Studies on the Prediction of Oxidant Concentrations

Motohide MURATA

About two decades ago, the majority of Japanese industries were enthusiastic to promote their productions to fill the gap between supply and demand, and consumed huge amounts of fossil fuels, as an energy source to achieve their effective productions. A type of the air pollution at that time was a one so-called "London type pollution", which derived from the consumption of coal or low-quality petroleum by the big enterprises. In this type of the pollution, an accumulation of the excessive amounts of sulfate or particulate matter in the lower altitude of the ambient air often caused various type of public health hazard, and the people became aware of the importance of the atomospheric environmental protection.

Thus, since the middle of the 1960's, the challenge has been made under the cooperation between industries and government to control the air pollution to minimize the public health hazard. The utilization of numerous modern scientific techniques, such as the establishment of an automated monitoring system for the survaillance of air qualities in both urban and rural areas of Yokkaichi city, and the adoption of an alarming system to regulate the fuel consumption in industries has been taken into practice, in addition to the legislation on the air pollution control by the Japanese government. These countermeasures had taken were likely to be effective and seemed to have succeeded to solve the air pollution problems in the Yokkaichi area.

In 1970, however, a dramatic health hazard has arisen by a new type of air pollution, now known as "photochemical smog" of Los Angeles type pollution, involving handreds of the Risho Senior Highschool pupils in Tokyo. The frequent occurrence of this type of air pollution in summer months were followed by the all over the urban areas of the entire nation, and without any effective countermeasure to take, it brought great deal of casualties, not only on man and animals but also on plant and vegetables.

According to the results of many investigations, an area-wide control is indispensable to combat with this type of the air pollution, since the occurrence of photochemical smog is caused by the synthesis of variety of chemicals from nitrogen oxides and hydrocarbons in the atomosphere, with the help of ultraviolet rays in sunbeam. The sources of the photochemical pollutants were not restricted in the fixed places, such as in factories or in buildings of big enterprises, but the substances in exhaust gas from automobiles are also known to have been playing a very important role.

Among the chemicals synthesized in air, oxidants have been used for the indicator of the grade of the pollution by photochemical smog. And exact prediction of the would-be concentration of oxidants in air is considered to be the effective countermeasure to protect the inhabitants from such troublesome air pollution.

Thus, as a first step of this investigation, a statistical analysis was made on the correlation matrix of the following 19 variables of the environmental factors, by the use of FACOM 230-25 type computer. All the variables used in the factor analysis were the ones obtained at 9 o'clock in the morning, otherwise stated elsewhere. The variables analysed were 5 substanses; such as initial oxidant in ppb (OX), nitric oxide in ppb (NO), nitrogen dioxide in ppb (NO_2), sulfur dioxide in ppb (SO_2), and particulate matter in $\mu g/m^3$ x 10 (DST); and 14 meteorological factors, such as temperature at 6 a.m. in °C (T6), temperature at 9 a.m. in °C (T9), relative humidity in percent (HUM), wind direction (WD), wind velocity in m/s (WV), weather (WEA), visibility in km (VIS), expected diurnal range of temperature in °C (D6), expected maximum temperature minus normal maximum temperature in °C

(DTMX), Gozaisho wind direction (GWD), Gozaisho wind velocity in m/s (GWV), solar radiation between 7 and 9 a.m. in cal/ cm^2/hr (SRD), maximum temperature in °C (TMX), and minimum relative humidity in percent (HMN).

As another step in understanding the nature of the 19 variables, the principal components analysis and the factor analysis were also conducted simultaneously. Through these two analysis, three major components (Z_1~Z_3) were produced, which together accounted 61.5% of the total variable loadings within the data, and explained as follows:

Component I is the weather variables related to the initial concentration of oxidant.

$Z_1 \fallingdotseq 0.8 \times (HUM) + 0.9 \times (WEA) - 0.9 \times (D6) - 0.8 \times (DTMX) - 0.9 \times (SRD) + 0.9 \times (HMN) - 0.5 \times (OX)$

Component II is the meteorological variables related to the atomospheric temperature.

$Z_2 \fallingdotseq 0.8 \times (T6) + 0.9 \times (T9) + 0.8 \times (TMX) + 0.7 \times (DST)$

Component III is the pollutant variables related to the primary pollution.

$Z_3 \fallingdotseq 0.7 \times (NO_2) + 0.6 \times (SO_2) - 0.7 \times (VIS) - 0.6 \times (GWV)$

As a last step, the multiple regression analysis was made on the 19 variables, and it was found that a would-be maximum concentration of oxidant (Max. Con. Ox) can be estimated from the 7 extracted variables, such as initial concentration of oxidant, nitric oxide, diurnal range of temperature, visibility, minimum relative humidity, Gozaisho wind direction and its velocity. Finally the following equation for the prediction of maximum concentration of oxidant was produced:

$\text{Max. Con. Ox} = 7.78 \times (D6) - 3.74 \times (GWV) + 1.18 \times (OX) + 0.99 \times (HMN) + 3.29 \times (GWD) - 0.99 \times (VIS) + 3.21 \times (NO) - 77.59$

The analysis of variance clarified that F ratio of the values obtained on equation was 24.35, with a positive multiple correlation coefficients of 0.822, and with Durbin-Watoson ratio of 2.09. F ratio at a level of significance of 0.5% risk was 3.18, therefore the equation obtained can be regarded as a significant one.

During the period from June through September 1975, the 58 pair of data samples obtained at 9 o'clock in the morning, were re-examined retrospectively to prove the reliability of the prediction equation for the would-be maximum amount of oxidant. Consequently, it was found that the estimated amounts of the would-be maximum oxidant calculated by the equation were well agreed with a positive correlation coefficients of 0.758, with the actual amounts of the maximum concentration of oxidant. In other words, the achievement of the goal of the photochemical air pollution control is almost in our hand by the establishment of the prediction equation for the would-be maximum concentration of oxidant. And if we utilize the computed prediction information effectively, we may take three to four hour advanced administrative actions on the areal traffic regulation and fuel consumption in factories to minimize the public health hazard.