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# A Socio-Statistical Analysis of Air Pollution in Yamanashi Prefecture, Japan

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**Abstract.** Generally, air pollution is originated in human activities. However it is difficult to estimate the anthropogenic impacts on air pollution because they include so many factors i.e. population increase, economic development, climate change, and so on. Yamanashi prefecture is located on the west of Tokyo metropolitan area and the distance between both center is approximately 100km. Since there are few industrial areas and the automobile traffic is not so heavy in the prefecture, the air pollution status was not given attention before 1990. However, in 1990, the concentration of photochemical oxidant often exceeded the standard in the eastern part of the prefecture. Furthermore, the concentration of NOx is increasing year by year. The prefectural government is being pressed to take countermeasures. In this study, the relationships among air pollution monitoring data, meteorological data and socio-economic data were analysed on the statistical basis. The obtained results are as follows: 1) The increase of the pollutant concentration is linked to the economic development. 2) The influence of the transport of pollutants from neighboring prefectures is suggested. 3) The climate change within these ten years is strongly affecting the pollution.

## 1. INTRODUCTION

Generally, air pollution is originated in human activities. However it is difficult to estimate the anthropogenic impacts on air pollution because they include so many factors i.e. population increase, economic growth, climate change, and so on.

It is generally considered that field measurements are the most reliable way to know the behavior of the pollutants in the atmosphere. However, it is difficult to obtain measurement data with sufficient spacial and temporal density, because they need much labor and fund.

In Japan, the continuous air pollution monitoring network has been established and is operated by Japan Environment Agency(JEA) and local governments. The monitoring species are $SO_2$, NO, $NO_2$, Ox, CO, NMHC, SPM(PM10) and so on, and the data are obtained on the hourly basis. The network includes approximately 1700 stations covering almost all over the country. The monitoring datasets are analysed on the statistical basis every year, and the results are reported by JEA.

It is useful for the understanding of the pollutants' behavior to analyse the relationship between these monitoring data and the meteorological data. Many investigation results have been already reported in relation to such analyses. However, most of them have limited objective areas, which are concentrated in the highly industrialized regions.

The another point of view is the analysis of the monitoring data on the social and economic basis. Since air pollution is fundamentally originated in human activities, these monitoring data should have a relation to the social and economic data. However, few examples can be found in which these relationships are investigated.

In this study, the relationships among air pollution monitoring data, meteorological data and socio-economic data were analysed on the statistical basis in order to know the mechanism of the pollution. The objective region was concentrated in Yamanashi prefecture, one of the rural and mountainous regions around Tokyo.

## 2. FEATURE OF YAMANASHI PREFECTURE

Yamanashi prefecture is located on the west of Tokyo metropolitan area and the distance between both center is approximately 100km as shown in Figure 1.

The socio-economic data of Yamanashi is shown in Table 1. The numbers in this table indicate the ranking among all 47 prefectures in Japan. As shown here, the principal activities are agriculture and forestry, and there are few industrial areas and the automobile traffic is not so heavy in the prefecture. Therefore, the air pollution status was not given attention before 1990. However, in 1990, the concentration of photochemical oxidant often exceeded the standard in the eastern part of the prefecture. Furthermore, the concentration of NOx is slightly increasing year by year. The prefectural government is being pressed to take countermeasures.

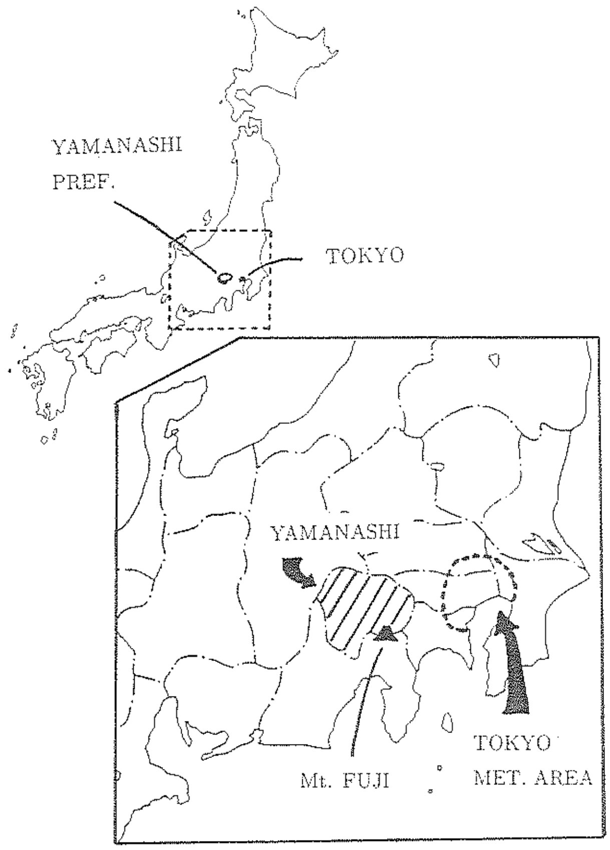



Figure 1. Location of Yamanashi prefecture

Table 1. Socio-economic feature of Yamanashi prefecture

| Item | Ranking* |
|---|---|
| Population | 43 |
| Fraction of agricultural production in prefectural GDP | 19 |
| Production of peach and grapes | 1 |
| Total industrial production | 35 |
| Chemical industrial production | 42 |
| Metallic industrial production | 33 |

* Ranking among all 47 prefectures in Japan.

## 3. DATA DESCRIPTION

### 3.1 Objective Duration

This study was concentrated on the year-by-year variation of air pollutants' behavior, as mentioned in the previous section. The total duration of the analyses was from 1975 to 1991. The considered data items are listed in Table 2.

Table 2. List of data items used in the analyses

| Class | Item |
|---|---|
| Air pollution monitoring data | $SO_2$ annual mean conc. |
| | NOx annual mean conc. |
| | $NO_2$ annual mean conc. |
| | $NO_2$ 98percentile conc. |
| | Photochemical oxidant annual mean of daily maximum conc. |
| | Frequency that photochemical oxidant exceeds the standard |
| Meteorological data | Annual mean temperature |
| | Monthly mean temp. of June |
| | Monthly mean temp. of July |
| | Monthly mean temp. of August |
| | Trimonthly mean temp. during June, July and August |
| | Annual total time with sunshine |
| | Annual precipitation amount |
| | Frequency of the day with maximum temp.$>$ 30 °C |
| | Frequency of the day with minimum temp.$<$ 0 °C |
| Socio-economic data | Population |
| | Number of households |
| | Number of industries |
| | Number of industrial employee |
| | Amount of material consumption |
| | Amount in value of industrial production |
| | Amount of fixed property |
| | Number of ownership of vehicles |
| | Per capita ownership of vehicles |
| | Number of public passenger transport |
| | Area of cultivated field |
| | Number of households engaged in agriculture |
| | Amount in value of agricultural production |

### 3.2 Air Pollution Monitoring Data

Monitorings of air pollution are carried out by many organizations in Japan. However, most of them are limited in the monitoring duration and the spacial coverage, then they are inapplicable to statistical analyses. In addition, since the monitoring techniques are not uniform among organizations, they cannot be easily mixed unless they are carefully checked on the data quality.

The air pollution monitoring data used in this study were derived from the publications by national and prefectural governments(JEA[1976-1992], Yamanashi Prefecture[1994]). There are seven stations in the prefecture, but some of them were established within five years, then four stations shown in Figure 2 were selected for the analyses.

The temporal scale of air pollution monitoring has a very wide range from instantaneous to annual or longer. The national and prefectural monitorings are generally carried out on the hourly basis. However, hourly data are seldom published, and most of the publications include the summed up data on the monthly and annual basis.

This study was principally concentrated on the annual data i.e. annual average concentrations, annual frequencies, and so on. The main reason why annual data were used is that most of the socio-economic data can only be derived on the annual basis. However, air pollution has a strong seasonality in general, then monthly based investigations are also important and useful.

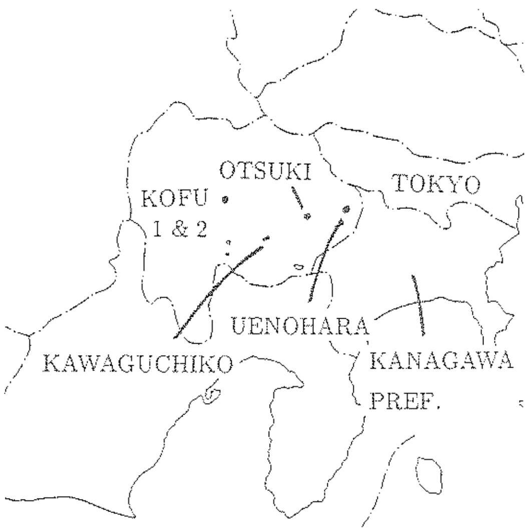



Figure 2. Location of Monitoring Stations

### 3.3 Meteorological Data

Some meteorological elements, i.e. wind direction, wind velocity, temperature, solar radiation, precipitation, and so on, have strong relationship with air pollution. Among them, wind direction and wind velocity can affect the short term behavior of the pollutants, but they have little influence on annual behavior. On the contrary, temperature and solar radiation themselves vary year by year and sometimes give extraordinary values. Then they have possibilities to affect the year-by-year variation of pollutants.

The meteorological datasets used in this study were derived from the annual report of local meteorological observatories (Kofu Meteorological Observatory[1976-1992]) in the prefecture.

### 3.4 Socio-economic Data

Many statistical yearbooks are published by national and local governments and some related organizations in Japan. They are generally available through the information center of each government.

Most of the data in these yearbooks are on the annual basis and few data are available with shorter time scale. The compilation of short term data will be important in the future work.

Additionally, some of the data were obtained on the fiscal year basis, and the other were on the calendar year basis. That difference is essentially important, however in this study, it was assumed that the difference is neglegible. Such an assumption can be made only when the year-by-year variation of each item is moderate.

## 4. PROCEDURE

The analytical methods used in this study consist of four popular multi-variate analyses i.e. multi-variate regression analysis, cluster analysis, principal component analysis and factor analysis. Multi-variate regression analysis was mainly used among these four methods.

It should be noted that the dataset used in this study is a type of time series data. The correlation between two sets of time series data is so high in many cases in which both series have similar time series tendencies. Judgements based on the correlation coefficients have possibilities to make misunderstandings. This study was carried out with careful consideration on such a problem.

## 5. RESULTS AND DISCUSSION

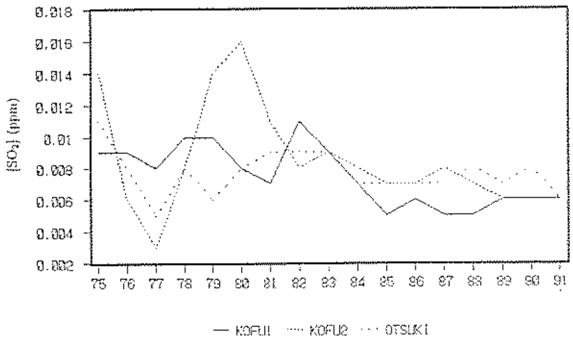
### 5.1 Trend of Each Item

First of all, year-by-year trend of each item was investigated using time series graphs. A few examples are shown in Figure 3 through Figure 5.

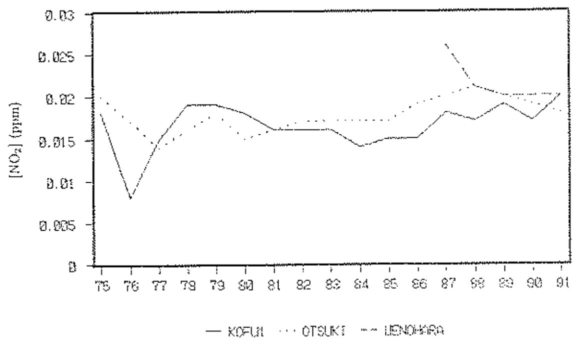
Among air pollution monitoring data, sulfur dioxide tends to decrease, nitrogen dioxide is slightly increasing or stable, and photochemical oxidant is clearly increasing with vibration. The frequency that photochemical oxidant exceeds the standard shows especially large variation and the maximum value in 1990 was the highest among all stations in Japan.

Meteorological data have complex variation year-by-year, but it should be noted that the temperature tends to increase. It can be judged as an indication of global warming.

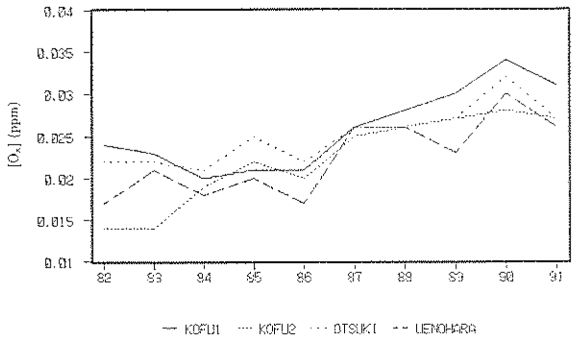
Most of socio-economic data show the tendency of constant increasing, which indicates the economic growth in the prefecture. On the contrary, items related to agriculture and forestry tend to decrease.



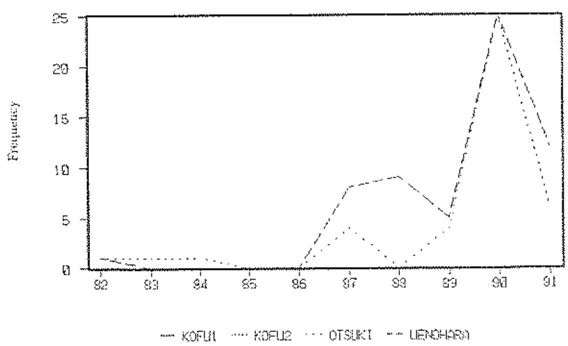

(a) $SO_2$ annual mean concentration




(b) $NO_2$ annual mean concentration

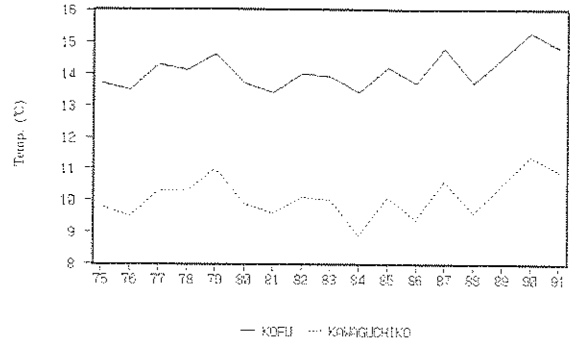



(c) Photochemical oxidant annual mean of daily maximum concentration

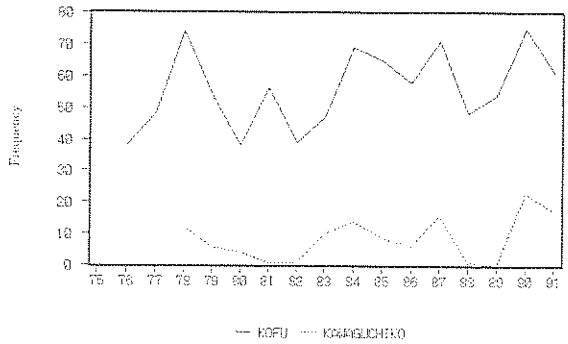



(d) Frequency that photochemical oxidant exceeds the standard

Figure 3. Trend of air pollution monitoring data

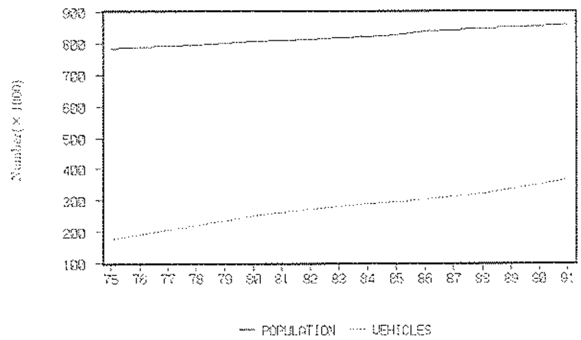



(a) Annual mean temperature

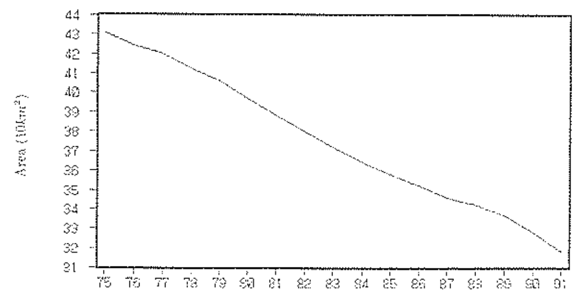



(b) Frequency of the day with maximum temp. $> 30^\circ C$

Figure 4. Trend of meteorological data




(a) Population and number of vehicles



(b) Area of cultivated area

Figure 5. Trend of socio-economic data

### 5.2 Variable Selection by Cluster Analysis

There are so many meteorological and socio-economic items that it is necessary to select variables for multiple regression analyses. Cluster analysis is one of the useful method to select variables based on the correlation between each pair of variables. The result shown in Figure 6 indicates that most of socio-economic items are strongly related one another and they can be represented by a few variables. However, correlations among meteorological items are not so strong, which indicate difficulties to be represented by a small number of variables.

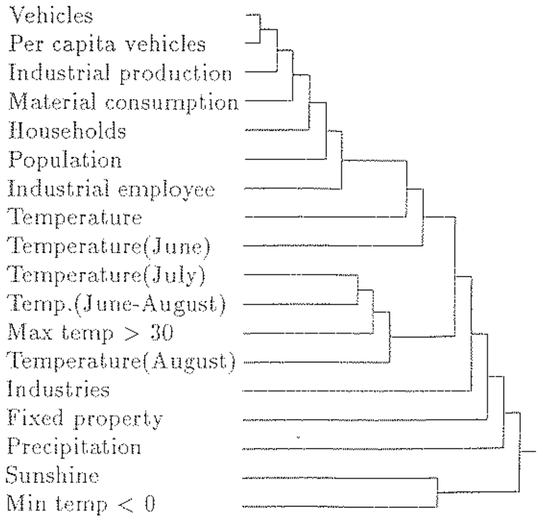



Figure 6. Example of the result of cluster analysis

### 5.3 Classification of Variables by Principal Component Analysis

In order to understand the general characteristics of input data, some principal component analyses were carried out. An example of the results is shown in Figure 7. The first principal component explains 53% of the variation and it can be judged as an indicator of economic growth. The second component, which has large loadings on meteorological items, indicates the meteorological fineness. As shown in this figure, all data items can be classified into some groups, however, the classification is not very clear.

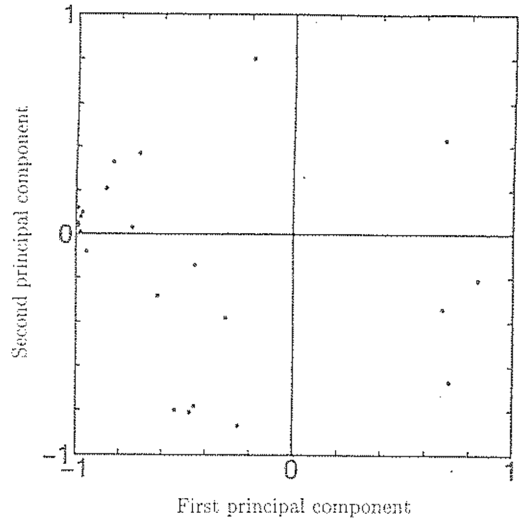



Figure 7. Example of the principal component Analysis

### 5.4 Factor Analysis

In order to find out the specific factor included in the input data, a factor analysis was carried out. Table 3 shows the varimax rotated factor loading matrix.

Factor 1 has large loadings on most of socio-economic items, and it can be judged as an direct indicator of industrial development. The concentrations of nitrogen oxides and photochemical oxidant, which is affected by such a development, are also given large factor loadings by factor 1.

Table 3. Varimax rotated factor loadings

| | Factor1 | Factor2 | Factor3 | Factor4 |
|---|---|---|---|---|
| $SO_2$(Kofu-1) | −0.839 | −0.679 | 0.244 | 0.196 |
| $SO_2$(Kofu-2) | −0.679 | 0.426 | −0.265 | 0.393 |
| $NO_x$(Kofu-1) | 0.770 | −0.167 | −0.407 | 0.401 |
| $NO_x$ 98%(Kofu-2) | 0.759 | 0.090 | −0.119 | 0.364 |
| $O_x$ >0.12ppm(Kofu-1) | −0.000 | 0.000 | −0.000 | −0.000 |
| $O_x$ >0.12ppm(Kofu-2) | 0.000 | −0.000 | 0.000 | 0.000 |
| $O_x$ (Kofu-1) | 0.903 | −0.260 | −0.155 | −0.192 |
| $O_x$ (Kofu-2) | 0.724 | 0.034 | −0.607 | 0.061 |
| Population | 0.970 | −0.118 | −0.133 | −0.057 |
| Households | 0.971 | −0.128 | −0.203 | −0.008 |
| Industries | 0.440 | −0.094 | 0.028 | −0.447 |
| Industrial employee | 0.951 | −0.254 | −0.005 | −0.159 |
| Material consumption | 0.955 | −0.182 | −0.178 | 0.057 |
| Industrial production | 0.958 | −0.204 | −0.176 | −0.033 |
| Fixed property | 0.226 | −0.219 | −0.082 | −0.748 |
| Vehicles | 0.957 | −0.193 | −0.204 | −0.036 |
| Per capita vehicles | 0.944 | −0.228 | −0.193 | −0.048 |
| Temperature | 0.498 | −0.293 | −0.744 | 0.078 |
| Sunshine | −0.824 | −0.400 | 0.198 | −0.292 |
| Precipitation | 0.275 | 0.572 | −0.352 | 0.341 |
| Max temp > 30 | 0.290 | −0.925 | −0.075 | −0.138 |
| Min temp < 0 | −0.520 | −0.079 | 0.813 | 0.101 |
| Temperature(August) | −0.028 | −0.881 | −0.139 | −0.296 |
| Temperature(July) | 0.236 | −0.943 | 0.063 | 0.118 |
| Temperature(June) | 0.485 | −0.521 | −0.085 | 0.335 |
| Temp.(June-August) | 0.217 | −0.968 | −0.039 | 0.039 |

Factor 2, which has large loadings on the monthly mean temperature and the frequency of the day with maximum temperature higher than 30 degrees centigrade, is judged as an indicator of meteorological condition in summer. Factor 3, whose large loadings are on the frequency of the day with minimum temperature lower than 0 degree centigrade, is indicating the meteorological condition in winter. Factor 4 shows no clear tendency on factor loadings.

### 5.5 Trend Analysis by Multivariate Regression Analysis

As mentioned before, nitrogen oxides and photochemical oxidant are given much attention in Yamanashi prefecture in recent years. Multivariate regression analyses were carried out using socio-economic data and meteorological data as explanatory variables in order to know the characteristics of the year-by-year trend of those air pollutants. The explanatory variables were selected through trial and error from the variable list obtained by the cluster analysis.

#### 5.5.1 Nitrogen Oxides

The obtained regression equations are as follows:

$$y_1 = 3.2 \times 10^{-5} x_1 + 6.8 \times 10^{-3} x_2 - 2.4 \times 10^{-5} x_3 \quad (R = 0.937) \tag{1}$$

$$y_2 = 2.7 \times 10^{-6} x_4 - 2.3 \times 10^{-3} x_5 \quad (R = 0.876) \tag{2}$$

where $y_1$ : annual mean NOx concentration at Kofu-2 station [ppm]
$x_1$ : number of vehicles in the prefecture
$x_2$ : annual mean temperature at Kofu observatory [°C]
$x_3$ : annual total time with sunshine at Kofu observatory [hour]
$y_2$ : annual mean NOx concentration at Otsuki station [ppm]
$x_4$ : number of vehicles in Otsuki city
$x_5$ : annual mean temperature at Kawaguchiko observatory [°C]

Both cases show that the NOx concentration is strongly dependent on the number of vehicles. However, since the trend of the number of vehicles are similar to that of another socio-economic item, this explanatory variable can be replaced by another item without losing high correlation. The reason why the correlation coefficient in Otsuki city is lower can be explained by the fact that the heavy traffic in that city is mainly depending on the through traffic.

The temperature is slightly increasing these ten years and the trend is similar to that of NOx. That is why it was selected as an explanatory variable. NOx concentration is generally affected by meteorological conditions, however, the effect of the temperature should be negative against NOx concentrations because stable condition in winter often causes high concentration of NOx.

#### 5.5.2 Photochemical Oxidant

The obtained regression equations are as follows:

$$y_3 = 2.6 \times 10^{-4} x_6 + 3.7 \times 10^{-6} x_7 + 9.2 \times 10^{-4} x_8 \quad (R = 0.956) \tag{3}$$

$$y_4 = 2.1 \times 10^{-6} x_9 + 1.4 \times 10^{-6} x_{10} + 4.0 \times 10^{-4} x_{11} \quad (R = 0.836) \tag{4}$$

$$y_5 = -4.6 \times 10^{-6} x_{12} + 6.4 \times 10^{-7} x_{13} + 1.8 \times 10^{-3} x_{11} \quad (R = 0.743) \tag{5}$$

where $y_3$ : annual mean of daily maximum photochemical oxidant concentration at Kofu-2 station [ppm]
$x_6$ : population in the prefecture
$x_7$ : number of vehicles in the prefecture
$x_8$ : June-August trimonthly mean temperature at Kofu observatory [°C]
$y_4$ : annual mean of daily maximum photochemical oxidant concentration at Otsuki station [ppm]
$x_9$ : population in Otsuki city
$x_{10}$ : number of vehicles in Otsuki city
$x_{11}$ : June-August trimonthly mean temperature at Kawaguchiko observatory [°C]
$y_5$ : annual mean of daily maximum photochemical oxidant concentration at Uenohara station [ppm]
$x_{12}$ : population in Uenohara town
$x_{13}$ : number of vehicles in Uenohara town

All cases show that photochemical oxidant concentration can be explained by emission related items (population and vehicles) and meteorological data item representing the condition in summer. The frequency that oxidant exceed the standard shows sudden increase in 1990, however, that can be understood as a mixed result of emission increase according to the economic growth and the recent extraordinary meteorological condition in summer.

It should be noted that these correlation coefficients are lower in the eastern part of the prefecture, which faces to Tokyo metropolitan area. This tendency shows the possibility of the transport of pollutants crossing the prefectural border. Some trajectory analyses also suggest the transport from Tokyo metropolitan area to surrounding prefectures(Wakamatsu et al.[1991] for example).

As a trial, the explanatory variables in equation(4) was replaced by the same item of Kanagawa prefecture, which is located in the upstream region of the trajectories. The result show higher correlation coefficient, and that is also indicating the transport of pollutants.

## 6. CONCLUSION

The air pollution monitoring data in Yamanashi prefecture were statistically analysed with meteorological data and socio-economic data. Following points can be suggested from the results:

1) The increase of the pollutant concentration is linked to the economic growth in the prefecture.

2) The influence of the transport of pollutants from neighboring prefectures is indicated.

3) The climate change within these ten years is strongly affecting the pollution.

Of course, it is necessary to conduct proper countermeasures to reduce air pollution. Monitorings and numerical model calculations are generally used in the consideration of such a policy-making, however, statistical analyses, especially using socio-economic data, are also useful for these activities. The results shown here are preliminary but it can be emphasized that this kind of study have a possibility to contribute so much to policy-making on environmental problems.

## ACKNOWLEDGEMENT

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