STATISTICAL ANALYSIS OF THE RELATIONSHIP BETWEEN PRTR DATA AND AIR TOXICS MONITORING DATA IN JAPAN

Noritaka Katatani and Akira Fukuyama

University of Yamanashi, Kofu, 400-8511, Japan
Email: katatani@js.yamanashi.ac.jp

ABSTRACT

In recent years, the toxicity of many chemical species has been getting much attention regarding their effect on human health. The largest problem in this issue has been the lack of emission inventories. In Japan, the PRTR Law was implemented in 2000 and the compiled data in the first year (2001) was opened in March 2003. This dataset gives us various informations on the status of pollutant emissions.

The objective of this study is to clarify the relationship between PRTR data and air toxics monitoring data. This paper reports some preliminary results. Socio-economic data were also used in the analysis. The analyses were carried out on the prefecture-by-prefecture basis. Principal statistical procedures used in this study are regression analysis, multiple regression analysis, factor analysis and so on.

The principal results are as follows:

1) PRTR data are partly proportional to the air monitoring data.
2) PRTR data for some specific species are strongly related to some social or economic data.
3) The status of chemical pollution strongly depends on the prefectures.

INTRODUCTION

In recent years, the environmental pollutions by toxic chemical species and their effects on human bodies have been getting much attention. To make countermeasures against this problem, it is necessary to know the pollution status precisely. Some procedures are available in order to know it, such as environmental monitoring by chemical analyses, model calculation using computers, emission inventories of pollutants by questionnaires, studies on the toxicity and environmental effects, development of emission prevention technology, and so on. Among these issues, emission inventory is the most fundamental and important one. However, it has been getting behind.

In Japan, The PRTR Law was implemented in 2000, and the result for the first year, FY2001, was opened in March, 2003 [1]. This dataset is expected to give an epoch-making information and to recover the arrears, and it is desired that this dataset will be utilized effectively.

Since PRTR data can show emission inventories, they can be utilized as input data for model calculations and as basic data for governmental administrations. Furthermore, they have a wide range of possibilities of utilization, e.g. environmental educations, administrative advertisement and statistical analyses. This paper show some results by these statistical analyses. Of course, PRTR data include some uncertainties and/or errors. We have to notice such uncertainties when we interpret the statistical results.

Environment protection activities should be carried out regarding regional characteristics because every region has its own characteristics on the environment. Consequently, it is important to analyze such characteristics prior to conduct environment protection activities. Authors have reported some results of statistical analyses using air toxics monitoring data in the previous papers [e.g. 2]. The objective of this study, following the results of the previous papers, is to analyze PRTR data precisely by statistical procedures, and to extract some knowledge on the status of the environmental pollutions by chemicals. This paper shows the first stage results.

DATA DESCRIPTIONS

The original PRTR data include the information on factory-by-factory basis. In this study, they were summed up and transformed into prefecture-by-prefecture basis. The target species were selected according to the air toxics monitoring campaign by Ministry of Environment [3], Japan in order to compare PRTR data with the monitoring data.

The emission inventories summed up from the PRTR data are being divided into environmental media such as atmosphere, surface water, seawater and soil. However, only the emission inventory into atmosphere was used in this study, because more than 90% of total emission is occupied by the release into the atmosphere.

The PRTR data which were summed up on the prefecture-by-prefecture basis reflect the characteristics of the prefectures. However it may be affected by the scale of each prefecture such as population, area, industrial production, and so on. In order to avoid such effects, normalization by each social factor was carried out. Table 1 shows the emission inventory of benzene, one of the principal pollutants in Japan. We can see that the rank among 47 prefectures in Japan varies widely by these normalizations. From this table, it can be said that the status of the pollution by chemicals in each prefecture varies widely and comparisons using such normalized values are important.

Table 1 Emission inventory of benzene in some selected prefectures

Prefecture	Total Emission		Per Capita		Per Area		Per Income		Per Production	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Hokkaido	88718.3	8	15.62	17	1.06	31	0.574	16	0.01582	7
Aomori	5044.6	35	3.42	32	0.53	38	0.138	32	0.00403	25
Iwate	1719.6	44	1.22	45	0.11	47	0.046	43	0.00076	43
Miyagi	28000.3	20	11.81	21	3.84	21	0.422	20	0.00765	16
Akita	5406.5	34	4.57	29	0.47	42	0.175	29	0.00362	26
Yamagata	6144.5	32	4.95	28	0.66	37	0.185	28	0.00230	32
Fukushima	38641.9	17	18.18	14	2.80	23	0.644	15	0.00719	18
Ibaragi	110814.9	6	37.04	8	18.18	8	1.220	9	0.01078	11
Tochigi	4231.5	37	2.11	39	0.66	36	0.066	39	0.00056	45
Gunma	7411.8	30	3.65	31	1.16	29	0.119	35	0.00095	41
Saitama	13979.8	26	2.00	40	3.68	22	0.062	40	0.00100	39
Chiga	250946.5	4	42.05	7	48.67	3	1.319	8	0.02305	5
Tokyo	15184.8	24	1.25	44	6.94	15	0.031	46	0.00092	42
Kanagawa	62143.7	13	7.25	26	25.73	6	0.226	27	0.00313	27
Niigata	356865.2	1	144.30	2	28.36	5	4.850	2	0.08143	1

The monitoring data were obtained from above-mentioned campaign by Ministry of Environment, Japan. It was started in 1997 and it has been maintained up to now. The number of monitoring sites depends on species, but approximately 200 through 300 covering all over Japan. The monitoring frequency is generally once a month, and 24-hour sampling method by canister is used. The chemical analysis is carried out mainly using GC-MS. In order to compare these monitoring data with PRTR data, average values were calculated on the prefecture-by-prefecture basis.

In addition, some socio-economic data, such as population, industrial production, GDP, and so on [4], were also used for the correlation analysis with PRTR data.

RESULTS AND DISCUSSIONS

1) Correlation between PRTR data and monitoring data

Since concentrations of chemical species in the atmosphere vary widely by atmospheric dispersion, deposition, chemical reaction, and so on, they are not proportional to the emission inventories. However, those effects were not considered in this study because it is still on the preliminary stage.

Table 2 shows the correlation coefficients between air toxics monitoring data and PRTR data. The air toxics monitoring data are divided into three categories by the characteristics of monitoring sites, such as general environment, roadside and around sources. According to that, Table 2 is divided into three. In these tables, bold characters show the statistically significant (1%) coefficients.

Table 2 Correlation coefficients between PRTR data and air toxics monitoring data

Category of monitoring sites	Acrilo nitryle	Aceto aldehide	Vinyl chloride monomer	Chloro form	1,2-Dichloro ethane	Dichloro methane	Tetra chloro ethene	Tri chloro ethene
General	**0.482**	**0.435**	**0.748**	**0.538**	**0.453**	**0.501**	**0.530**	**0.695**
Roadside	**0.482**	0.105	−0.113	**0.489**	0.075	**0.456**	**0.706**	**0.640**
Sources	0.194	0.264	0.324	0.071	**0.395**	**0.516**	**0.685**	**0.379**

Category of monitoring sites	Nickel	Arcenic	1,3-Butadiene	Benzene	Form aldehyde	Manganese	Chromium
General	−0.082	0.137	**0.432**	0.195	−0.024	0.001	0.144
Roadside	0.168	−0.253	0.194	0.095	0.033	**0.487**	0.047
Sources	0.051	0.359	**0.446**	**0.385**	−0.007	−0.059	0.174

Generally speaking, high correlations were obtained in the category of general environment. Among them, vinylchloride monomer showed the highest correlation, whose coefficient is 0.748. Fig.1 shows the scatter diagram of it, in which most of the data plots are lying around the regression line. In such a diagram, some plots which are apart from the regression line may show important information. For example, Hyogo prefecture has a large emission in spite of low concentration, and Toyama prefecture has a small emission in spite of high concentration. The reason of such outliers can not easily be explained only from this result, however, following reasons have some possibilities:

1) Since the sources in Hyogo prefecture are concentrated in the seaside area, the effects to the concentrations in the general environment tend to relatively low level.

2) Toyama prefecture may be affected by sources in neighboring prefectures.

Fig.2 shows another example, trichloroethylene, whose correlation coefficient was relatively high. The most specific plot can be found near the lower right corner who

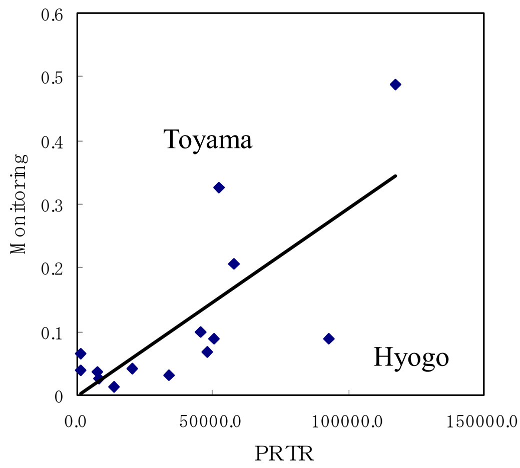


Fig.1 Scatter diagram between PRTR and air toxics monitoring data (Vinyl chloride)

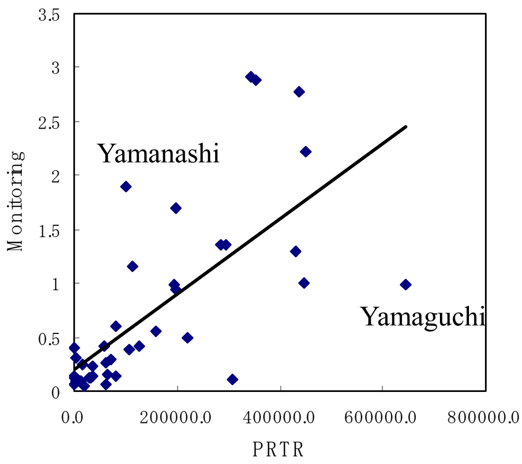


Fig.2 Scatter diagram between PRTR and air toxics monitoring data (Trichloroethylene)

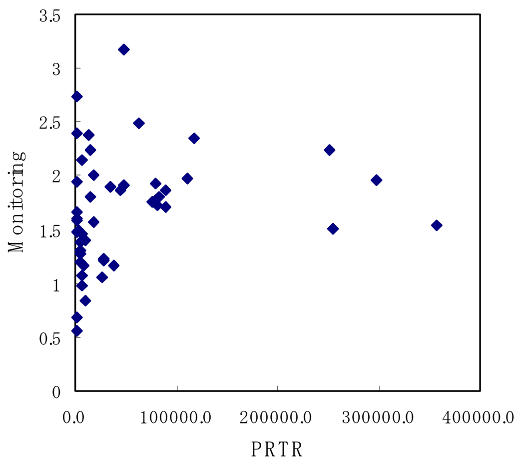


Fig.3 Scatter diagram between PRTR and air toxics monitoing data (Benzene)

represents Yamaguchi prefecture. The reason why it shows such a low concentration in spite of the large emission volume is that most of the sources in Yamaguchi prefecture are concentrated in the combinato area which is located at the south end of the prefecture and they can not effect whole area of the prefecture. On the contrary, Yamanashi prefecture shows very high concentration in spite of the small emission. It can be estimated as the effect of the topographic feature and the effects by small scale sources which are not included in the PRTR data.

Fig.3 shows an example which showed very weak correlation, benzene in the general environment. Formaldehyde also showed similar result. It can be easily judged that many data plots which are lying around vertical axis caused such low correlations. These plots show the prefectures which have high concentrations and low emissions. These trends are originated in the effects by mobile sources and small scale sources for benzene, and in the effects by photochemical reactions for formaldehyde.

It is expected that these results can be discussed quantitatively by the comparison of the monitoring data with the estimated data by some dispersion model calculations.

2) Correlation between PRTR data and socio-economic data

In order to consider the countermeasures against environmental pollutants, it is important to know the social background of the emission of the pollutants. Generally, since concentrations and emission inventories of the pollutants depend on the scale of human activities, they have some relationships with socio-economic factors. If we can find which factor has the strongest correlation, we can know the social structure of the pollutant emission, then it leads to the effective countermeasures. According to such understandings, some trial calculations were carried out using various socio-economic factors such as population, nature, industries, economy, energy, and so on.

Table 3 shows the correlation coefficients between PRTR data and various socio-economic data. Due to the space limitation, only some typical items are shown in the table. Bold characters show the combinations which showed the significant correlations. Not so many combinations showed high correlations, however, tetrachloroethylene showed relatively high correlations with many socio-economic factors. Especially, the highest correlation coefficient, 0.821, was obtained with the number of industries.

Table 3 Correlation coefficients between PRTR data and socio-economic data

Socio-economic item	Acrylo nitryle	Aceto aldehyde	Vinyl chloride monomer	Chloro form	1,2-Dichloro ethane	Dichloro methane	Trichloro ethene	Nickel
Population	0.058	−0.267	0.182	−0.112	0.136	**0.718**	**0.452**	−0.212
Increasing rate of population	−0.116	**-0.381**	−0.001	−0.177	0.143	0.353	**0.410**	−0.329
Daytime population	0.051	−0.260	0.170	−0.119	0.119	**0.694**	**0.437**	−0.199
Population under14	−0.309	−0.229	**-0.457**	−0.193	−0.146	−0.269	−0.154	0.101
Population from 15 to 64	−0.074	**-0.464**	0.134	−0.067	0.201	**0.518**	**0.401**	−0.183
Population over 65	0.167	**0.515**	−0.050	0.116	−0.174	**-0.473**	**-0.379**	0.168
DID population	0.075	−0.222	0.183	−0.121	0.096	**0.703**	**0.409**	−0.173
Number of households	0.074	−0.243	0.184	−0.108	0.131	**0.686**	**0.416**	−0.191
Area	−0.119	0.022	0.088	0.122	−0.116	0.025	−0.076	0.071
DID area	0.089	−0.246	0.195	−0.057	0.126	**0.751**	**0.431**	−0.203
Forest area	−0.114	0.091	0.062	0.131	−0.145	−0.008	−0.088	0.128
Caltivated area	−0.141	−0.035	−0.041	0.098	−0.061	0.039	−0.085	0.025
Gross prefectural production	0.053	−0.281	0.174	−0.125	0.117	**0.626**	**0.420**	−0.190
Production of 1st industries	−0.122	0.143	−0.129	0.096	0.037	0.058	−0.025	0.105
Production of 2nd industries	0.110	−0.382	0.246	−0.117	0.214	**0.694**	**0.514**	−0.238
Production of 3rd industries	0.038	−0.233	0.160	−0.125	0.073	**0.575**	**0.373**	−0.166
Number of employee for 1st ind.	−0.072	0.133	−0.146	0.058	0.100	0.109	0.082	0.048
Number of employee for 2nd ind.	0.059	−0.337	0.183	−0.113	0.127	**0.789**	**0.567**	−0.258
Number of employee for 3rd ind.	0.057	−0.254	0.171	−0.111	0.126	**0.677**	**0.426**	−0.204

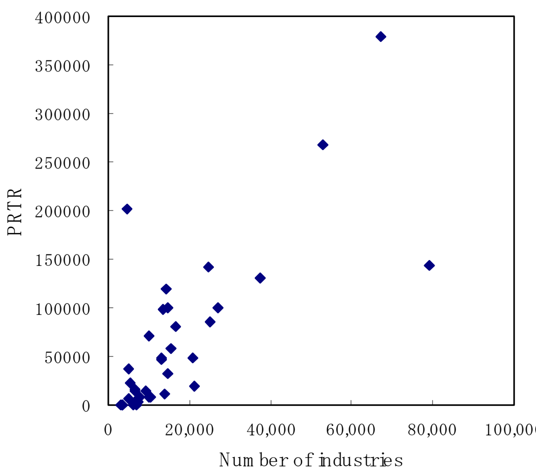
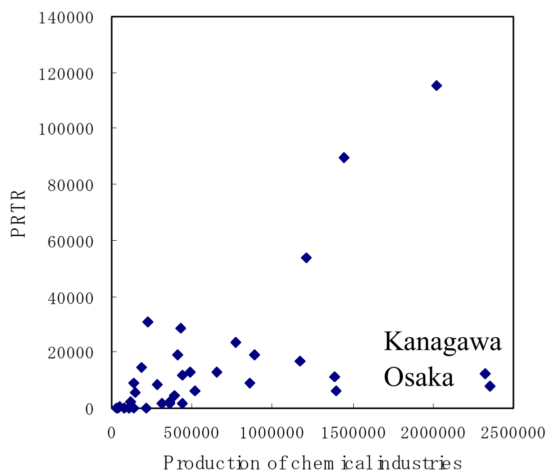


Fig.4 Correlation between number of industries and PRTR data (Tetrachloroethylene)



Fog.5 Correlation between production of chemical industries and PRTR data (Formaldehyde)

Fig.4 shows the scatter diagram of them. Most of the data plots are lying around the regression line except some outliers. Yamaguchi prefecture shows the most specific feature that it has very large amount of emissions in spite of the very small number of industries. It can be caused by the large amount of emissions from some large petrochemical industries. Fig.5 shows the relationship between formaldehyde emission and production of chemical industries, where relatively high correlation was obtained, some outliers can be found near horizontal axis. Especially, Kanagawa prefecture and Osaka prefecture show remarkable tendencies. It can be considered that the productions of chemical industries in these prefectures are dominated by those which are not related to formaldehyde.

Trichloroethylene showed relatively high correlation, same as tetrachloroethylere, with many socio-economic factors. These two species are considered to be emitted proportionally to the scale of human activities in each prefecture. On the contrary, other species may have some complex social mechanisms which determine the volume of emission, so they can not be explained by individual socio-economic factor.

According to this consideration, some trial calculations by multiple regression analyses were carried out. The prefecture-by-prefecture emission inventories were set to the dependent variables. The independent variables were selected from many socio-economic factors through cluster analyses. As a result, following variables were selected:

1) Population
2) Increasing rate of population
3) Fraction of over 65 years old population
4) Fraction of cultivated area
5) Production of first industries
6) Production of chemical industries
7) Production of nonferrous metals industries
8) Rate of environmental standard clearance of suspended particulate matters

Using these variables, calculations were carried out by the variable decreasing method.

Two results are shown as examples as follows:

(1) Dependent variable: Chloroform

	Standardized regression coefficient	t-value	p-value
Polulation	-0.547	-2.455	0.018
Production of chemical industries	0.368	1.833	0.075
Rate of environ. std. clearance(SPM)	-0.354	-1.930	0.062
Constant		3.126	0.004

$R^2 = 0.114$ F-value = 2.634 p-value = 0.065

(2) Dependent variable: Tetrachloroethylene

	Standardized regression coefficient	t-value	p-value
Polulation	0.598	4.062	0.000
Increasing rate of population	-0.266	-1.984	0.055
Production of chemical industries	0.455	3.383	0.002
Constant		-1.471	0.150

$R^2 = 0.619$ F-value = 21.65 p-value = 0.000

Since these results show statistically significant regression equations, it can be said that these results are useful for the understanding of the structure of pollutants emissions. However in some case, e.g. trichloroethylene and nickel, only one independent variable was remained as a result of variable selection. In general, two types of independent variables were selected. One is the variables which indicate the scale of prefectures, e.g. population. The other is the variables which indicate the distribution of sources, e.g. production of chemical industries. This means that emission amounts of many species are mainly depending on the scale of prefectures and the scale of industries which emit pollutants.

CONCLUDING REMARKS

PRTR data in Japan were analyzed statistically with air toxics monitoring data and some socio-economic data. The principal results are as follows:
1) PRTR data are partly proportional to the air monitoring data.
2) PRTR data for some specific species are strongly related to some social or economic data.
3) The status of chemical pollution strongly depends on the prefectures.
Since these results are still on the preliminary stage, further investigations are necessary. For example, extension of target years and application of other statistical procedures are the next work.

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