Report of an Air Pollution Incident in New York City, November 1953

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HEALTH OFFICIALS and other workers concerned with air pollution have for some time been aware that intense concentrations of air pollution are associated with increased numbers of deaths among the exposed population groups (*1*).

Three episodes which have frequently been cited in the literature support this conclusion. In the Meuse Valley of Belgium in December 1930, 6,000 persons became ill and approximately 60 persons died. In the Donora, Pa., episode in October 1948, about 6,000 persons became ill and 20 persons succumbed as a result of the pollution of the atmosphere. And in the London incident of December 1952 an excess of some 4,000 deaths occurred during the ensuing 2-week period (*2*).

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Carl Erhardt, director of the bureau of records and statistics, New York City Department of Health, supplied mortality data for this project. The study, initiated in the New York City Department of Air Pollution Control, was supported in part by a grant (RG–7546) from the National Institutes of Health, Public Health Service.

In the three instances cited, the degree of air pollution was so intense and the morbidity and mortality of the exposed population increased so markedly that these episodes immediately attracted public attention. The meteorologic conditions in these events were markedly similar. In all three, anticyclonic conditions and inversions were present, accompanied by fog. Because of insufficient atmospheric cleansing action, pollutants increased to a great extent (*3*).

Many students of the relationship between air pollution and health are of the opinion that air pollution affects health even when the degree of pollution is not so intense and the amount of illness not so dramatic as to demand instant public attention. Numerous studies along these lines are now in progress.

An incident of increased air pollution occurred in November 1953 in New York City. We were first alerted on the morning of November 18. Observations at the New York City Department of Air Pollution Control Laboratory disclosed that the concentrations of sulfur dioxide were considerably greater than those of the previous day and above the range which was considered normal for New York City's air. At the same time, telephone calls from city residents, reporting eye irritation and coughing, flooded the office of the department. The calls originated from various sections of the metropolitan area, indicating that the phenomenon was widespread.

As a rule, the temperature of the air at ground level is higher than that of the upper air regions. The adiabatic decrease in temperature of unsaturated air is 5.5° F. per 1,000 feet of elevation. Temperature decreases in excess of 5.5° F. per 1,000 feet of elevation are indicative of an unstable air mass, and the greater the fall in temperature with increase in height, the more unstable is the air mass. Under these conditions the air at ground level containing the pollutants rises with the convection currents, removing the pollution from the ground surface layer. If, however, the rate of change of temperature with elevation is less than 5.5° F. per 1,000 feet, or if the air temperature actually increases with increasing elevation, the air mass is stable. Such an increase in temperature with elevation, instead of the normal decrease, is termed a "temperature inversion." It is the temperature inversion which acts as a cover or lid, confining the pollutants to levels at or near the earth's surface.

Synopsis of Weather Conditions

Appreciating the possible influence of meteorologic conditions on the concentration of pollutants in the air, we studied the records of the U.S. Weather Bureau. These disclosed that on November 12 a cold high-pressure mass of continental polar air had moved from its Hudson Bay source region to a center over the Great Lakes (fig. 1). By November 13, the center had shifted to Buffalo and merged with the remains of an earlier high-pressure area over the southeast. This anticyclonic circulation extended from Newfoundland to Tampico, Mexico. By November 16, this high was centered over Asheville, N.C., and its influence in the northern areas of the country was supplanted by a complex frontal system extending from the Great Lakes through the Middle Atlantic States. After a comparatively short period of 42 hours, the Canadian polar air, modified by its passage from Hudson Bay to the southeastern States, pressed back into the Virginias on November 17.

The slow steady anticyclonic circulation brought warmer air and above normal temperatures to New York City. Each night, however, with the radiation of heat from the earth's surface into space through the cloudless atmosphere, the lower few hundred feet of the atmosphere remained colder than the air mass immediately above. The warmer, lighter air above formed a lid trapping the cooler, denser air near the ground and thus prevented its contaminants from rising and being dispersed. This cooling process at the surface and the warming aloft through subsidence and advection continued in effect throughout the long autumn nights forming an intense nocturnal inversion. The short duration of insolation was not sufficient to warm the air at ground level and terminate the inversion formed during the night.

The presence of this stagnant air mass is confirmed by the smoke, haze, and fog which were widespread during the period (fig. 1). Wind data observations at Mitchel Air Force Base, which is close to metropolitan New York, indicate that during November 16–22 there was little or no wind from the ground level to an elevation of 500 feet (table 1). Additional data from the weather bureau disclose that on No-

Table 1. Wind data (miles per hour), Mitchel Air Force Base, N.Y., November 1953

Date	Hour (e.s.t.)	Level		
		Surface	500 feet	5,000 feet
14	10 p.m.	calm	5	29
15	10 a.m.	10	20	25
	10 p.m.	5	10	27
16	10 a.m.	6	6	29
	10 p.m.	calm	4	32
17	10 a.m.	8	15	25
	10 p.m.	calm	calm	12
18	10 a.m.	5	7	18
	10 p.m.	calm	6	18
19	10 a.m.	calm	calm	16
	10 p.m.	calm	calm	calm
20	10 a.m.	calm	5	6
	10 p.m.	calm	calm	13
21	10 a.m.	calm	2	16
	10 p.m.	calm	calm	13
22	10 a.m.	5	9	27
	10 p.m.	14	23	40
23	10 a.m.	6	6	28
	10 p.m.	6	7	24
24	10 a.m.	calm	--------	--------

vember 20 "calm" conditions prevailed to an elevation of 13,000 feet.

The slow drift of this huge stable air mass, which dominated New York from November 12 to 21, resulted in an accumulation of air pollutants from the entire area it dominated (see track of high, fig. 1). This area included the industrial regions of Ohio, Pennsylvania, New Jersey, and New England as well as New York.

A cold front moving from the west promised relief, but not until the prefrontal rains reached New York City on November 23 was the inversion broken and the pollutants returned to near normal levels.

The unusual persistence of the inversion which resulted in the air pollution incident of November 1953 is depicted in figure 1. The diagram of elevation and temperature is used by meteorologists to depict atmospheric stability. The chronologic features of this inversion are indicated as an irregular pattern developing on November 14. The inversion ranged from the surface to higher elevations, but starting on November 18 the inversion remained at ground level and persisted until 10 p.m. on November 21.

Atmospheric Pollutants

The New York City Department of Air Pollution Control was organized in November 1952, and all of the air pollution data now available were not recorded in 1953. Sootfall in New York City had been sampled monthly for some years before the department laboratory was organized, but the sampling was not sufficiently detailed for this study.

Because of these limitations, the two most reliable measures of atmospheric pollutants available to us for the period under investigation were sulfur dioxide and smokeshade determinations. According to Martin, "It is clear that from the chemical point of view both black suspended matter and SO_2 are somewhat crude indices but until more is known of the actual toxic substances in the air, they provide a convenient and ready method of measuring the general air pollution" (*4*).

Determinations of sulfur dioxide were customarily made twice daily. However, because

Table 2. Sulfur dioxide concentrations in New York City, November 1953

Date	Morning		Afternoon	
	Hour (e.s.t.)	SO_2 (ppm)	Hour (e.s.t.)	SO_2 (ppm)
12	9:30	0.09	3:00	0.08
13	9:30	.25	3:00	.11
16	9:30	.16	3:00	.08
17	9:30	.17	3:00	.07
18	9:30	.65	1:15	.33
	10:15	.65	2:00	.20
	11:30	.47	--------	--------
19	9:30	.54	3:15	.21
	11:30	.26	--------	--------
20	9:30	.86	12:30	.73
	10:00	.85	1:15	.54
	11:15	.75	3:30	.26
22	9:30	.11	--------	--------
	11:15	.21	--------	--------
	12:00	.14	--------	--------
23	9:30	.28	3:30	.24
	11:30	.12	--------	--------
24	9:30	.19	3:00	.09

of the higher concentration of this gas revealed in the 9:30 a.m. observation on November 18, the number of samplings and analyses was increased. Actually, we determined total acidity expressed as sulfur dioxide, as explained by Greenburg and Jacobs (*5*). This is an accepted practice since the major portion of such acidity has been shown to be sulfur dioxide. The method has been described in detail by Jacobs (*6*).

The sulfur dioxide determinations during the period November 12–24 are shown in table 2. On November 16 and 17 the SO_2 concentrations were in the average range for New York City (0.15–0.20 ppm). In contrast, the concentrations during the period November 18–22 were markedly higher than the normal values for New York, particularly the morning concentrations. The afternoon concentrations on these days were lower than the morning ones. As a

Meteorologic symbols used in illustrations on next page

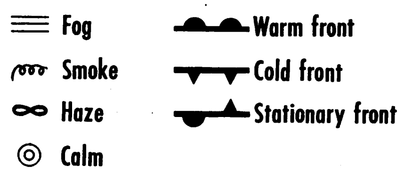
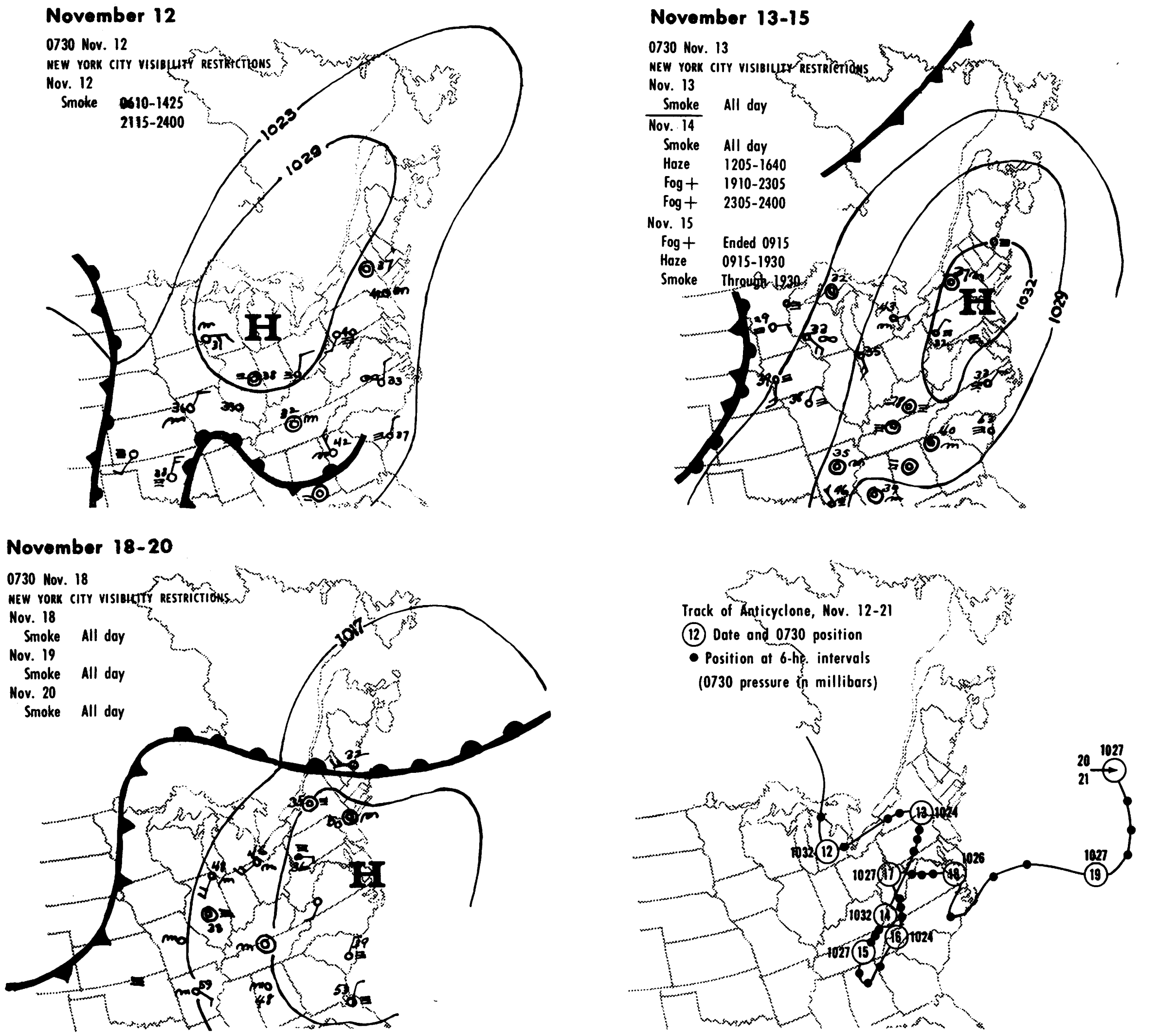
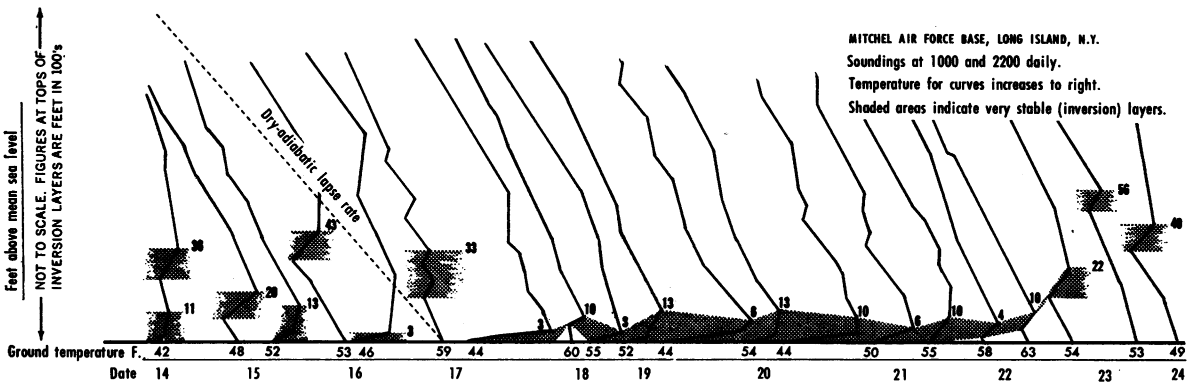


Figure 1. Meteorologic conditions, November 12–24, 1953



On Nov. 12 high pressure mass of continental polar air over Great Lakes. High degree of stability and subsidence associated with smoke, haze, and fog. High drifts east to coast Nov. 13–14. By morning, Nov. 15, high breaks down to 1,027 mb. and is over Tennessee. Cold front moves toward New York City on Nov. 15, becomes stationary south of city. High over mid-Atlantic States on Nov. 18, drifting offshore Nov. 19–20. Continued surface cooling and subsidence created low-level inversion deepened through Nov. 18–20.



NOTE: All times Eastern Standard Time.

Figure 2. Daily smokeshade values, Central Park Station, U.S. Weather Bureau, November 1950–56

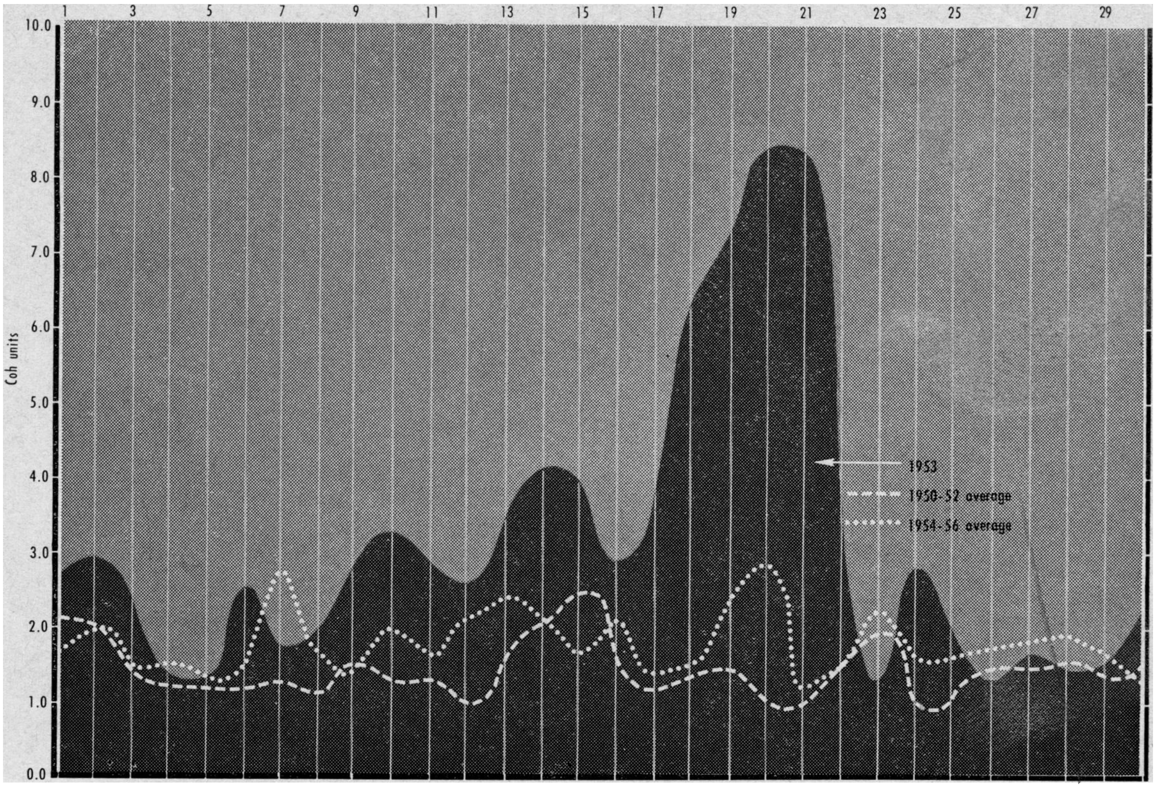
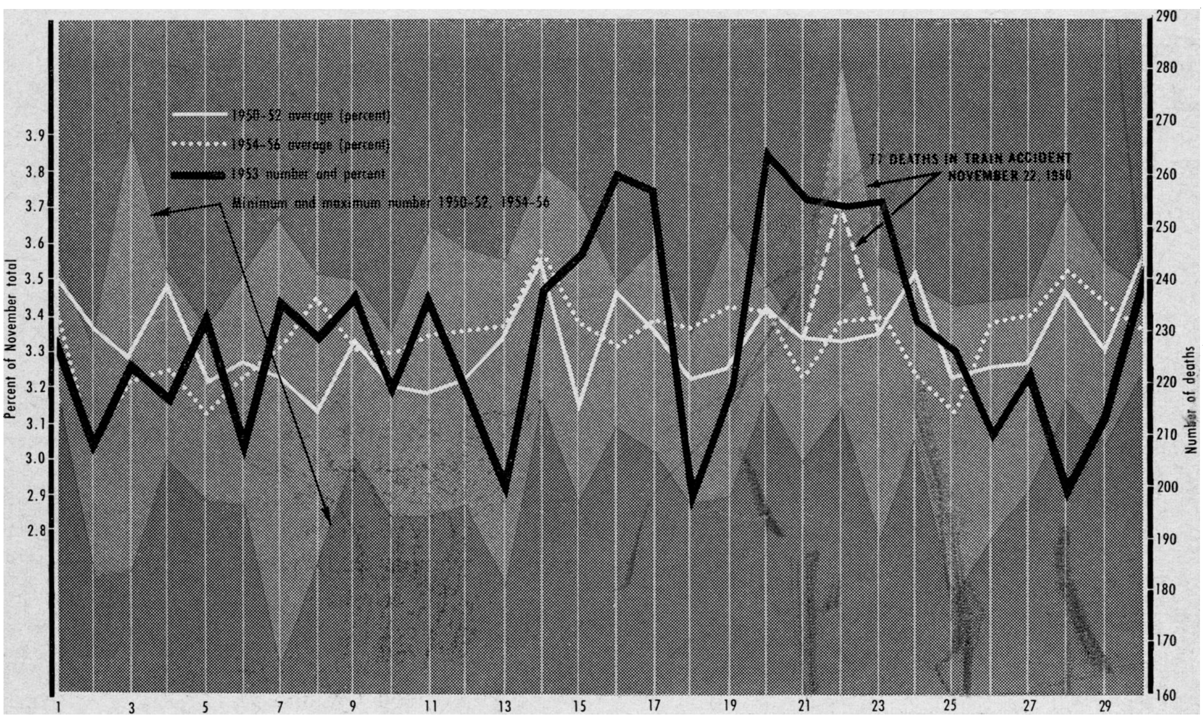


Figure 3. Number of daily deaths and daily deaths as percentage of total, New York City, November 1950–56



rule the diffusion effects produced by the slight warming of the earth's surface even during an inversion period cause this afternoon drop. However, even the afternoon observations on November 18 to 20 showed SO_2 concentrations above the general average for the city's air.

For the determination of smokeshade at the New York City Department of Air Pollution Control Laboratory, an Atomic Energy Commission air sampler was employed (*7*). In this instrument, air is filtered through a strip of Whatman No. 1 filter paper moved at a rate of 1 inch per hour. The instrument recorded a maximum optical density of stain on November 20.

Smokeshade data were obtained from samplings taken with an Owens automatic air filter at the Central Park Observatory of the U.S. Weather Bureau (*8–10*). These findings are presented in table 3 and figure 2. The November 17 value was greatly in excess of that for November 16, and the values increased progressively until November 21 when they began to decline. The daily averaged values for the 3 years preceding and following 1953 were significantly lower (fig. 2).

Effects on Health

The meteorologic observations and the sulfur dioxide and smokeshade determinations convinced us that an unusual atmospheric condition confronted New York City. Temperature inversions frequently occur in the city, but they generally last 24 hours or less and rarely more than 2 days. We decided to analyze health data in an effort to determine if the health of the city's inhabitants was influenced by these unusual meteorologic and air pollution conditions.

Table 3. Average daily smokeshade values (Coh units), New York City, November 1953, and control years 1950–52 and 1954–56

Date	Averaged values 1950–52	1953	Averaged values 1954–56
12	1. 04	2. 50	2. 12
13	1. 36	3. 54	2. 42
14	1. 86	4. 13	2. 01
15	2. 42	3. 79	1. 71
16	1. 47	2. 79	2. 14
17	1. 08	4. 04	1. 40
18	1. 24	6. 42	1. 48
19	1. 35	7. 29	2. 36
20	1. 03	8. 38	2. 76
21	1. 04	8. 25	1. 23
22	1. 37	2. 92	1. 40
23	1. 89	1. 21	2. 19
24	1. 15	2. 79	1. 63

The effects of air pollution on health may be evaluated by an analysis of morbidity or mortality data. Both methods have been employed in the three studies cited. As a rule, morbidity data serve as a more satisfactory measure of health effects, for the number of persons who become ill generally exceeds the number of those who succumb. However, there often are difficulties in obtaining morbidity estimates, and unless such data are carefully collected, they may be subject to wide variations due to a lack of uniformity in diagnosis and classification.

For this study we were unable to use morbidity data. On the hypothesis that major changes in morbidity are reflected in mortality figures, at least to a certain extent, we investigated the changes in mortality as an indicator of the effects of air pollution during the period of the inversion.

Daily deaths in New York City for the month of November in each of the 7 years 1950–56 provide the basic measure of the effects on health. The data for November 1950 through 1952 and 1954 through 1956 serve as controls for November 1953, when the temperature inversion occurred. Additional controls are the data for the days preceding and following the inversion period in November 1953 (table 4).

In this 7-year period there were only 12 days on which deaths exceeded 250 in number; that is, on only 5.7 percent of these 210 days were the deaths in excess of 250. In the control years, 1950–52 and 1954–56, the November days with more than 250 deaths were distributed sporadically. In striking contrast is the period associated with the inversion. From November 15 through November 24, 1953, there were 6 days, or 60 percent of these 10 days, on which the number of deaths exceeded 250.

On November 22, 1950, an accident occurred on the Long Island Railroad in Queens Borough, New York City, in which 77 persons were killed. On November 3, 1952, a dense cloud of smoke produced by smoldering forest fires in

West Virginia, the Carolinas, and Tennessee covered the whole of the eastern seaboard and, according to the *New York Times*, completely "blotted out" the sun in New York City at midday. It is possible that this event contributed to the large number of deaths reported on that day. There may also be some special explanation of which we are unaware for the other 4 high days. On the other hand, some fluctuations in deaths from day to day are naturally to be expected.

To compare the data for the 7 years, the deaths by day in November are expressed in figure 3 as a percentage of total November deaths for each of the years 1950 through 1956. The data for 1950–52 and for 1954–56 were averaged. The height of the November 1953 curve (solid black line) is obvious. If the deaths from the train accident on November 22, 1950, are excluded, the 1953 curve is even more striking.

Figure 3 also shows the minimum and maximum numbers of deaths (light grey area) for each day in November for the 6 years 1950–52 and 1954–56, as well as the daily number of deaths for November 1953.

On the majority of the days from November 15–24, the deaths for 1953 are greater than the number reported for these days in any of the 6 control years, excluding the effect of the railroad accident.

It is worth noting that the low point in this period is not significantly lower than the other 2 lowest days (November 13 and 28) in November 1953.

The graphic assessment of the mortality data was confirmed by analytic procedures. To evaluate the effects on health of the meteorologic incident and its concomitant increased air pollution, it was decided to investigate mortality data for November 15–24. This judgment assumes that the effect of the anticyclone which dominated the New York area from November 12 to 21, 1953, and was characterized by an extensive temperature inversion would be felt 3 days after its onset. The fact that the

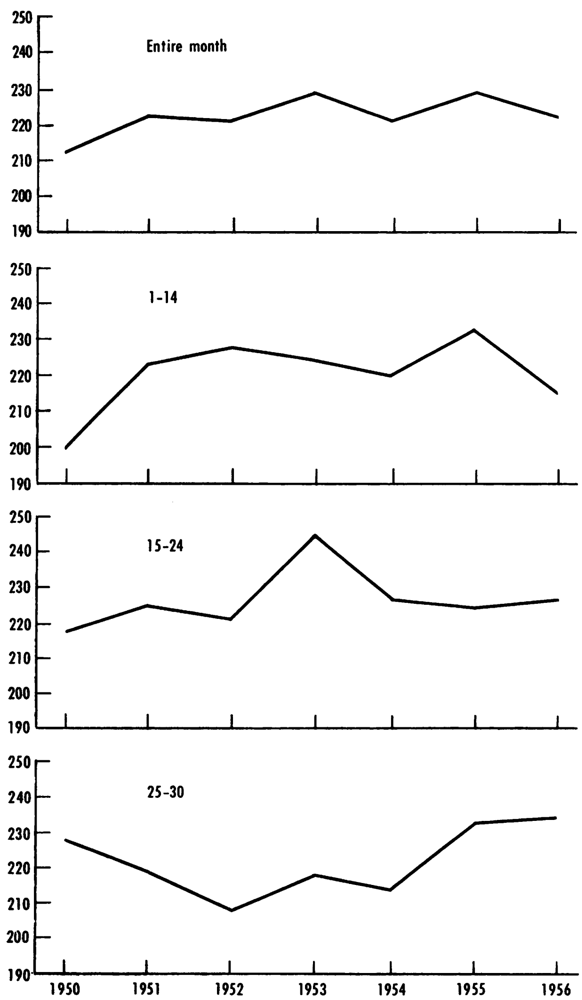
Table 4. Deaths by day in New York City, November 1950–56

Date	1950	1951	1952	1953	1954	1955	1956
1	220	225	245	227	232	230	226
2	211	223	228	208	215	215	183
3	184	200	268	224	235	214	200
4	223	242	222	217	220	229	206
5	198	231	204	233	212	212	209
6	197	204	241	208	222	216	218
7	165	231	238	235	208	252	208
8	186	218	211	229	237	241	220
9	208	222	224	237	224	240	206
10	195	225	210	218	219	217	230
11	195	207	223	237	227	250	197
12	197	230	204	218	203	227	246
13	181	239	235	200	211	244	222
14	230	228	238	238	217	262	243
15	197	198	224	245	210	217	256
16	226	239	212	260	224	220	226
17	207	217	237	257	223	246	215
18	214	223	197	198	229	226	224
19	207	233	198	218	250	211	230
20	221	226	227	264	234	218	239
21	205	226	223	256	228	213	211
22	282	215	234	254	228	234	221
23	190	231	236	255	232	243	212
24	230	239	222	232	210	211	233
25	235	188	208	226	178	223	232
26	211	236	190	209	213	234	235
27	234	207	199	221	216	237	234
28	225	241	217	199	219	256	235
29	221	218	208	214	225	226	243
30	238	226	230	240	234	222	223
Total	6, 333	6, 688	6, 653	6, 877	6, 635	6, 886	6, 683

first death reported in Donora occurred on the third day of that incident would, we feel, lend support to our assumption.

Mortality data for all ages and causes were divided into three time periods; November 1–14, November 15–24, and November 25–30, for each of the 7 years 1950–56. For the November 15–24 period in 1953 the average number of deaths per day was 244, whereas for the other 6 years, the controls, the average ranged from 218 to 227. An analysis of variance and a test for outliers indicate that the difference between the average for 1953 and that of any other year is statistically significant at the .05 level or better, and that there is no other year which differs significantly from the overall average of 226 deaths per day.

Figure 4. Average daily November deaths, New York City, 1950–56



It is important also to analyze data from the early and late periods of November for these 7 years. For November 1–14, there is also a significant difference in the average number of deaths per day occurring in these 14 days over the 7 years. However, no one year differs from the overall average. This also holds true for the period November 25–30 (fig. 4).

The number of deaths at any time depends on the population at risk of dying. Because the population changed very slightly during this 7-year period, according to the best estimates which we were able to make, an analysis of death rates would have led to the same conclusion as that reported previously.

The evidence is, then, that there was an excess of deaths in the November 15–24, 1953, period over the numbers for that same period in the 6 control years. We make this statement with more than 95 percent confidence. The question of whether or not the impact of this increased number of deaths was felt by some ages more than others was next considered. The distribution of deaths by age groups for this period of November in each of the 7 years is shown in table 5. The percentage distributions by age for 1951 through 1956 are similar; in fact, the usual chi-square test does not disclose any differences. However, in 1950 deaths in the age group 65 years or older appear to be unusually low, and the number of deaths in the age group 25–44 is much higher than for other years. This is largely accounted for by an excessive number of deaths on the date of the railroad accident, November 22, 1950.

For 1953, the first 14 days of November and the last 6 days of that month may also be used as controls for the November 15–24 period (table 6). An analysis of variance of daily deaths, after a square root transformation, showed that there are no remarkable differences in the age distribution of deaths in these three periods.

The increase in mortality for the period November 15–24, 1953, over the deaths in that same period for the other 5 years, 1951–56, appears to be generally distributed among all age groups. This is in agreement with Logan's statement (*2*) about the London incident.

In table 7 data on the average number of daily deaths by cause for all ages for November

1953 are separated into three periods and grouped in seven categories. The similarity of the percentage distributions in the three time periods is obvious.

Summary and Conclusions

An anticyclone associated with temperature inversion dominated the New York City area from November 12 to 21, 1953. During this period, air pollution in terms of sulfur dioxide and smokeshade increased and reached unusually high levels as the temperature inversion intensified. Mortality data for New York City disclosed a statistically significant increase in the number of deaths from November 15–24, 1953. This increase apparently was generally distributed over all age groups.

Table 5. Distribution of deaths by age groups, New York City, November 15–24, 1950–56

Age group (years)	1950		1951		1952		1953		1954		1955		1956	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Under 1	106	4. 9	107	4. 8	97	4. 4	120	4. 9	120	5. 3	115	5. 1	104	4. 6
1–24	63	2. 9	72	3. 2	61	2. 8	47	1. 9	66	2. 9	50	2. 2	42	1. 8
25–44	201	9. 2	164	7. 3	166	7. 5	180	7. 4	165	7. 3	153	6. 9	173	7. 6
45–64	782	35. 9	784	34. 9	775	35. 1	811	33. 3	746	32. 9	756	33. 8	754	33. 3
65 and over	1, 027	47. 1	1, 120	49. 8	1, 111	50. 2	1, 281	52. 5	1, 171	51. 6	1, 165	52. 0	1, 194	52. 7
Total	2, 179	100. 0	2, 247	100. 0	2, 210	100. 0	2, 439	100. 0	2, 268	100. 0	2, 239	100. 0	2, 267	100. 0

Table 6. Average deaths per day by age groups, New York City, November 1953

Age group (years)	November 1–14		November 15–24		November 25–30		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Under 1	10. 6	4. 8	12. 0	4. 9	11. 3	5. 2	11. 2	4. 9
1–24	4. 7	2. 1	4. 7	1. 9	4. 0	1. 8	4. 6	2. 0
25–44	14. 8	6. 6	18. 0	7. 4	16. 0	7. 3	16. 1	7. 0
45–64	77. 6	34. 7	81. 1	33. 3	73. 0	33. 5	77. 8	34. 0
65 and over	115. 8	51. 8	128. 1	52. 5	113. 9	52. 2	119. 5	52. 1
Total	223. 5	100. 0	243. 9	100. 0	218. 2	100. 0	229. 2	100. 0

Table 7. Average deaths per day, by cause, in three periods of November 1953, New York City

Cause of death	November 1–14		November 15–24		November 25–30		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
All causes	223. 5	100. 0	243. 9	100. 0	218. 2	100. 0	229. 2	100. 0
Accidents	7. 1	3. 2	7. 3	3. 0	7. 7	3. 5	7. 3	3. 2
Automobile	1. 4		1. 3		2. 0		1. 5	
Other	5. 7		6. 0		5. 7		5. 8	
Homicides and suicides	2. 4	1. 0	2. 0	. 8	2. 0	. 9	2. 2	. 9
Tuberculosis, influenza, pneumonia	9. 8	4. 4	10. 6	4. 4	10. 3	4. 7	10. 2	4. 4
Cerebral hemorrhage, heart and other circulatory	121. 9	54. 6	135. 4	55. 5	116. 7	53. 5	125. 4	54. 7
All causes, under 1 year	10. 6	4. 7	12. 0	4. 9	11. 3	5. 2	11. 2	4. 9
Cancer	45. 7	20. 5	47. 6	19. 5	43. 3	19. 9	45. 9	20. 0
All other	26. 0	11. 6	29. 0	11. 9	26. 9	12. 3	27. 0	11. 9

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Water Quality Measurement and Instrumentation. Proceedings of a symposium held at Cincinnati, Ohio, August 29–31, 1960. W61-2. 1961; 238 pages.

Algae and Metropolitan Wastes. Transactions of the Seminar held at Cincinnati, Ohio, April 27–29, 1960. W61-3. 1961; 162 pages.

World Health Organization

WHO publications may be obtained from the Columbia University Press, International Documents Service, 2960 Broadway, New York 27.

Programme Development in the Mental Health Field. Tenth Report of the Expert Committee on Mental Health, WHO Technical Report Series No. 223. 1961; 60 cents; Geneva.

Expert Committee on Biological Standardization. Fourteenth Report. WHO Technical Report Series No. 222. 1961; 60 cents; Geneva.

Fourteenth World Health Assembly, New Delhi, 7–24 February 1961. Part II. Plenary meetings, verbatim records; Committees, minutes and reports. Official records of the World Health Organization, No. 111. September 1961; 447 pages; $3.25; Geneva.