ions. By comparing a time sequence of such pictures, motion of inhomogeneities could be seen. A study of such motions and of variations in magnetoglow intensity should provide new insight into magnetospheric phenomena. The data should be interpretable in terms of the state of the earth's magnetic field in its integrated ionization content. The situation is analogous to that of an observer inside a comet. The observer sees a glow in all directions. Variations in the glow tell him about the content of the matter in the line of sight but not about its distribution along this direction.

The perspective is altered, however, as the altitude of the observing satellite is increased. Comparison of pictures obtained at different altitudes provides a three-dimensional picture of the magnetoglow. If the observation altitude is increased to beyond the magnetosphere boundary, the situation is similar to that of an observer on earth looking at a comet in space. By viewing the magnetoglow from such a position, a comprehensive picture of the earth's ionization entrapped in the magnetic field lines (Fig. 3) and buffeted by the solar wind might be obtained.

The relationship of the magnetoglow intensity in rayleighs (*R*) to the total column content of helium ions (*N*) in an optically thin layer is given by Brandt and Chamberlain (*7*) as

$$R = N(\pi F_\nu)\frac{\pi e^2}{mc} f\, 10^{-6}$$

where (πF_ν) is the flux per unit frequency interval at the solar 304-Å emission line center, and f is the oscillator strength. If we assume that the equivalent solar line width is 0.1 Å, that the line intensity is 4.6×10^9 photons $\mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$ (*8*), and that $f = 0.416$, the above expression reduces to $N = (6.4 \times 10^{10})R$. This implies that, for the zenith magnetoglow intensity observed, there were about 2×10^{11} helium ions per square centimeter of column illuminated by the sun. At the time of flight, about 0.5 earth radius of the overhead atmosphere fell within the earth shadow. Because the measurements of Taylor *et al.* (*5*) and Hoffman (*9*) suggest lower concentrations of helium ions, it would be useful to investigate the solar 304-Å emission line profile so that the intensity of the magnetoglow might be correlated absolutely with the magnetospheric helium ion content.

The minimum detectable level of magnetoglow depends on the signal-to-noise ratio of the detector and the background radiation falling within the instrument bandpass. The present detectors have a broad passband and an instrumental noise level of about 1 count per second. Thus a helium column content of 10^9 ions per square centimeter could be "seen" in magnetoglow. For the magnetoglow measurement shown in Fig. 1, most of the intensity is of plasmaspheric origin. However, it is within the capability of the existing instrument to view dense plasma outside the plasmasphere of the kind reported by Chappell *et al.* (*10*). It is also possible that the extended earth magnetotail possesses a sufficient helium ion content to be visible in magnetoglow.

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12. We thank C. S. Weller, who played a major role in the study; P. E. Stevanus for his skillful design of the rocket instruments; J. Kruly, L. S. Kegley, and W. W. Wassam for their meticulous construction and preparation of the flight experiments; T. A. Chubb for helpful discussions. Supported by NSF grant GP 4010.

16 September 1970

Sulfur Dioxide Emissions from Power Plants: Their Effect on Air Quality

Abstract. *A modeling study of atmospheric diffusion indicates that emission from power plants contributed only a modest percentage of the yearly average concentration of sulfur dioxide at ground level in the most polluted areas of Cook County, Illinois, during 1968.*

Sulfur dioxide is one of the major air pollutants in industrial cities in the eastern United States. Since 30 to 80 percent (*1*) of the sulfur dioxide emissions in these cities may come from electric power plants that burn fossil fuels, it has been said that curbing emissions from power plants would considerably alleviate the sulfur dioxide pollution problem. We report a modeling study of atmospheric diffusion which indicates that emissions from power plants contributed only a modest percentage of the yearly average concentration of SO_2 at ground level in the most polluted areas of Cook County, Illinois, during 1968.

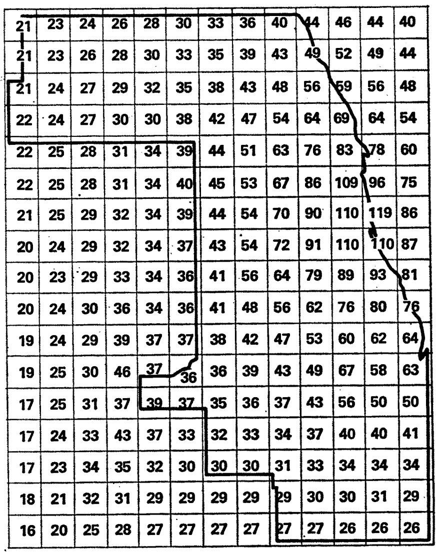
The Air Quality Display Model (AQDM) developed by the National Air Pollution Control Administration (NAPCA) (*2*) was used to simulate the air quality of Cook County, Illinois. The AQDM is based on a Gaussian diffusion equation which describes the diffusion of a plume as it is transported from a continuously emitting source. The model computes the expected annual average concentrations at ground level at specified receptor points, which result from both point and area sources, as well as the percent of the concentration contributed by each contaminant at the receptor points ascribable to each source. We feel that the AQDM represents a useful first approximation to the physical situation in areas with level topography.

To exercise the AQDM, we first established a grid of receptor points which was overlaid on a map of Cook County. With an inventory of emissions for 1968 compiled by NAPCA, we entered the location and strengths of point and area sources of SO_2. The meteorological data required to execute the AQDM were obtained from the National Weather Records Center in Asheville, North Carolina, and the measured annual average concentrations of SO_2 for 1968 which were necessary to calibrate the model were taken from data compiled by the city of Chicago. Then the model was used to calculate SO_2 concentrations for the Cook County areas (Fig. 1). These calculated concentrations provide a reasonable representation of the air quality around Cook County, partly because the predictions of the AQDM are adjusted to be consistent with observed air quality data. Next, the contributions at each receptor point ascribable to power plants were subtracted from the calculated concentration (Fig. 2).

Emissions from power plants, as used in the AQDM, constituted 78 percent of the SO_2 emissions in the Cook County area in 1968. The elimination of SO_2 emissions from power plants at the beginning of 1968 would have produced an 11 percent reduction in the yearly average concentration of SO_2 at ground level in the most polluted area of Chicago during 1968. Although large reductions would have occurred in the outlying areas of Cook County, it should be noted that the initial concentrations at these points were already well below those at which adverse effects from sulfur dioxide have been observed (*3*). It is not our intention, however, to minimize any detrimental effect due to these low concentrations. Reductions in these concentrations may prove significant.

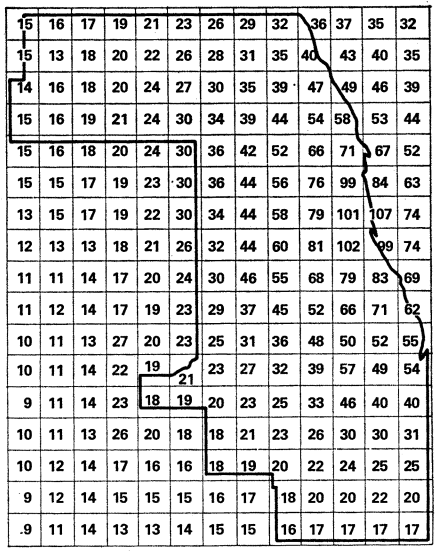
Lave and Seskin (*4*) have claimed that, with respect to human health, "it is the minimum level of air pollution that is important, not the occasional peaks." To provide an estimate of the reduction in exposure of the population to SO_2 which might be brought about by the elimination of emissions from power plants, we approximated the SO_2 dose to the population of Cook County in 1968 by summing the products of the average annual SO_2 concentration and the population (obtained from 1960 census data) of the appropriate receptor blocks. Repeating the procedure with the concentrations expected in the absence of emissions from power plants, we estimate that the 78 percent reduction of SO_2 emissions obtained by eliminating those from power plants would have produced a 14 percent reduction in the exposure of the population of Cook County to sulfur dioxide during 1968.

These data show that even if SO_2 emissions from all power plants in the Cook County area had been completely eliminated in 1968, the area would still have been plagued by a sulfur dioxide pollution problem of considerable magnitude and extent. This can be understood by the following reasoning. To avoid high concentrations of sulfur dioxide at ground level in the vicinity of a power plant, the plants are usually equipped with tall stacks which help ensure that stack gases are significantly diluted before reaching ground level. Because stacks are designed to give the greatest possible dilution within the limits set by construction costs, their effect is, on the average, to distribute emissions fairly evenly over a large area determined by the prevailing atmospheric conditions. Of course, whenever there is a large source of sulfur dioxide, there is the possibility of high concentrations at ground level under unfavorable meteorological conditions. For this reason, large point sources must be a prime target for control. Nevertheless, the yearly average concentration of SO_2 ascribable to a power plant at a particular receptor site is likely to be low, even though emissions are considerable, because the emissions from a given plant are dispersed over a large area. This argument indicates that long-term emissions from power plants that burn fossil fuels are likely to cause a relatively uniform "background" pollution over a wide area determined by topography and the prevailing atmospheric conditions. Furthermore, if the plants are properly located and designed, it might be expected that this background pollution will be within the limits of standards for air quality set by most communities. Thus, in many cases, long-term high average concentrations of SO_2 at ground level are largely produced by small localized sources of pollution (such as space heating) tied to the distribution of population and industry within a city and would not be greatly reduced by the complete removal of sulfur dioxide emissions from power plants. Also, in highly polluted areas, the percentage of contamination, on a long-term average basis, that results from the operation of power plants is likely to be small. These expectations are supported by the observation that concentrations of SO_2 at ground level during the summer in the center cities are generally lower than those observed in winter, although the power output and the associated emissions of SO_2 from electric generating stations in the area are the same or even higher in summer than they are in winter. This indicates that power plants are responsible for a relatively constant amount of SO_2 whereas the higher winter contributions represent increased fuel consumption by smaller sources for such uses as space heating.



21	23	24	26	28	30	33	36	40	44	46	44	40
21	23	26	28	30	33	35	39	43	49	52	49	44
21	24	27	29	32	35	38	43	48	56	69	56	48
22	24	27	30	30	38	42	47	54	64	69	64	54
22	25	28	31	34	39	44	51	63	76	83	78	60
22	25	28	31	34	40	45	53	67	86	109	96	75
21	25	29	32	34	39	44	54	70	90	110	119	86
20	24	29	32	34	37	43	54	72	91	110	110	87
20	23	29	33	34	36	41	56	64	79	89	93	81
20	24	30	36	34	36	41	48	56	62	76	80	76
19	24	29	39	37	37	38	42	47	53	60	62	64
19	25	30	46	37	36	36	39	43	49	67	58	63
17	25	31	37	39	37	35	36	37	43	56	50	50
17	24	33	43	37	33	32	33	34	37	40	40	41
17	23	34	35	32	30	30	30	31	33	34	34	34
18	21	32	31	29	29	29	29	29	30	30	31	29
16	20	25	28	27	27	27	27	27	27	26	26	26

Fig. 1. Yearly average ground level concentrations (micrograms per cubic meter) of sulfur dioxide resulting from emissions from all sources. Grid squares are 4.5 kilometers on a side.



15	16	17	19	21	23	26	29	32	36	37	35	32
15	13	18	20	22	26	28	31	35	40	43	40	35
14	16	18	20	24	27	30	35	39	47	49	46	39
15	16	19	21	24	30	34	39	44	54	58	53	44
15	16	18	20	24	30	36	42	52	66	71	67	52
15	15	17	19	23	30	36	44	56	76	99	84	63
13	15	17	19	22	30	34	44	58	79	101	107	74
12	13	13	18	21	26	32	44	60	81	102	99	74
11	11	14	17	20	24	30	46	55	68	79	83	69
11	12	14	17	19	23	29	37	45	52	66	71	62
10	11	13	27	20	23	25	31	36	48	50	52	55
10	11	14	22	19	21	23	27	32	39	57	49	54
9	11	14	23	18	19	20	23	25	33	46	40	40
10	11	13	26	20	18	18	21	23	26	30	30	31
10	12	14	17	16	16	18	19	20	22	24	25	25
9	12	14	15	15	15	16	17	18	20	20	22	20
9	11	14	13	13	14	15	15	16	17	17	17	17

Fig. 2. Yearly average ground level concentrations (micrograms per cubic meter) of sulfur dioxide resulting from emissions from all sources except electric power generating plants. Grid squares are 4.5 kilometers on a side.

Thus, a desirable strategy for controlling pollution due to sulfur dioxide might be to direct available low-sulfur fuel when possible to small emission sources in highly polluted areas rather than to power plants. The lack of a direct connection between the magnitude of SO_2 emissions from a source and the percentage contribution of that source to long-term average concentrations of SO_2 at ground level, which results from the dilution effect, must not be overlooked in the preparation of abatement plans. From the standpoint of long-term exposure and overall effects on the community, control of emissions from power plants is only one facet of a desirable strategy, and considerable effort must be devoted to the control of emissions from smaller sources. Effective abatement and control of air pollution requires that emissions resulting from the day-to-day activities of individuals and small business be significantly reduced as well as those from large industrial sources.

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6 October 1970

Arsenic in Potable Desert Groundwater: An Analysis Problem

Abstract. *An accuracy investigation, initiated because of conflicting analytical data on the arsenic content for some 24 drinking water locations in the Mojave Desert, revealed that interference with the evolution of arsine in the American Public Health Association silver diethyldithiocarbamate method caused either color enhancement or arsine suppression. For certain types of natural waters this method is unreliable.*

Conflicting reports (*1, 2*) were published during the early part of 1969 on the arsenic content of the underground drinking water basins shown in the index map (Fig. 1). Whitnack and Brophy (*3*) had determined the As content for 15 locations at China Lake by single-sweep polarography and alleged the unreliability of the American Public Health Association colorimetric silver diethyldithiocarbamate (SDDC) method (*4*) used by most other laboratories. A comparative study of methods for the determination of As was initiated; the results of this study and the consequent investigation of metal interference in the arsine (AsH_3) evolution step are reported here. It must be recalled that the U.S. Public Health Service regards an As content of 10 parts per billion (ppb) as a caution limit and 50 ppb as a maximum allowable limit (*5*).

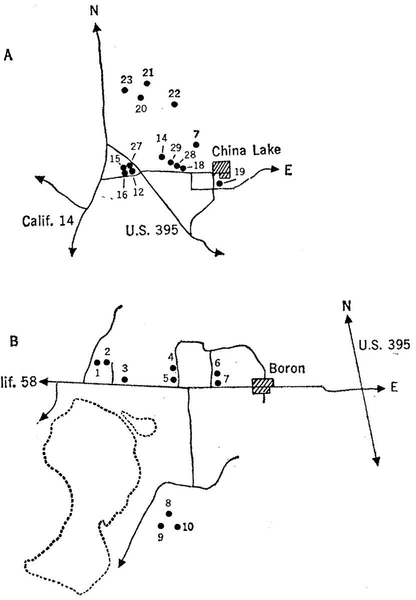

Fig. 1. Index map of two areas in the Mojave Desert. The China Lake area (A) is 60 miles (96 km) north of the Boron area (B).

The methods used for the comparative analyses on portions of 1-gallon (3.8 liters) samples of well water from the locations shown in Fig. 1 were those used by earlier investigators (*3, 4*). In addition, the x-ray fluorescence analysis of a chloroform-extracted arsenic–ammonium pyrrolidinedithiocarbamate complex of a 1000-ml aliquot was performed as reported by Marcie (*6*). One-liter portions of water samples from locations 4 and 5 were sent to a U.S. Geological Survey laboratory and a commercial laboratory, both of which used the SDDC method, in order to obtain an interlaboratory comparison. In our laboratory we analyzed water by the techniques of x-ray fluorescence and single-sweep polarography. In addition, we confirmed the reported data of the SDDC method for the Boron well locatons, using a double-beam scanning spectrophotometer (Cary model 14) and examining the absorption spectrum of the arsenic diethyldithiocarbamate color complex between 700 and 400 nm. Water samples were analyzed within 30 days.

Table 1 shows the comparison in As values derived from the three methods described. Some of the results from the SDDC method duplicate the range of values reported by up to seven laboratories over a period of 1.5 years for the Boron area. They indicate an apparent As constancy for each location of the underground water basin. In addition, Table 1 shows two significantly different As concentrations for each location. Some of the data for As derived from use of the SDDC method are larger and some of the data are smaller than the values determined by the other two methods. For example, by means of the colorimetric method no As was detected for ten locations in the China Lake area, whereas by polarography methods a range for As of 8 to 33 ppb was found for all 14 locations. Since the data derived from x-ray measurements and single-sweep polarography are in good agreement, we concluded that the SDDC data on As were suspect, especially since no increase in the polarographic As^{3+} value was obtained when samples were treated with hydrazine to reduce any As^{5+} present. Loss of As or AsH_3 inhibition was assumed to have occurred in those cases where the SDDC values were lower. All colorimetric analyses were reproducible within the preci-

Table 1. Comparative data on the amount of arsenic (in parts per billion) at two sites in the Mojave Desert; N.D., not detected (<2 ppb); N.A., not analyzed.

Location of sample (Fig. 1)	Methods of analysis		
	SDDC	Single-sweep polarography	X-ray fluorescence
	*China Lake**		
7	N.D.	19	N.A.
12	N.D.	27	N.A.
14	N.D.	8	N.A.
15	N.D.	27	N.A.
16	N.D.	27	N.A.
18	6	25	N.A.
19	8	19	N.A.
20	N.D.	8	N.A.
21	N.D.	16	N.A.
22	N.D.	33	N.A.
23	N.D.	19	N.A.
27	29	16	N.A.
28	N.D.	27	N.A.
29	22	27	N.A.
	Boron		
1	110–250	N.A.	N.A.
2	110–250	15	N.A.
Faucet at 1	160	8	5
3	330–400	13	15
4	70–80	25	N.A.
5	50	25	N.A.
Faucet at 5	28–50	18	10
6	90	N.A.	15
7	45	N.A.	N.A.
Faucet at 6, 7	50	10	10
8	N.D.	11	8
9	30	8	5
10	N.D.	8	8

* See (*3*).