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An Examination of the Relationship between Air Pollutants and Weather Factor

— Comparison of Sagamihara and Ebina, Kanagawa Prefecture in 1996 —

大気汚染物質と気象要因の検討
—1996年度における神奈川県相模原市と海老名市の比較について—

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Abstract: Modern air pollution problem is developing in cities as satellite towns. It is important for environmental administration to find ways to cooperate with local residents, and it is necessary to provide easily understood visual expression and to utilize it to give environmental information to the population. It is the purpose of this study to examine the relationship between air pollutants and weather factors in Sagamihara in 1996, and make a comparison with the results of a survey at Ebina. And the following conclusions were obtained:

1. Compared to air pollution conditions in two cities under visual expression, each pollutant is shown with its characteristic seasonal variation. Also there is seen a similar variation in the moving average method (three months) to grasp the trend.
2. In the correlation analysis, it is shown that variations in SO_2-NO_2 and O_X-NMHC in Ebina are different from those in Sagamihara, and it is clear that there is different relationship in the NO/NO_2/O_X/SPM/NMHC density between the two stations and a different relationship each month.
3. As to weather factors, it is supposed that differences in measurements and distribution of frequencies are affected by the local surroundings.

Key words: Air Pollution, Sagamihara, Ebina, Weather factor, Correlation analysis, Seasonal variation

Introduction

The actual circumstances of the modern air pollution problem relate not only to big developed cities that already have highly concentrated traffic and industry, but also the city suburbs. Especially, since the problem has been stressed because it adversely affects lifestyle, pollution is closely related to the life of the population[1–2, 4)], and it is important for environmental administration in future to find ways to cooperate with local residents. It is therefore necessary to be provided easily understood visual expression of environmental information and to utilize it for providing environmental information to the population[5)]. It is the purpose of this study to examine the relationship between air pollutants and weather factors on the basis of the data from continuous observation and measurement stations in Sagamihara in 1996 in a previous paper[3)], in addition to the data for Ebina, for comparison.

Materials and Methods

1) Materials

Materials are hourly measurements of pollutant density (SO_2/NO/NO_2/O_X/SPM/NMHC/CH_4) and weather factors

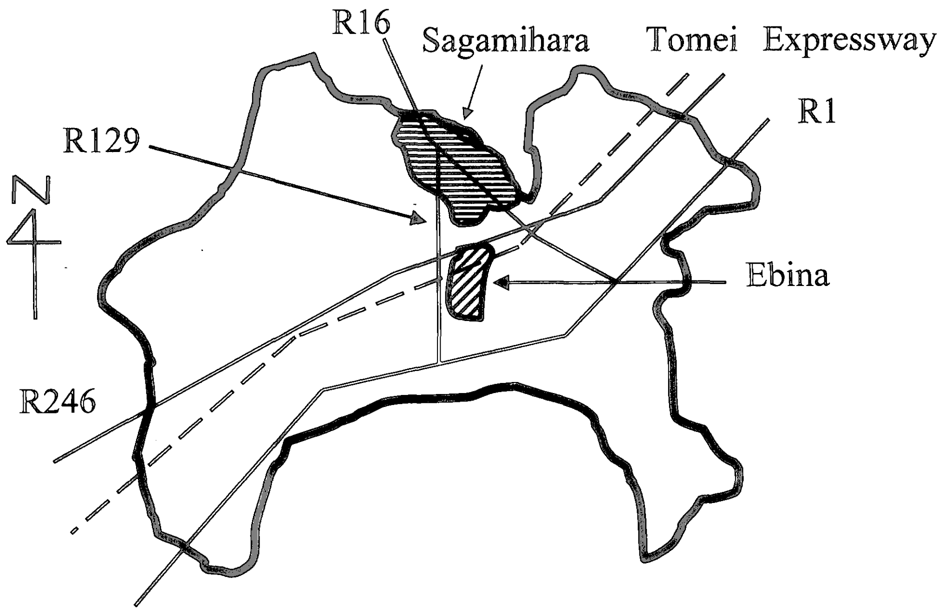

Fig. 1. Location of Sagamihara and Ebina in Kanagawa

such as wind velocity, temperature and humidity in 1996 measured at continuous observation and measurement stations such as the city hall in Sagamihara and Ebina, and the calculated monthly averages.

2) Methods

1. Observation of seasonal variation in pollutants.
2. Correlation analysis.

3) Outline of two cities and measurement stations

The two cities are in the middle of Kanagawa Prefecture (Fig. 1). As for geographical features, in Sagamihara there are three differences in level with the city hall in the upper section. In Ebina, there is hilly terrain in the eastern parts and rice field in the western part, with the city hall in the latter region. The two cities are satellite towns for population movement from big cities, as the population has been increasing. Also as to networks of roads, in Sagamihara there is heavy traffic density on R16, R129 and the roads linked to these, so that the road network covers most of the region, whereas in Ebina, traffic density is concentrated on R246 in the north and two highways linked to R129 in Atsugi. And the Tomei Expressway runs through the south.

Results and Discussion

1) Variation in pollutants

1. Observaiton of seasonal variation

It is found that the SO_2 density (Fig. 2) in Sagamihara is a trough from May to July, increasing rapidly in August, and thereafter, there is an irregular trend in the range 8-10ppb. In Ebina there is a peak in June, then it decreases slowly until there is a level trend under 7ppb, but at two stations there is seen a seasonal cycle of one peak. Also it is seen that there is similar variation in the moving average method (three months) to grasp the trend of density. This remarkable trend shows that at the two stations the SPM density (Fig. 3) peaks in June and July, is a trough in September, and peaks in December, again there is a trough in January, and a seasonal cycle of two peaks, the smaller one in summer and the other in winter. It is higher in Ebina, and there is a very large difference from measurements in Sagamihara in winter. Because it is higher in Ebina at SPM density, it is supposed to be

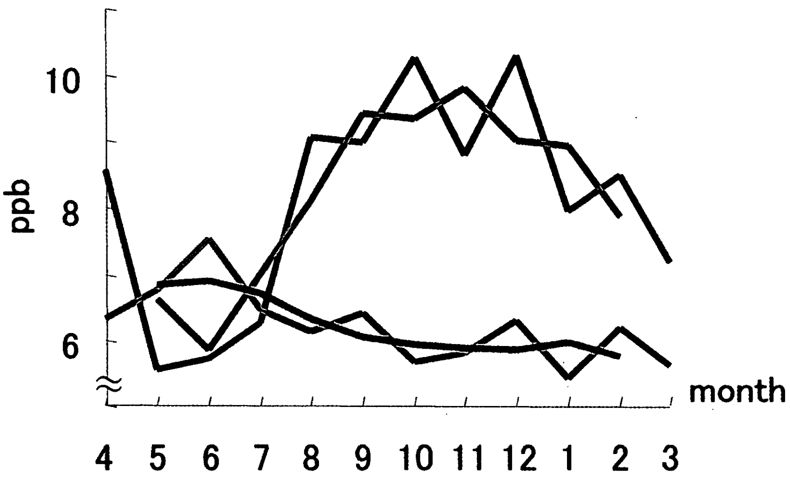

Fig. 2. Seasonal variation in SO_2 density at the two stations

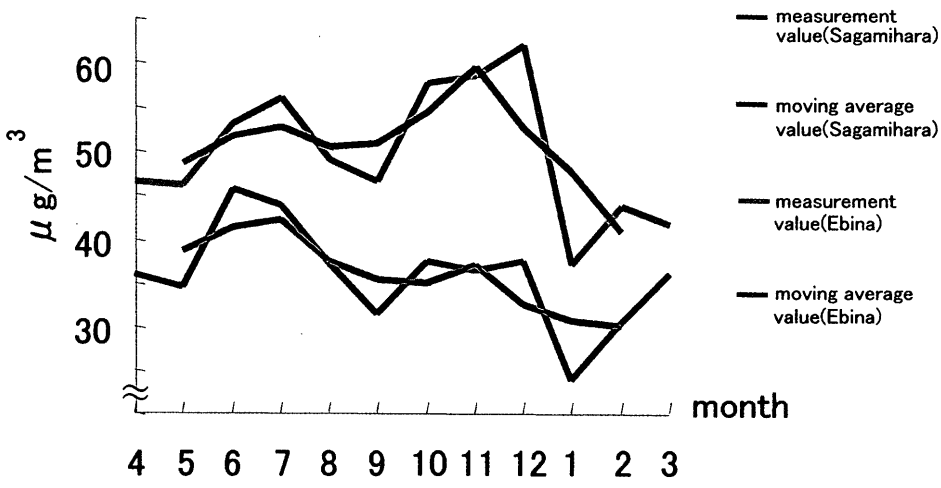

Fig. 3. Seasonal variation in SPM density at the two stations

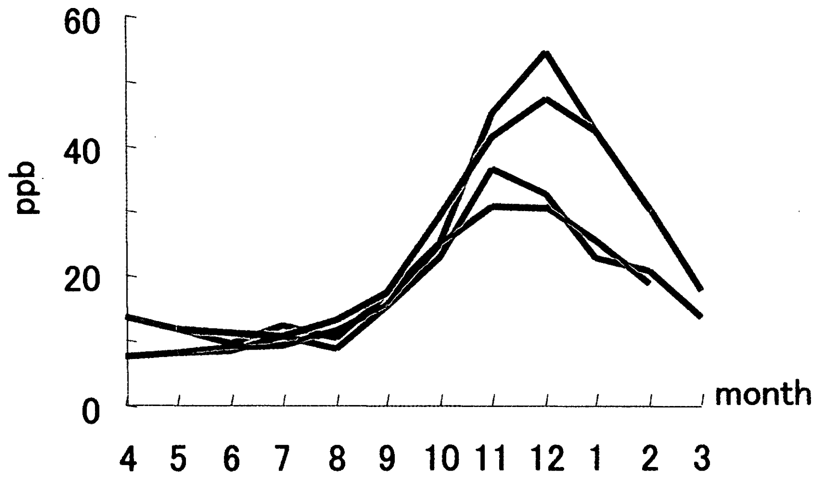

Fig. 4. Seasonal variation in NO density at the two stations

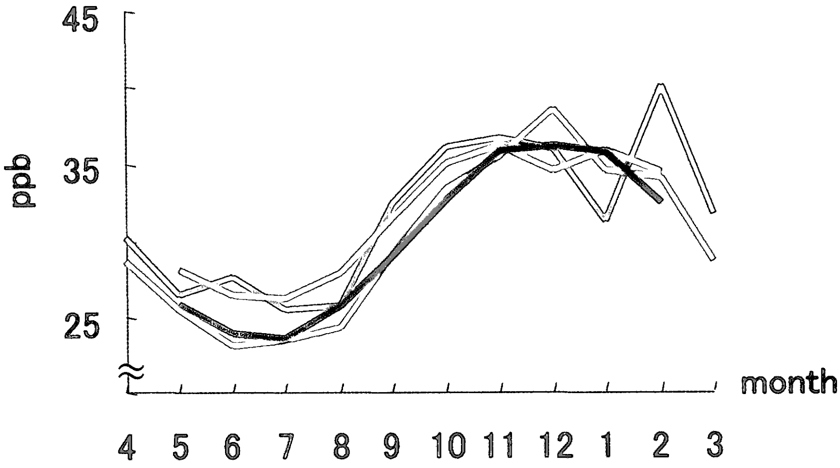

Fig. 5. Seasonal variation in NO_2 density at the two stations

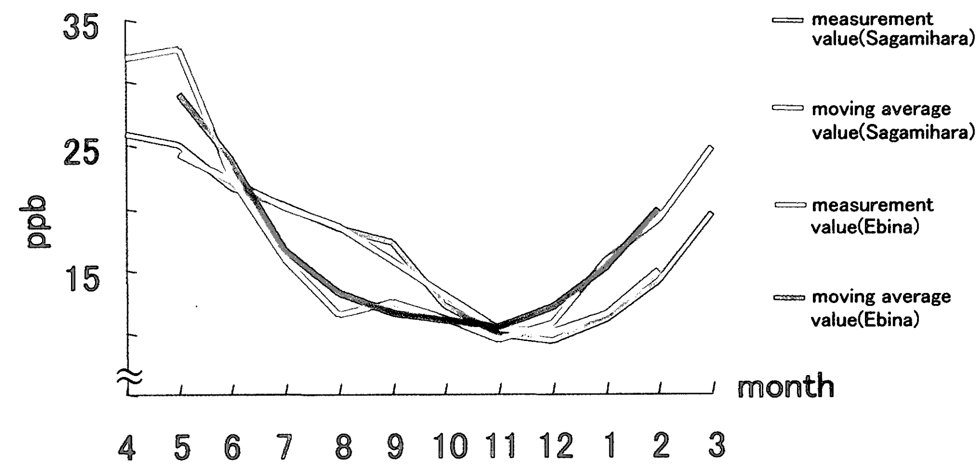

Fig. 6. Seasonal variation in O_X density at the two stations

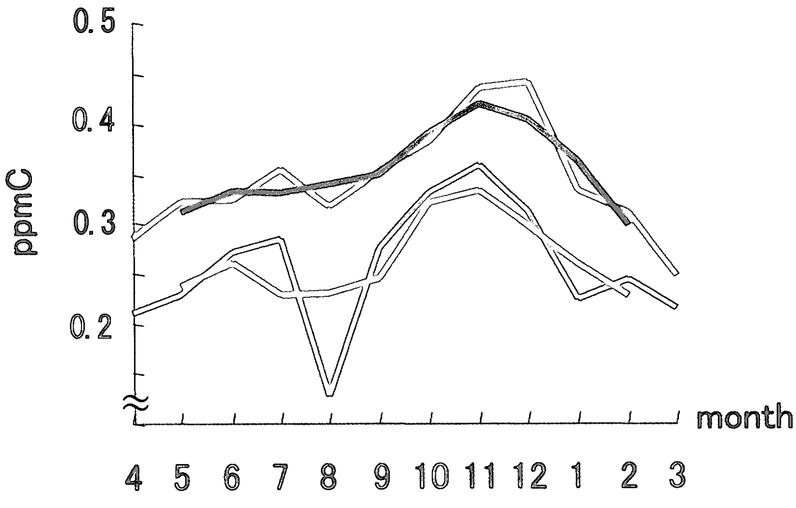

Fig. 7. Seasonal variation in NMHC density at the two stations

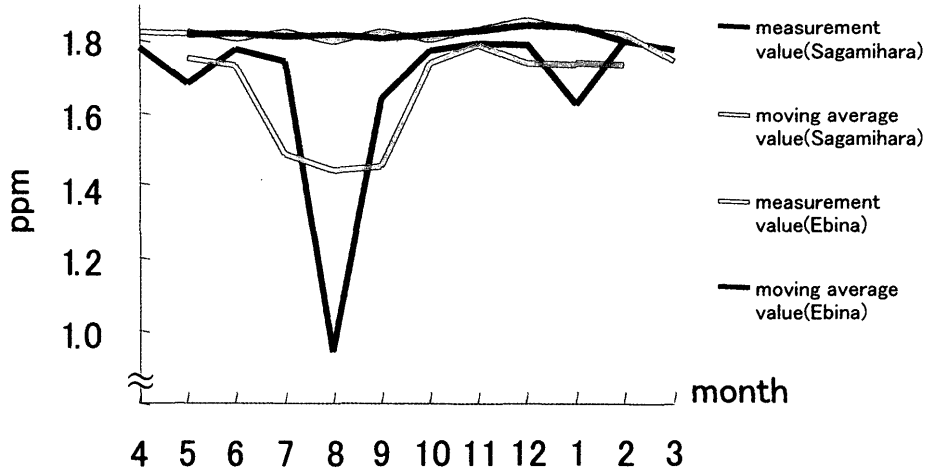

Fig. 8. Seasonal variation in CH_4 density at the two stations

affected by the surroundings rice fields, and because the SO_2 density is higher in Sagamihara after August, it is supposed to be affected by the location, being topographically higher than Ebina, and by the roads that run near the stations[6-10]. The seasonal cycle is seen in that the NO density (Fig. 4) peaks in November (Sagamihara), December (Ebina), and NO_2 density (Fig. 5) is a trough in summer and a peak in winter. At two densities, it is higher at Ebina in winter[11-12]. Variation in the O_X density (Fig. 6) decreases slowly after April, and is a trough in December in Sagamihara, and decreases rapidly from May, forming a gentle trough from August to December, therefore increasing rapidly at Ebina. The seasonal cycle shows NMHC density (Fig. 7) caused by two photochemical oxidant peaks in July and November/December at the two stations, and it is higher in Ebina. It is seen that in Sagamihara, in spite of a decrease in August, the CH_4 density trend (Fig. 8) is irregular, and it is level in Ebina. It is supposed that the difference between the measured values at the two stations indicates the low NMHC/CH_4 density in August at Sagamihara and is affected by the change in traffic density[13-15].

2. Correlation analysis

The results of correlation analysis for monthly averages of pollutant density, combinations of NO-NO_2/NMHC and NMHC-CH_4 are found to be positive at the two stations. A combination of SO_2-NO_2 is positive at Sagamihara, negative at Ebina, and it is supposed to be affected by the seasonal cycle of SO_2 density. SPM-NMHC is found positive at Ebina. The O_X density is found negative in the SO_2/NO/NO_2 density at Sagamihara, and the NMHC density at Ebina (Table 1). And in the results of analysis of the two stations, it is positive at NO/NO_2/O_X/SPM/NMHC density. Also in the relationship each month, it is found that there is a close relation between the two stations. Therefore, it is seen that the variation in SO_2-NO_2 and O_X-NMHC in Ebina is different from that in Sagamihara, and there is a clear difference in the relationship at NO/NO_2/O_X/SPM/NMHC density between two stations a difference in the relationship each month.

2) Relationship between air pollutants and weather factors

1.Weather conditions in 1996 at the two stations

It is seen that the wind velocity falls from July, after November rises again in Sagamihara, and in Ebina the wind falls to June, and afterward rises with a similar trend to that in Sagamihara, but falls to December, afterward rises again, and at Ebina wind is not as strong as in Sagamihara. As for temperature, there is a similar trend at the two stations, but temperature at Ebina is higher from March to September. As for humidity, it rises from July to October, and falls in winter, and it is measured lower at Ebina throughout the year (Table 2).

Table 1. Result of correlation analysis of pollutant density at each station

City hall	SO_2	NO	NO_2	Ox	SPM	NMHC	CH_4
SO_2	1.00						
NO	0.60*	1.00					
NO_2	0.63*	0.76**	1.00				
Ox	−0.66*	−0.91**	−0.70*	1.00			
SPM	−0.30	−0.27	−0.39	0.36	1.00		
NMHC	0.23	0.68*	0.52	−0.51	0.22	1.00	
CH_4	−0.13	0.32	0.47	−0.09	0.07	0.69*	1.00

level of significance * :5% **:1%

Ebina

	SO_2	NO	NO_2	Ox	SPM	NMHC	CH_4
SO_2	1.00						
NO	−0.48	1.00					
NO_2	−0.58*	0.93**	1.00				
Ox	0.37	−0.52	−0.44	1.00			
SPM	0.23	0.26	0.17	−0.47	1.00		
NMHC	−0.06	0.68*	0.55	−0.70*	0.78**	1.00	
CH_4	0.20	0.47	0.36	−0.23	0.34	0.67*	1.00

level of significance * :5% **:1%

Table 2. Monthly average of weather factors at the two stations

Wind velocity

0.1 m/s	Sagamihara	Ebina
April	35.90	13.23
May	35.56	12.27
June	36.04	11.15
July	35.10	11.67
August	33.04	13.67
September	32.27	14.24
October	29.16	13.21
November	31.98	15.48
December	34.32	12.12
January	34.91	12.85
February	35.49	13.75
March	40.98	15.85

Temperature

0.1°C	Sagamihara	Ebina
April	113.08	117.75
May	166.04	175.46
June	215.09	224.60
July	250.14	258.20
August	251.88	258.78
September	212.94	217.44
October	168.30	169.98
November	121.58	124.24
December	79.55	77.81
January	53.53	50.90
February	59.18	60.67
March	92.14	99.43

Humidity

0.1%	Sagamihara	Ebina
April	655.63	611.48
May	738.68	688.16
June	796.24	735.72
July	800.68	739.89
August	777.34	740.51
September	769.02	754.97
October	762.58	717.31
November	731.32	667.68
December	661.88	619.19
January	588.86	563.68
February	571.21	499.61
March	680.75	594.97

The weather units are 0.5m/s for wind velocity, 5°C for temperature, 5% for humidity. Wind velocity starts at 1.5–2.0 m/s at Sagamihara, 0–0.5 m/s at Ebina, and the highest is 2.5–3.0 m/s at Sagamihra and 1.0–1.5 m/s at Ebina. It is almost concentrated at 3.0–3.5 m/s at Ebina, and it is supposed to a weak, constant wind environment throughout the year. As for temperature, Ebina is more in 0–5°C and rise to above 25°C. Humidity shows a similar trend at the two stations, but frequency is higher at Ebina than that at Sagamihara above 75% (Table 3). In the results of analysis of weather factors at each station, it is found positive for temperature and humidity, and combinations of wind velocity-temperature, wind velocity-humidity are not found significant, and the correlation coefficient is negative. The results of correlation analysis of the two stations show positive results for temperature and humidity. This agrees with the trend as a whole for the two cities. But, especially in wind velocity, it is supposed that differences in measured values and distributions of frequency are affected not only by the surrounding locality, but also the geographical and topographical environment.

Table 3. Frequency in class of weather factors.

Wind velocity			Temperature			Humidity		
m/s	Sagamihara	Ebina	°C	Sagamihara	Ebina	%	Sagamihara	Ebina
0–0.5		1	0–5	24	27	0–5		
0.5–1.0		112	5–10	98	89	5–10		
1.0–1.5		149	10–15	60	59	10–15		
1.5–2.0	4	64	15–20	76	71	15–20		
2.0–2.5	39	33	20–25	72	69	20–25		1
2.5–3.0	100	4	25–30	33	47	25–30		1
3.0–3.5	89	1	30–35	2	3	30–35	1	3
3.5–4.0	60					35–40	2	3
4.0–4.5	26					40–45	4	17
4.5–5.0	15	1				45–50	14	23
5.0–5.5	13					50–55	28	24
5.5–6.0	6					55–60	25	42
6.0–6.5	6					60–65	36	54
6.5–7.0	1					65–70	53	52
7.0–7.5	2					70–75	47	56
7.5–8.0	3					75–80	62	29
8.0–8.5						80–85	35	25
8.5–9.0						85–90	31	21
9.0–9.5						90–95	25	13
9.5–10.0						95–100	2	1
10.0–10.5	1							

2. Influence of weather factors on variations in air pollutants

The average for weather factors in each class is calculated. In relation to wind velocity, it is not found to relate to frequency, and basically the trend in Sagamihara is similar to that in Ebina[16–17], but in SO_2/NO density, the density until the greatest frequency decreases in Sagamihara, and increases in Ebina. In relation to temperature and humidity, there are similar trends at the two stations. In a comparison of the stations in Sagamihara and the station in Ebina in different of geographical conditions, there is not found a great difference between the two. Therefore it is supposed that this does not exhibit a strong direct influence of temperature and humidity on the variation in pollutants, and that variation in weather factors, including wind velocity, must be considered to affect pollutants remarkably.

Conclusions

We examined the relationship between air pollutants and weather factors in Sagamihara in 1996, in a comparison of results of a study conducted at Ebina, and the following conclusions were reached.

1)It is found that the SO_2 density in Sagamihara is a trough from May to July, increasing rapidly in August, and thereafter, there is an irregular trend in the range 8–10 ppb. That of Ebina peaks in June, then decreases slowly and levels out under 7 ppb, but at the two stations there is one seasonal cycle peak. In SPM density, there is a remarkable trend, but this trend is a seasonal cycle of two peaks: the smaller one in summer and the other in winter. There is very large difference from the measure values at Sagamihara in winter. The seasonal cycle shows that NO density reaches a peak in November and December, the NO_2 density is a trough in summer and peaks in winter. Density is higher in Ebina in winter. The O_X density decreases slowly after April, and is a trough in December in Sagamihara, decreases rapidly from May, and is a gentle trough from August to December, thereafter increasing rapidly in Ebina. The seasonal cycle shows that NMHC density has two peaks, in July and November/December, and shows that in Sagamihara, in spite of a small decrease in August, CH_4 density has an irregular trend, and it is level in Ebina. Also it is seen that there is a similar variation with the moving average method (three months) to grasp the trend in density change.

2) In the results of correlation analysis of the monthly average of pollutant density, combinations of NO-NO_2/NMHC and NMHC-CH_4 are found to be positive at the two stations. SO_2-NO_2 is positive at Sagamihara, and negative at Ebina. SPM-NMHC is found positive at Ebina. O_X density is found negative in the SO_2/NO/NO_2 density at Sagamihara, and the NMHC density at Ebina. And in the results of analysis for the two stations, the NO/NO_2/O_X/SPM/NMHC density is positive. Also in the relationship each month, a close relationship is found between the two stations.

3) It is seen that the wind drops from July, after November rises again in Sagamihara; and in Ebina the wind falls to June, afterward rises in a similar trend in Sagamihara, but falls to December, afterward rises again, and in Ebina the wind is not as strong as in Sagamihara. In temperature, there is a similar trend at the two stations, but at Ebina it is higher from March to September. Humidity rises from July to October, and falls in winter, and it is lower in Ebina throughout the year. As to variation in the frequency class, it starts at 0–2.0 m/s and in Ebina it is almost concentrated at 3.0–3.5 m/s. In the results of correlation analysis for weather factors, temperature and humidity are positive. There is a positive relationship between the two stations in temperature and humidity.

4) Easily visualized expression of air pollution condition results for comparison with the surrounding cities based on environmental information, shows that they are apparently affected by the locality, for example the surrounding environment and geographical and topographical features. And in correlation analysis, it is seen that variation in SO_2-NO_2 and O_X-NMHC in Ebina is different from that in Sagamihara, and it is clear that it is a difference in the relationship of the NO/NO_2/O_X/SPM/NMHC densities at the two stations plus the relationship each month. As to weather factors, it is supposed that differences in measured values and distribution of frequencies are affected by the locality. But it is supposed that this does not greatly affect temperature and humidity directly in the variation in pollutants, and there is a great difference between readings at stations in Sagamihara, in consideration of seasonal variations in weather factors, and the geographical and topographical environment affect wind velocity, causing great variations in pollution.

5) The two cities have become urbanized, but there is a difference between them in the scale and speed of the urbanization and geographical conditions. Therefore, it is supposed that measurement similar variations in pollutants should be done to cooperate over a wide area, and measurement of factors related to variations in pollutant, especially wind velocity, is needed, taking the local conditions into account.

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