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Atmospheric SO_2 Concentration Observed in Tokyo and Its Relation to Meteorological Elements*

— On Atmospheric Pollution (I) —

by

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Abstract

In order to examine the atmospheric contamination, we observed the concentration of sulphur dioxide. From January 18th, 1955, through the 24th, we observed 5 times per day at 7 localities in Tokyo Prefecture. In the following pages the result of our observation and its relation to meteorological elements will be given a concise description.

1. Introduction

We selected sulphur dioxide as a part of the atmospheric contamination in the urban districts. Sulphur dioxide is chiefly produced by coal burnt and is contaminating the lower atmosphere. It is observed with deposited dust and fly smoke particles. It is generally admitted that the concentration of sulphur dioxide plays a major role on the occasion of a number of persons dying of atmospheric contamination [1][2][3].

2. Method of measuring sulphur dioxide

Putting into an impinger a dilute solution of hydrogen peroxide and sucking the open air in, the following chemical change will occur with the aid of sulphur dioxide in the air.

$$H_2O_2+SO_2=H_2SO_4.$$

We selected the impinger made of polystyrol, and, to measure pH, mixed solution of bromcresalgreen alcohol and methylred alcohol was used for the experiment as an indicator. The atmosphere containing not only sulphur dioxide but also other sulphur compounds, the total sulphur would be, after all, measured by this method. As, however, the atmosphere contains far more sulphur dioxide than any other sulphur compounds [4], we counted the result obtained from this method as the value of sulphur dioxide in the air.

3. Localities of observation

Fig. 1 shows the localities of observation. Owing to various circumstances we could not have localities of observation in the heavily contaminated area of Tokyo. We picked up the values of the Central Meteorological Observatory as the data on meteorology and those of the Aerological Observatory, Tateno, Ibaragi Prefecture, as the data on the upper atmosphere.

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4. Number of observations

Sulphur dioxide was measured 5 times per day, 09h 00m, 12h 00m, 15h 00m, 18h 00m, 21h 00m, from Jan. 18th through the 24th. It was measured every hour at some localities of observation.

5. Meteorological situation

Fig. 2 shows the weather chart at 09h 00m on Jan. 24th, 1955. During this period the Siberian anticyclone overlay there, a part of which was extending as

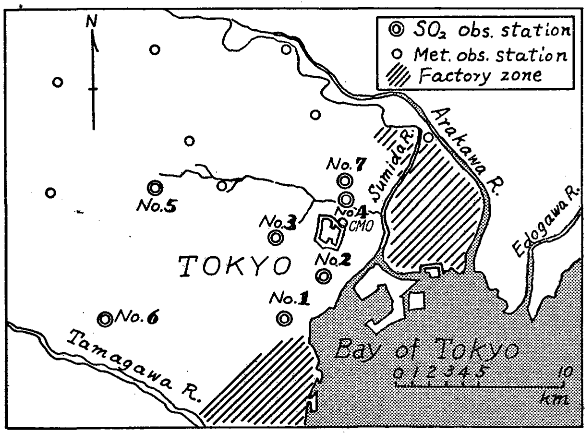

Fig. 1. Locality of SO_2 observation.
No. 1: The Institute of Public Health, No. 2: The Jikei University, No. 3: The Keio University, No. 4: The Tokyo Medico-Dental University, No. 5: Meteorological Research Institute, No. 6: The Institute for Science of Labour, No. 7: The Tokyo University, CMO: The Central Meteorological Observatory.

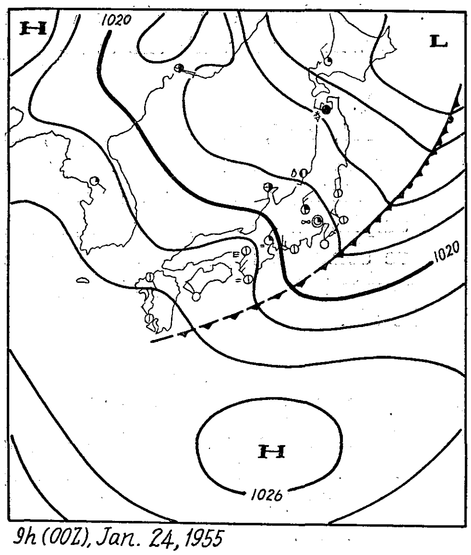

Fig. 2. Surface weather chart at 09h 00m Jan. 24, 1955.

Table 1. SO_2 concentration (p.p.m.) at No. 4 and No. 5.

date	hour	No. 4	No. 5
18	9	0.029	0.014
	12	0.004	0.009
	15	0.015	0.013
	18	0.117	0.015
	21	0.218	0.016
19	9	0.068	0.017
	12	0.069	0.012
	15	0.008	0.008
	18	0.024	0.014
	21	0 045	0.013
20	9	0.188	0.015
	12	0.000	0.014
	15	0.000	0.011
	18	0.034	0.016
	21	0 069	0.005
21	9	0.011	0.007
	12	0.004	0.006
	15	0.007	0.007
	18	0.030	0.008
	21	0.026	0.011
22	9	0.118	0.013
	12	0.021	0.009
	15	0.015	0 008
	18	0.030	0.009
	21	0.023	0.013
23	9	0.003	0.002
	12	0.000	0.003
	15	0.007	0.011
	18	0.032	0.038
	21	0.038	0.031
24	9	0.105	0.018
	12	0.083	0.014
	15	0.055	0.009
	18	0.177	0.019
	21	0.068	0.036

far as the seas to the south of the mainland. Accordingly the weather was almost clear. The lower atmosphere in Tokyo was stable and much contaminated.

6. Result of observation

Of the results of the observation, the concentrations at No. 4 and No. 5 are shown in Table 1 as the example. The concentration of sulphur dioxide is adjusted and shown in Figs. 3, 4 and 5. The average by the locality of observation is shown in Fig 3, the daily mean in Fig. 4, and the hourly mean in Fig. 5. Applying the average by the locality, we show the line of equivalence in Fig. 6. While the concentration of sulphur dioxide is 0.1 ppm in the center of Tokyo, it is far less,

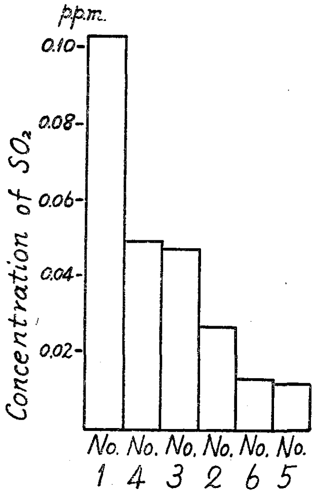

Fig. 3. Average concentration of SO_2.

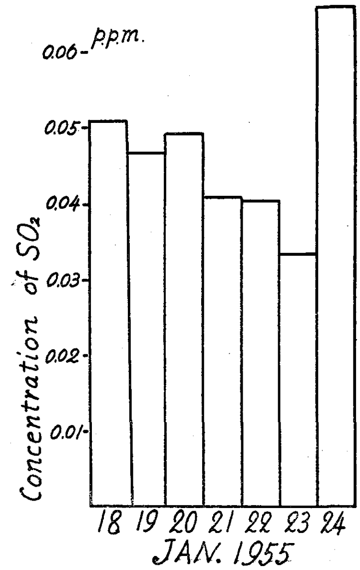

Fig. 4. Daily mean of concentration of SO_2.

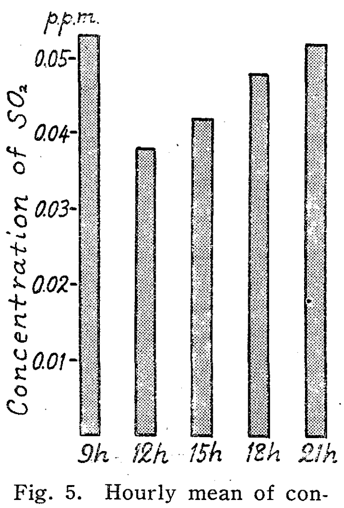

Fig. 5. Hourly mean of concentration of SO_2.

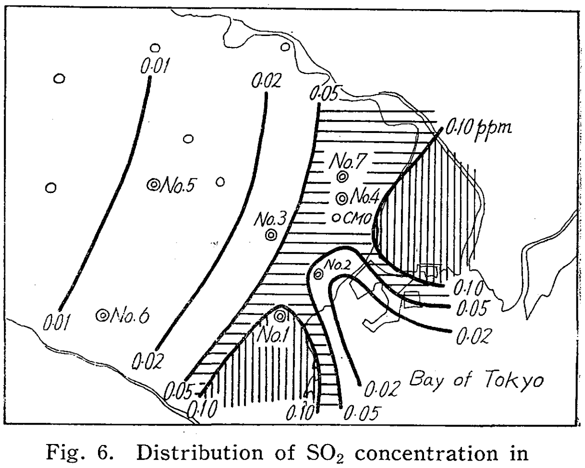

Fig. 6. Distribution of SO_2 concentration in Tokyo.

around 0.01 ppm, on its western outskirts. And it may be considered sulphur dioxide is less on Tokyo Bay. According to the average by the data in Fig. 4, the concentration of sulphur dioxide is the largest on the 24th, which will be explained later on. We can see the daily variation of the atmospheric contamination from the hourly mean in Fig. 5.

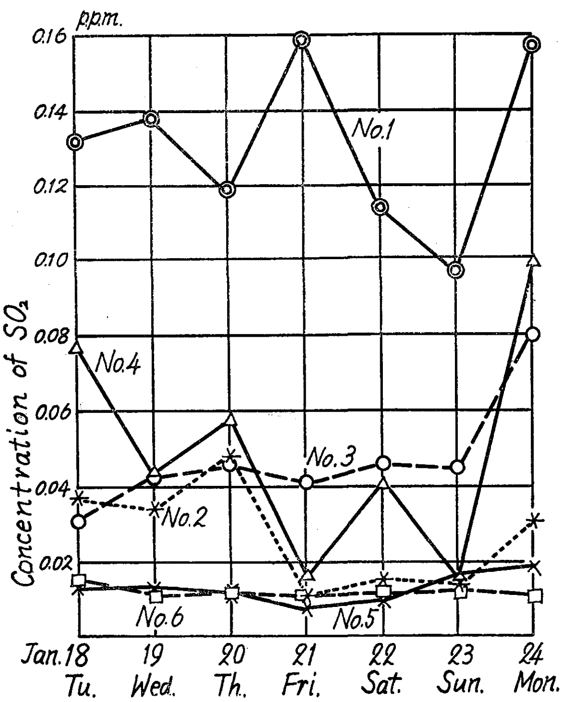

Fig. 7. Daily mean concentration of SO_2 at each locality.

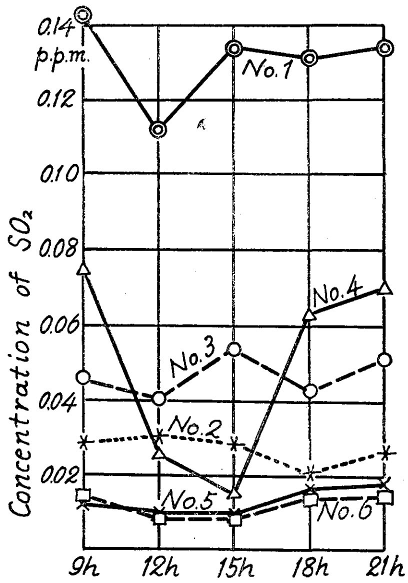

Fig. 8. Hourly mean concentration of SO_2 at each locality.

The daily and hourly variations at each lacality are shown in Figs. 7 and 8 in order that one may examine it in detail. The daily and hourly variations are shown distinctly at the observation localities, No. 1 and No. 4. On the contrary, their peak is recorded at 15h 00m at No. 3 observation locality. On the 23rd, Sunday, the average of the concentration of sulphur dioxide decreases remarkably at No. 1 and No. 4 localities. Those localities are near the factory areas and therefore seem to be much affected by it.

7. Its relation to meteorological elements

Meteorological elements are the diffusion factors of the atmospheric contamination [2]. Among those, wind direction, wind force, stability of the atmosphere, etc are the major ones [5]. Now, the wind directions and wind velocities during the observation period are shown in Table 2. Herein are shown the average wind velocities and the most frequent wind directions. Table 3 above given shows the wind directions and wind velocities at the upper atmosphere, which were observed at the Aerological Observatory. The difference between the sur-

Table 2. The wind directions and wind velocities (m/sec) at the upper atmosphere.

date / height \ hour	18th 00h	18th 13h	19th 00h	19th 12h	20th 00h	20th 12h	21st 00h	21st 12h
0.5 Km	SSW 4	WNW 7	W 2	SW 6	W 6	SSW 8	WNW 13	W 15
1.0 Km	WSW 14	WNW 12	SW 5	SSW 6	W 9	SW 13	NW 13	W 17
2.0 Km	W 15	W 12	W 8	WSW 8	WSW 15	W 15	WNW 16	W 26
3.0 Km	W 18	WNW 24	WNW 16	W 17	WSW 25	WSW 30	WSW 8	WNW 23

date / height \ hour	22nd 00h	22nd 12h	23rd 00h	23rd 12h	24th 00h	24th 12h
0.5 Km	WNW 3	W 8	NW 16	NW 5	SW 1	W 5
1.0 Km	WSW 6	WNW 14	WNW 19	WSW 6	SW 3	NW 5
2.0 Km	W 9	WNW 15	WSW 10	WSW 8	W 10	NW 9
3.0 Km	W 21	WNW 22	W 20	W 18	W 18	WNW 9

Table 3. The wind directions and wind velocities (m/sec) during the observation period.

date \ hour	09h	12h	15h	18h	21h	24h	daily mean
18th	NNW 6.3	N 8.2	NNE 2.2	— 0.4	NNW 1.3	NNW 2.2	3.4
19th	NW 2.8	SSE 4.0	SW 6.1	S 4.4	NNN 2.0	WNW 0.9	3.3
20th	SE 1.7	SW 11.5	SSW 11.5	W 4.4	WNW 5.5	WNW 4.0	4.9
21st	NW 4.8	NW 6.1	NW 4.6	N 2.6	NW 2.0	NW 1.7	4.1
22nd	WNW 1.1	NW 3.2	NNW 7.1	NW 5.2	NW 3.2	WNW 3.8	3.1
23rd	NW 5.9	NNW 3.0	SE 3.8	ESE 3.2	E 1.5	NW 2.2	2.7
24th	— 0.0	E 2.4	SSE 4.8	S 2.6	SE 2.8	WNW 2.2	2.1

face wind velocity in Tokyo and at an altitude of 1,000 meters in Tateno is expressed in Table 4 as an objective point for wind shear. The ground inversion layer begins to appear clearly at night and so the upward diffusion of smoke is restricted. Therefore, seeing the value at 12h 00m in Table 4, we know that the vertical diffusion is powerful on the 21st and the 22nd, while it is weak on the 19th, 20th and 24th.

In Fig. 9 is shown the values of the radio sonde observed at Tateno. An ordinate expresses atmospheric pressure, an abscissa temperature (°C) and the arabic numerals altitude (m). In the figure the dotted lines indicate dry adiabatic and the netted space the stable layer of the atmosphere. In this case the ground inversion caused by radiational cooling during the night is so remarkable. It is clearly demonstrated that at night the contaminated air is kept between the atmospheric layers near the ground. Calculated in Table 5 is the difference between the air temperature near the ground and at an altitude of 1,000 meters,

Table 4. Temperature and potential temperature at 1000 m height and the surface, and the difference between them.

January, 1955

date	18		19		20		21		22		23		24		25
hour	00	12	00	12	00	12	00	12	00	12	00	12	00	12	00
temperature at 1000m height	°C −1.0	°C −3.1	°C −3.8	°C −1.8	°C 0.8	°C 3.7	°C −3.3	°C −3.1	°C −2.0	°C 0.1	°C 0.0	°C −0.8	°C −0 6	°C 1.5	°C 2.2
surface temperature	−4.7	6.8	−5.0	6 0	−2.6	11.7	2.4	6.2	−5.3	9.6	1.5	8.6	−2.5	9.2	−1.7
difference	−3.7	9.9	−1.2	7.8	−3.4	8.0	5.7	9.3	−3.3	9.5	1.5	9.4	−1.9	7.7	−3.9
potential temperature at 1000m height	281.0	278.2	277.8	279.8	282.6	286.3	279.0	279.0	280.1	282.9	282.0	281.0	281.0	283.2	284.0
potential petemrature at the surface	267.6	278.6	266.7	278.1	269.9	285.2	275.8	279.0	267.2	282.2	274.1	280.9	269.8	281.3	270.8
difference	13.4	−0.4	11.1	1.7	12.7	1.1	3.2	0	12.9	0.7	7.9	0.1	11.2	1.9	13.2

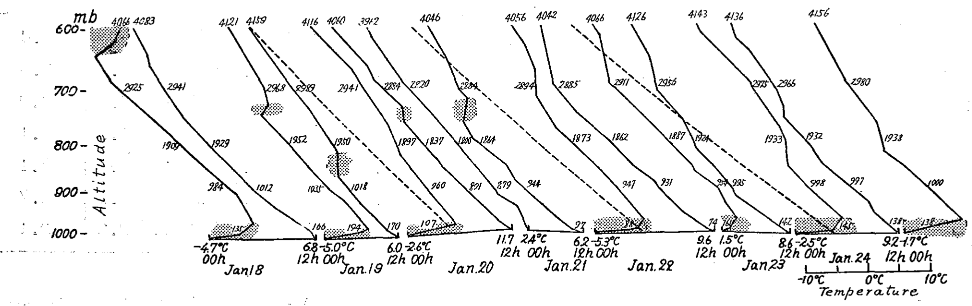

Fig. 9. State curves at the Aerological Observatory in Tateno are shown in full line. Figures: height (m). Half-tones: inversion. Broken line: dry adiabat.

Table 5. Difference between the wind velocity at 1000 m height and at the surface.

January, 1955

date	18		19		20		21		22		23		24		25
hour	00	12	00	12	00	12	00	12	00	12	00	12	00	12	00
* m/sec	9.6	5.7	2.8	2.0	8.1	1.5	9.0	11.9	4.3	10.8	15.2	3.0	0.8	2.6	2.3

* (wind velocity at 1000 m height) —(wind velocity at the surface)

as well as the potential temperature between them. Fig. 10 sums up our studies given above. In this figure (a) indicates the reciprocal of wind velocity on the ground, (b) and (c) indicate respectively the difference of potential temperature at 12h 00m and 24h 00m, (d) the reciprocal of the difference between the wind velocity on the ground and that at an altitude of 1,000 meters which is supposed to be vertical diffusion factor. In addition, the arrows show the prevailing wind directions. It is thought, on one hand, the diffusion power of (a), (b), (c) and (d) are weak in the upper parts and, on the other, they are powerful in the lower parts. Examining the diffusion power from 18th through 24th, that on the 24th is the most weak. Consequently it is seen that the atmospheric contamination is most concentrated on that day. The actual result of our observation proves this fact to be true.

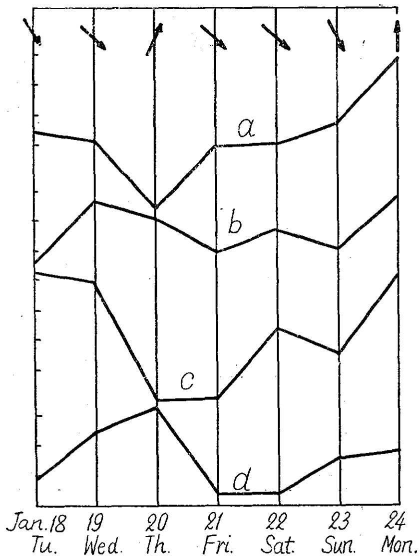

Fig. 10. Atmospheric diffusion factors

a : The reciprocal of wind velocity on the ground

b : The difference of potential temperature at 12h 00m.

c : The difference of potential temperature at 24h 00m.

d : The reciprocal of the difference between the wind velocity on the ground and that at the altitude of 1,000 meters.

arrows : The prevailing surface wind direction.

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