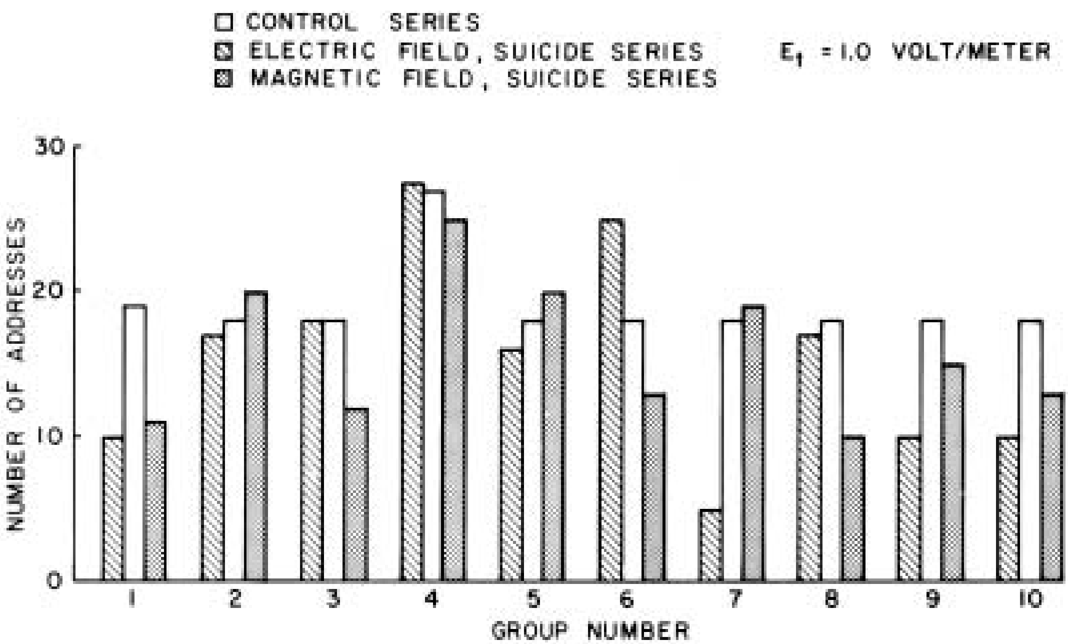

FIGURE 3. Variation in electromagnetic environment at addresses of suicide victims compared to control addresses. Threshold = 1.0 V/m.

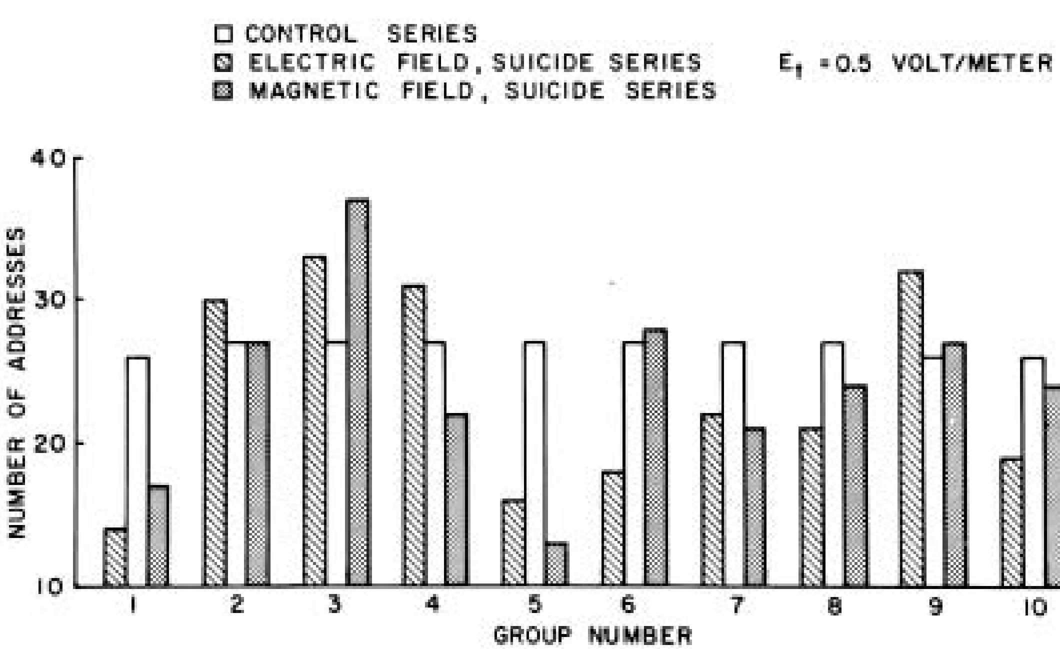

FIGURE 4. Variation in electromagnetic environment at addresses of suicide victims compared to control addresses. Threshold = 0.5 V/m.

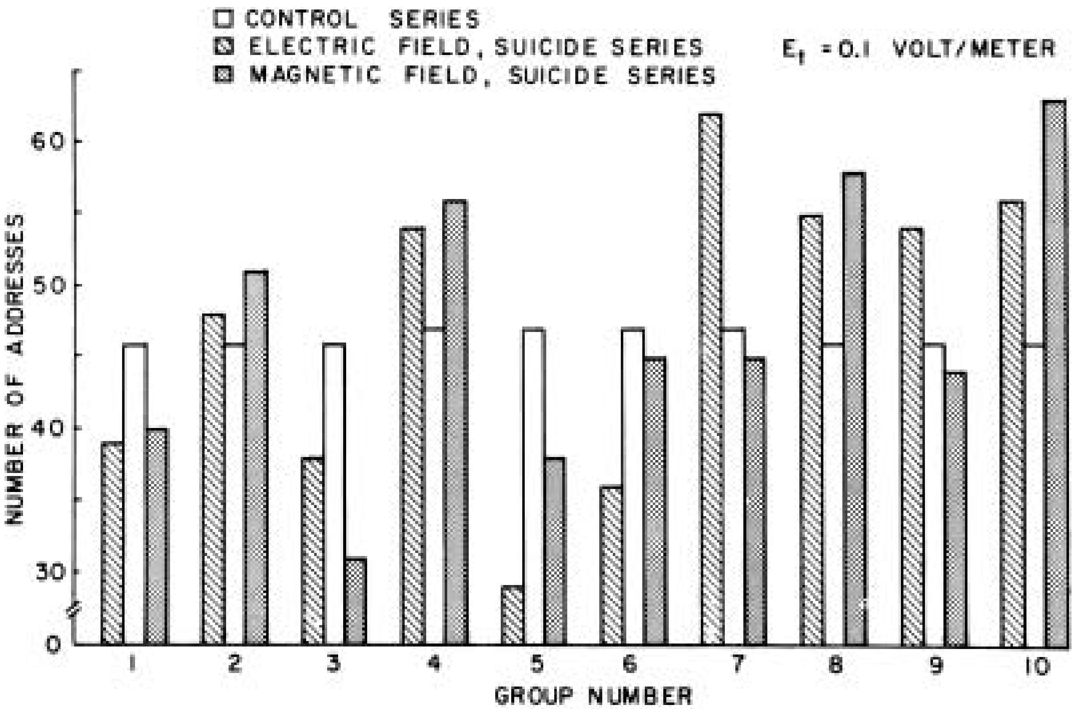

FIGURE 5. Variation in electromagnetic environment at addresses of suicide victims compared to control addresses. Threshold = 0.1 V/m.

and total magnetic fields arising from OH-HV lines—the domiciles of suicide victims differed from those of non-victims. Although the intensities of such fields are not totally independent, the finding that each is correlated strengthens the association between OH-HV lines and suicide.

The data are insufficient to establish a trend. It is not possible to determine whether more or less than the expected number of suicides occurred at the higher field-strength addresses. In Table IX, for example, fewer suicides than controls were found in Group 1 (39 suicides and 46 controls, $E > 11.0$ V/m). However, when compared to the rest of the group ($E < 11.0$ V/m), this difference is not large enough to justify the conclusion that significantly fewer suicides than expected were found in Group 1. While the overall picture is indicative of a correlation between OH-HV lines and suicide, more data are needed to determine the specific nature of this relation.

The physical basis of the observed correlation may be a direct interaction between the field and the individual, or a secondary effect in which the field interacts with some other environmental factor. Such an agent might be anything from an air pollutant to the subatomic particle capable of interaction with electromagnetic fields recently postulated by Cope.[10]

One of the initial motivating factors for the present work was the observation that individuals residing in the study area near OH-HV lines seemed to exhibit a higher than normal incidence of depressive mental illness. Suicide may be considered an ultimate manifestation of such a condition. With regard to suicide, however, the data did not establish a specific relation. More detailed studies are required, in which less extreme manifestations of mental illness are also considered with respect to the electromagnetic field of OH-HV lines.

Such lines, of course, furnish only part of the power-frequency electromagnetic environment at any particular location. We would expect, therefore, based on the results reported here, that suicide locations would also be correlated with other field sources and with actual field measurements. We have found both; there is a correlation between suicide location and underground high-voltage transmission lines, and between suicide location and actual magnetic field strength. These results will be reported elsewhere.

We thank H. M. Coroners, the Police, and the staffs of the Local Authority Planning Departments in all regions of our study area for the very great assistance given us from 1976 onward. We also acknowledge the ready cooperation of the C.E.G.B. (Midland Region), the M.E.B., and MANWEB during the earlier stages of the investigation.

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