

4.3 Concentration Variation of Air Pollutants

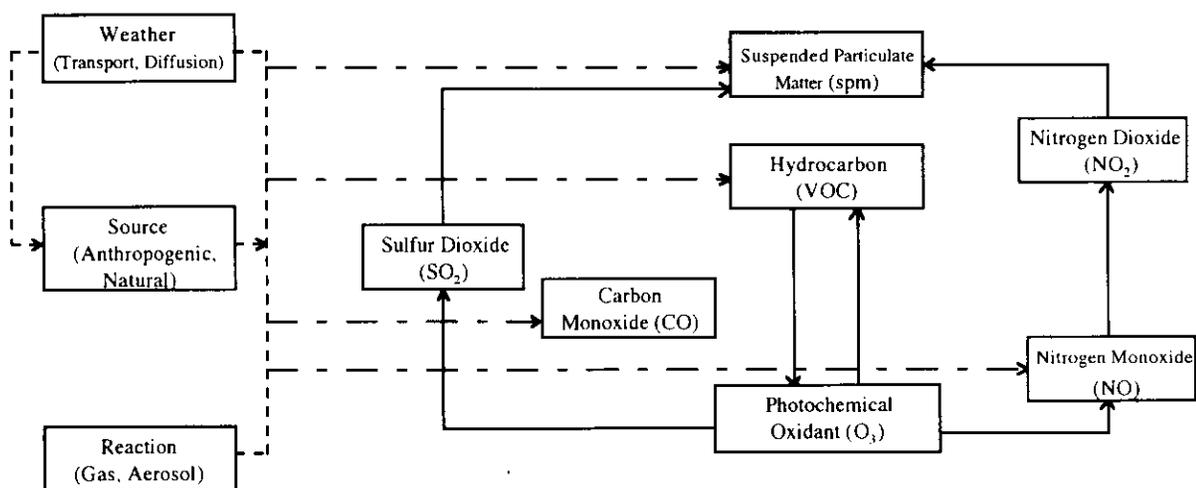
4.3.1 Introduction

The concentration of air pollutants changes as a result of changes in the meteorological factor, chemical reactions in the atmosphere, variation of the amount of air pollutants released, etc. In the variation of concentration, diurnal, seasonal and annual variations should be considered. In this section, the governing factors for the variation of air pollutant concentration in each time scale will be explained.

4.3.2 Diurnal Variation of Air Pollutant Concentration and the Mutual Relationship Among Pollutants

The weather and the chemical reaction give the largest effect on the diurnal variation of air pollutant concentration. Among the weather factors, the wind and stability have quite a large influence. Also, the amount of air pollutants generated has an influence on the diurnal variation. The primary factor of diurnal variation is the operational pattern of factories and the usage pattern of automobiles. It is also related with the life pattern of the people. For instance, in the diurnal variation of automotive traffic, a double-peaked distribution is common with peaks at morning and evening period of commuting hours, and the concentration increases significantly when stable, low wind speed weather condition would fall on those peaks.

Generally, the diurnal variation of pollutant concentration in the winter is different from that in the summer, and also very different by substance. In order to identify specific differences, it is necessary to understand the mutual relationship of air pollutants. The mutual relationship of air pollutants is shown in Fig.4.3.1.



Note: Dashed line indicates the flow of primary air pollution and solid line indicates that of secondarily generated air pollution.

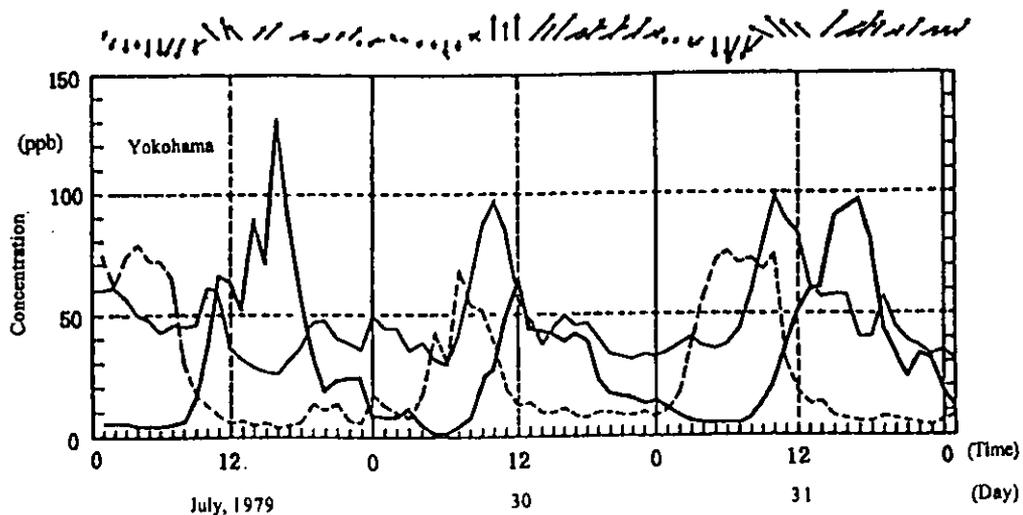
Source: Shinji Wakamatsu, Air Pollution Simulation Model, Air Conditioning and Sanitary Engineering, Vol. 70, (11), p.879-887 (1996)

Fig.4.3.1 Mutual Relationship of Air Pollutants

The dotted line in Fig.4.3.1 indicates the route in which air pollutants are released directly from the source of air pollutants. There are complex relationships among NO (nitrogen monoxide), NO₂ (nitrogen dioxide), VOCs (volatile organic compounds) and ozone. Some hydrocarbon species are included in the volatile organic compounds, but aldehydes are also included to be called generally as VOCs. Details of the reaction mechanism of hydrocarbon species are explained in Section 4.2, and the essential points will be described again below.

The VOCs would accelerate the formation of photochemical air pollution through the following mechanism. The major component of photochemical air pollution is ozone, and the only reaction that produce ozone in the troposphere is the photochemical decomposition of nitrogen dioxide. That is, nitrogen dioxide would be photochemically decomposed to nitrogen monoxide and oxygen, and this oxygen would combine with an oxygen molecule to form ozone. However, since nitrogen monoxide will react with ozone to become nitrogen dioxide again, the ratio of nitrogen monoxide to nitrogen dioxide to ozone becomes constant. This condition is called a photostationary state. When VOCs are not existing, such a stable condition will be established. However, when there are any VOCs in the atmosphere, the substance with very high reactivity called radical would be produced, and it will oxidize nitric oxide to nitrogen dioxide. As this reaction would produce nitrogen dioxide without destroying ozone, ozone would be produced further. Since more than 90% of the nitrogen oxide generated from automobiles and combustion facilities is nitrogen monoxide, the existence of highly reactive VOCs is a key for the increase of ozone.

This radical would also accelerate the production of aerosols (spm). Roughly more than 100 VOC components, which have up to 10 carbon atoms and are volatile, are existing in the atmosphere. Because each of those VOCs would have different rate of radical formation, the amount of each component contained is very important for ozone formation. As well as promoting the photochemical reaction, some of the VOCs such as benzene are hazardous by themselves. A typical diurnal variation of air pollutant concentration is shown in Fig.4.3.2.



Note: Shows the time variation of the concentration of NO (---), NO₂ (-), and Ox (-·-) and the wind direction and velocity at Yokohama in the period of July 29 to 31, 1979. There is a peak in nitrogen monoxide (NO) concentration in the early morning, and, after that the concentration of nitrogen dioxide (NO₂) increases. As the sea breeze from the Bay of Tokyo, from southeast to south, excels in the late morning to midday, and then as that from the Bay of Sagami, from southwest, excels in the afternoon, the concentration of oxidant (Ox) increases.

Fig.4.3.2 Typical Diurnal Variation of Air Pollutant Concentration

4.3.3 Seasonal Variation of Air Pollutant Concentration

The concentration of ground level ozone of stratospheric origin sometimes increases to more than 80 ppb in the northern hemisphere at latitude of 30 degrees in the spring. In Japan, the concentration of nitrogen dioxide increases in Kansai region in the spring. Those phenomena are caused by the facts that the ozone of stratospheric origin would give influence on the ground in the spring, and that ozone is produced by photochemical air pollution.

In the summer, the photochemical air pollution would be generated as the intensity of ultraviolet radiation and the temperature are high. As a result, the amount of secondarily produced particulate matters would also increase. The ozone concentration in the oceanic air mass in the summer is relatively low with around 20 ppb.

In the winter, the air pollutant concentration becomes higher because the radiation inversion is often formed and stable atmospheric layers are formed during the night and early morning hours. However, as most people in Japan takes holidays in the new year season and the automobile traffic decreases, the air pollutant concentration decreases. Although the nitrogen oxides by background ozone or photochemical ozone would occur even in the winter time, its degree is lower than in the summer and the ratio of NO within NO_x increases.

4.3.4 Annual Variation of Air Pollutant Concentration and Its Statistical Analysis

In order to evaluate the countermeasures for air pollution and to understand the structural changes of environmental loads, the information of the annual variation of air pollutant concentration is quite useful. It is necessary to remove the effect of weather conditions to correctly understand the characteristics of annual variation in relation to pollution sources.

As the environmental standard is usually determined as annual average values and hourly values, it is important to understand the relationship between average values and high concentration values to evaluate the environmental concentration of air pollutions. For these purposes, the analysis of the type of cumulative frequency distribution of hourly values and the relationship between percentile values and annual average values is performed. The evaluation by hourly values would respond to acute effects, while the analysis by annual average values would respond to chronic effects. Also, the evaluation by a cumulated concentration (dosage) in excess of certain threshold value is used in analysis of the damage to plants or the risk.