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A Methodology of Estimation on Air Pollution and Its Health Effects in Large Japanese Cities

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1. Introduction

The correlation between air pollution and health effects in large Japanese cities presents a great challenge owing to the limited availability of data on the exposure to pollution, health effects and the uncertainty of mixed causes. A methodology for quantitative relationships (between the emission volume and air quality, and the air quality and health effects) is analysed with a statistical method in this chapter; the correlation of air pollution reduction policy in Japan from 1974 to 2007.

This chapter discusses a step-by-step methodology of determining the direct correlation between emission volumes, air quality, and health effects. Figure 1 shows the Japanese compensation system with two hypotheses in order to clarify the correlation. Hypothesis 1 states that the total emission volume affects air quality. Hypothesis 2 states that the air quality influences the number of certified patients.

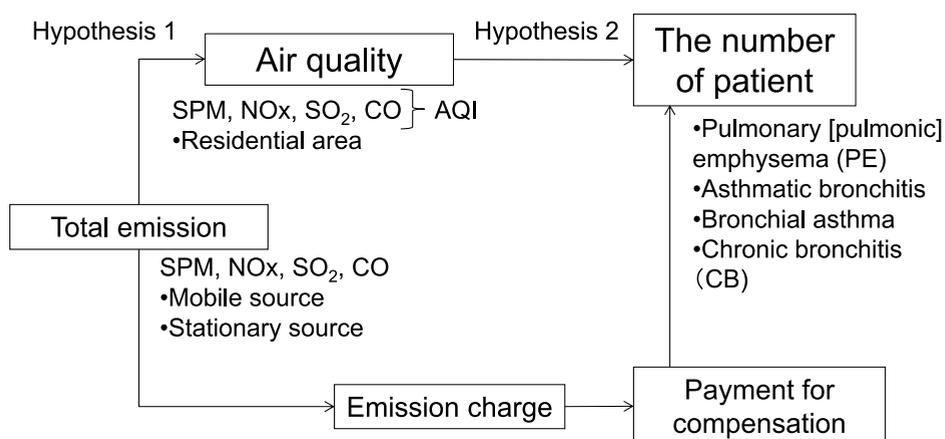


Fig. 1. The relationship between emissions, air quality and the number of certified patients (above) and flow of compensation (below)

The relationship between total emissions (NO_x, PM) (from both stationary and mobile sources) and air quality (NO₂, SPM) was found to be significant, which supports hypothesis 1. The correlation analysis of emission volume, and air quality suggests that NO_x and PM levels worsen according to increases in NO₂.

When the correlation between the air pollutant and the type of health effects (certified, mortality, recovery, and newly registered) was examined according to the certified area, an inverse relationship was observed. The relationship between air quality (NO₂) and health effect was found to be significant, which support hypothesis 2. When NO₂ worsens, certified patients, mortality rates and newly certified patients increase, according to the data from 1989 to 2007 with dummy variable analysis.

2. Methodology

2.1 Pollution-related health damage compensation system and the law concerning special measures to reduce the total amount of nitrogen oxides and particulate matter emitted from motor vehicles in specified areas

Mie prefecture rapidly deteriorated as a result of rapid economic growth in the early 1960s, the air quality in the industrial sector of Yokkaichi. Residents had higher rates of morbidity and higher prevalence rates of respiratory and circulatory diseases in Yokkaichi than in other areas.

Environmental laws and standards were established to address those issues by the government in order to mitigate this deterioration of air quality in the late 1960s to early 1970s. The Basic Law of Pollution Prevention was established in 1967. This law determined the permissible limits of each contaminant in the air (SO₂ in 1969, CO in 1970, suspended particulate matter (SPM) in 1972, and NO₂ in 1973). The policies initially focused on stationary sources such as industries for reducing air pollution.

The health effects caused by air pollution became a social issue. A major issue was the apportioning of the compensation among the potential polluters. There was strong opposition from the industrial sector when discussions began among the polluters [Matsuura, 1994 a, 1994 b, 1994 c]. The affected patients sought compensation from the Japanese government and the industrial sector.

To address the social issues associated with the health effects observed since the early 1960s, the Pollution-related Health Damage Compensation Law (Abbreviation: the compensation law) was enacted in 1973 to support the affected patients by providing prompt and fair compensation to cover damages and by implementing the necessary programs for the welfare of these patients. The Pollution-related Health Damage Compensation and Prevention System (Abbreviation: the compensation system) was established in June 1974 in accordance with the compensation law. The certified regions and diseases for the compensation system were determined by the government in 1974 [Amagasaki City Government 1994, Kawasaki City Government 1994, Kita Kyushu City Government 1994 & Osaka City Government 1974] (See (6) of Figure 2).

The compensation system implements welfare services to facilitate the recovery of patients with health impairments based on the compensation law. The compensation law is responsible for determining the groups that should bear the expenses in the designated

areas "Class 1", where health damage has occurred. The compensation law also classifies "certifying patients" who are affected by one of the four pollution-related respiratory and circulatory diseases (pulmonary emphysema, asthmatic bronchitis, bronchial asthma, and chronic bronchitis). The patients with one of these four diseases are considered as certified patients if they satisfy certain other conditions (such as extended residence in the certified area, non-smoker status, or illness diagnosed by a medical doctor) in the certified areas [ERCA Homepage <http://www.erca.go.jp>]. The compensation system collects emission charge from 9,000 factories and companies on the basis of their SO₂ emission volumes. SO₂ emission charge from polluting industries (80%) and a vehicle tax (20%) covered the welfare services for the certified patients.

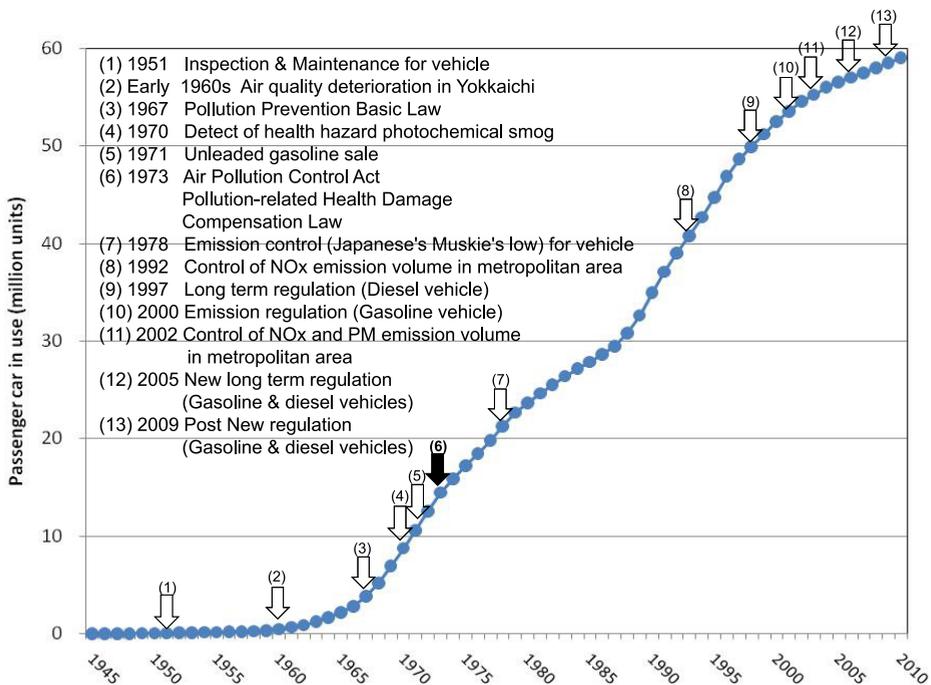


Fig. 2. Motorization and emission reduction measures from the automobile sector in Japan

The industrial sector promoted the government to amend the compensation law in the beginning of 1980s. The committee of air pollution reduction measures reported that certain areas could have had higher rates of morbidity and higher prevalence rates of chronic obstructive pulmonary disease (Abbreviation: COPD) caused by air pollution in 1950s and 1960s. However, it is not the same situation as those of 1950s and 1960s. In September 1987, amendments were made to the compensation system based on the report of the committee.

In March 1988, the Association of Environmental Restoration and Conservation Agency of Japan started an additional project to prevent health damage caused by air pollution on the basis of the revision of the compensation law. This new project intended to assist local public organizations with health consultations, health examinations, and functional training

to carry out research and to distribute knowledge leading to health maintenance in local communities. The Law was revised in 1988 to remove the Class 1 specification (compensation disbursement was continued) and to start health damage prevention projects [ERCA Homepage <http://www.erca.go.jp>].

The focus of emission reduction policies shifted from the industrial sector to non-industrial sources, namely, mobile sources in 1990s due to motorization. The Ministry of the Environment adopted a total emission volume control measure by the "Law Concerning Special Measures to Reduce the Total Amount of Nitrogen Oxides Emitted from Motor Vehicles in Specified Areas", called in short "The Motor Vehicle NO_x Law" in 1992. The law copes with NO_x pollution problems from existing vehicle fleets in highly populated metropolitan areas. Under the Motor Vehicle NO_x Law, several measures had to be taken to control NO_x from in-use vehicles, including enforcing emission standards for specified vehicle categories.

The regulation was amended in June 2001 to tighten the existing NO_x requirements and to add PM control provisions. The amended rule is called the "Law Concerning Special Measures to Reduce the Total Amount of Nitrogen Oxides and Particulate Matter Emitted from Motor Vehicles in Specified Areas", or in short "the Motor Vehicle NO_x and PM Law". The amended regulation became effective in October 2002.

The law concerning Special Measures for Total Emission Reduction of Nitrogen Oxides and Particulate Matter (Abbreviation: The NO_x-PM Law) introduces emission standards for specified categories of in-use highway vehicles including commercial goods (cargo) vehicles such as trucks and vans, buses, and special purpose motor vehicles, irrespective of the fuel type. The regulation also applies to diesel powered passenger cars.

2.2 Literature survey

This section explains why this research focuses on correlation analysis by comparing some previous studies. Iwai K, Mizuno S, Miyasaka Y, and Mori T [2005] analysed the odds ratio from the 2001 data for particulate matters PM_{2.5} converted from suspended particulate matter (SPM) for the whole of Japan. The authors tried to find out the direct correlation between respiratory diseases and air quality. Their contribution showed a strong correlation between the classification of diseases and air quality. Following this methodology of the direct correlation analysis, this chapter focuses on the diseases caused by air pollution and air quality.

Makino [1996] focused on 23 Tokyo wards from 1958 to 1989, analysing SO_x, NO_x, and dust and comparing those to the total registered vehicles. In this research, a time lag of 15 to 20 years from the time of exposure to the appearance of the health effect was found. This demonstrates the importance of long-term analysis.

Sunyer J et al. [2006] focused their research on 21 European cities from 1991 to 1993. The author analysed the correlation (cross section) between the prevalence ratio of chronic bronchitis and air quality. The prevalence ratio was adjusted for attributes such as sex, place of residence, smoking habits, income level, and social status based on a questionnaire (n = 6824). Higher NO₂ levels resulted in a higher prevalence ratio of female patients.

The Japanese definition of disease caused by air pollution is narrower compared to those of USEPA and WHO. NO₂ and SO₂ affect the four certified respiratory diseases in the compensation system in Japan. Emission fees are determined by the volume of SO₂ emissions in the compensation system because SO₂ measurement method was already established. NO₂ measurement did not seem to be well-established in the early 1970s. The relationship between NO₂ and health effects has been a representative indicator for the evaluation of health effects in epidemiological research in Japan.

First, we used both SPM and NO₂, but we found that the analysis with NO₂ has more significant results than SPM. Second, the Air Quality Index (abbreviation: AQI) data were also revised in order to include all the pollutants. The results of the AQI data confirm that PM and NO_x are the main indicators for the assessment of the health effects of air pollution. Finally, NO_x was selected for the analysis based on previous literature and on its strong relationship to health effects.

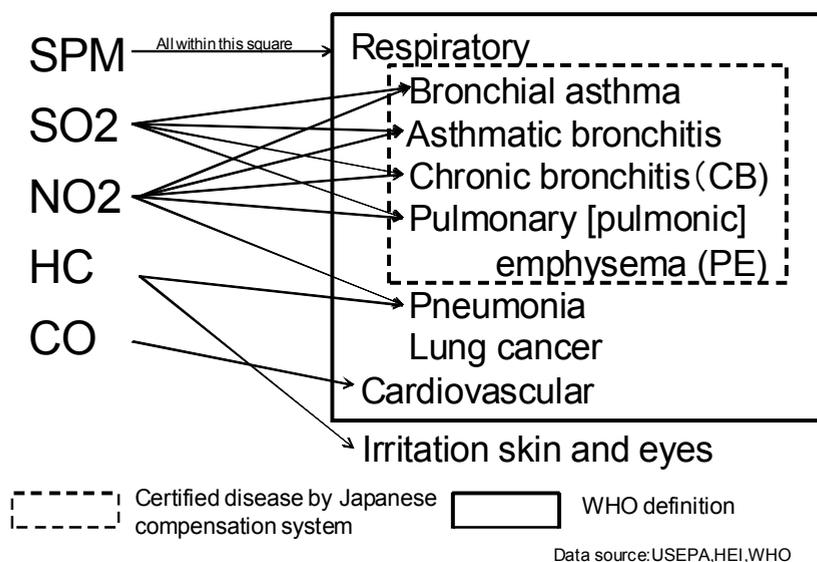


Fig. 4. Air pollutants and their affected diseases

2.3.3 Health effects caused by air pollution

The data of the compensation system has two benefits. First, local governments issue white paper. The white paper shows the number of certified, mortality, newly registered and recovered patients in public. These consistency data is useful to check if it is reliable by calculation. Second, a certified patient is required to be non-smoker as a rule. The data is classified patients of certified 4 diseases and non-smokers in the compensation system.

There are two different trends according to statistical data of certified patients in the compensation system; one before 1988 and one after 1989 (Figure 5). The air quality dramatically diminished and the number of patients increased before 1988. The number of

certified patients reduced because no new patients could be registered after 1989. Two time series will be considered in order to present the correlation. One is for the whole time period (1974–2007), and the other is for two separate time series (1974–1988 and 1989–2007).

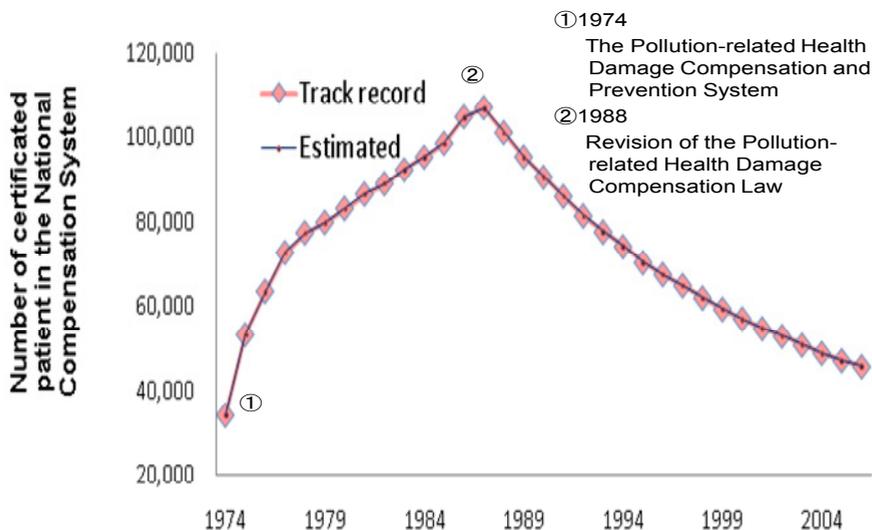


Fig. 5. Number of certified patient in the pollution-related health damage compensation and prevention system (compensation system)

2.3.4 Estimation models

These two hypotheses are expressed by the following 5 equations. The annual average value NO₂ of residential areas depends on emission volumes including those from stationary and mobile sources (hypothesis 1) in Eq. 1. The health effects (certified patients, mortality rates, recovery, and newly registered patients) depend on NO₂ level (hypothesis 2) from Eq. 2 to Eq. 5.

The emission volume is divided by the surface area in order to compare the health effects. The number of certified patients is divided by the total population because this group becomes patient group from normal population group. Certified patient includes newly registered and re-registered patients. The numbers of deceased and recovered are divided by the number of certified patients because these groups change status from certified patients. The number of newly registered patients is divided by the number of population because this group becomes patient group from normal population group.

Methodology of hypothesis 1 (Emission-air quality)

$$M_{t,c} = \alpha \ln X_{t,c} + c \tag{1}$$

M: Annual average value of NO₂ in residential area (ppm)

X: Emission volume of NO_x (stationary + mobile sources) (t/year/km²)

t: year (t = 33)

Tokyo: 1974–1976,1980,1985,1990,1995,1997

Kawasaki:1985,1993,1995,1997,2000,2005

Osaka:1972,1978,1980,1988,1990,1992,1994,1996,1998,2000,2002–2006

c: certified area (n = 1–3)

Methodology of hypothesis 2 (Air quality and health effects)

Q, D, R, N , are estimated from the coefficients and NO_2

$$Q_{t,r} = a_1 M_{t,r} + b_1 \quad (2)$$

$$D_{t,r} = a_2 M_{t,r} + b_2 \quad (3)$$

$$R_{t,r} = a_3 M_{t,r} + b_3 \quad (4)$$

$$N_{t,r} = a_4 M_{t,r} + b_4 \quad (5)$$

Q: certified patients per 1000 population of certified areas

D: mortality per 1000 certified patients of certified areas

R: recovery per 1000 certified patients of certified areas

N: newly certified patients per 1000 population of certified areas

M: annual average value of NO_2 in residential areas

t: year (t = 1–33)

a: coefficient (n = 1–4)

b: constant (n = 1–4)

c: certified area (n = 1–5)

3. Data description

3.1 Emission volume

The NO_x , PM, SO_2 , and CO emission volumes from stationary sources have been measured since the early 1970s in Tokyo, Kawasaki, Osaka, Amagasaki, and Kita Kyushu. The data was in public by environmental white paper of each local government. The NO_x and PM emission volumes from mobile sources have been measured since the 1970s primarily to evaluate policy implementation of the NO_x -PM law.

The total emission data (stationary and mobile sources) were estimated for certain years in Tokyo, Kawasaki, and Osaka (Table 1). They were not continuous data of every year. The Amagasaki data were included in the total emissions from Hyogo prefecture according to the Hyogo prefecture environment white paper [Hyogo Prefecture Government 2003]. There was no separate data set available for only Amagasaki. There was no data set of emissions from mobile sources in Kita Kyushu because Kita Kyushu is not certified of the NO_x -PM law [Kita Kyushu City Government, 1982]. Only the data set for emission volumes from stationary sources was available in Kita Kyushu.

There appear to be some outliers in the correlation analysis. There are four estimated values of emission volumes for 1985 in four different reports of the Tokyo metropolitan

government. The outlier for Osaka was 1972. It is also the highest level of emission volume among the Osaka data.

These data were checked by the Tokyo metropolitan government and the Osaka city local government for verification. There are multiple data sources from different research projects for the same year. The criterion for selection is that the estimation must represent the actual situation without any policy implementation assumption.

Data on total NOx emission volumes (stationary and mobile sources) in Tokyo (23 wards) [Environmental Bureau of Tokyo Metropolitan Government, 1971, 1973, 1984, 1994, 1996, 2000a, 2000b, 2004, 2005, 2009, Tokyo Metropolitan Government, 1983, 1995, 1998], Kawasaki [Kawasaki City Government 2008, 2009], and Osaka [Osaka City Government, 1975, 1976, 1991, 2001, 2004, 2007] from 1972 to 2007 are available from various annual environmental reports written by local governments.

	Data source	Emission Volume (NOx, PM)	Air quality (NO2,SPM, CO,HC, SO2)	Certified Patient	Mortality	Recovery	Newly registered patient
Tokyo (19 wards)	Environmental Bureau of Tokyo Metropolitan Government	● (Tokyo 23 wards)	●	●			
Kawasaki	Kawasaki City Government, Kanagawa Prefecture Government	● (Whole city)	●	●	●	●	●
Osaka	Osaka City Government	● (Whole city)	●	●	●	●	●
Amagasaki	Amagasaki City Government, Environment in Amagasaki, Hyougo Prefecture Government	● (Hyogo prefecture)	●	●	●	●	●
Kita Kyushu	Kita Kyushu Government, Fukuoka Prefecture Government		●	●	●	●	●

Emission volume = stationary + mobile sources

Table 1. Data sources of each item (1974–2007)

3.2 Air quality

The annual average values of the pollutants (NO2) in residential areas in Tokyo (All 23 wards), [National Institute for Environmental Studies. <http://www-gis.nies.go.jp/>], Kawasaki [Kawasaki City Government 2008 a, 2008 b, 2009, Kanagawa Prefecture Government 1983], and Osaka [Osaka City Government, 1975, 1976, 1991, 2001, 2004, 2007] from 1960 to 2007 were used.

3.3 Certified, mortality, recovered and newly registered patients

We used the records of certified, deceased, recovered patients, and newly registered for correlation analysis. As certified areas, the data from Tokyo (19 wards), Kawasaki (Saiwai, Kawasaki wards), Osaka city, Amagasaki city (East region and South regions), and Kita Kyushu city (Wakamatsu, Tobata, Yawata, Nijima, Kurosaki, and Higashi-Kokura) were used.

Some data regarding mortality rates, newly registered patients, and recovered patients in the 19 wards of Tokyo are missing. The term 'recovered patients' includes actual recovery, non-renewal of registration, and cancelation of registration.

4. Correlation analysis

4.1 Hypothesis 1

To support hypothesis 1, the NO_x and PM emission volume and their air quality data are analyzed to determine a direct relationship.

Figure 6 shows the correlation between the total NO_x emission (stationary and mobile sources) and NO_x air quality (residential area, annual average) in Tokyo, Kawasaki, and Osaka. The data for emission volumes (stationary and mobile sources) were obtained from the respective local governments. A log-linear regression model is assumed. The t-value of NO_x emission volume is 5.660, which is sufficiently high.

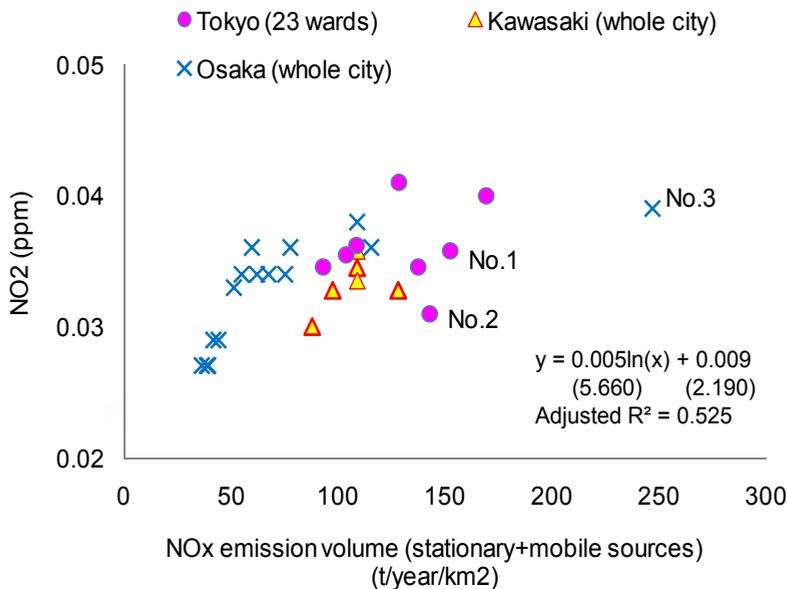


Fig. 6. Correlation between total NO_x emissions and NO₂ in Tokyo (23 wards), Kawasaki-city, and Osaka-city

Figure 7 shows the correlation between total PM emission (stationary and mobile sources) and SPM in Tokyo, Kawasaki and Osaka. The data for Tokyo (B) were estimated in 1975. The data in (A) were estimated in 1990. Both PM emission and SPM have improved from (B) to (A). The t-value of PM emission volume is 2.225, which is sufficiently high. The Osaka data of 1998 (C) seem to be lower than those of Tokyo.

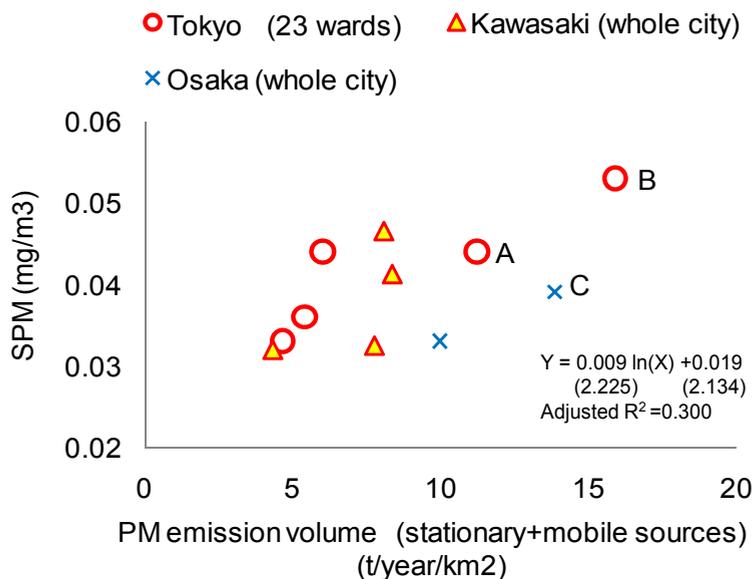


Fig. 7. Correlation between total PM emissions and SPM in Tokyo (23 wards), Kawasaki-city, and Osaka-city

4.2 Hypothesis 2

The second hypothesis focuses on the correlation between air quality and health effects (number of certified patients, recovered patients, new patients, and total mortality figures) in the areas that were certified as Class 1 under the compensation law. Figure 8 shows NO₂ and certified patients in the 5 Japanese cities. The range of NO₂ is from 0.02 ppm to 0.06 ppm for the Tokyo data. The Ohta ward (1974), the Itabashi ward (1987, 1988, 1991-1995, 2001), and the Kita ward (1975, 1991, 1992, 1995) have higher annual averages compared to the rest of the Tokyo wards, Kawasaki, Osaka, Amagasaki, and Kita Kyushu. The highest number of certified patients per 1000 people was in the Ohta ward (26 persons, 1974). The data from 1974 and 1975 are outliers; in the early 1970s.

Some values are outside the general trend because of the data instabilities caused by the introduction of the compensation system and air quality measurements. In fact, many experts have pointed out that the methodology for air quality measurements was not well-established around 1974, when the permissible limits were introduced. Owing to the variability of the measurements, different results were recorded in different governmental documents. Further, the data for certified patients, mortality, recovery, and new patients for that year were not stable as a result of the introduction of the compensation system in 1974.

An NO₂ dummy variable is applied when NO₂ exceeds 0.05 ppm and when the number of certified patients exceeds 5 persons per 1000 population. When the dummy variable is applied, the inverse relationship and R² improve.

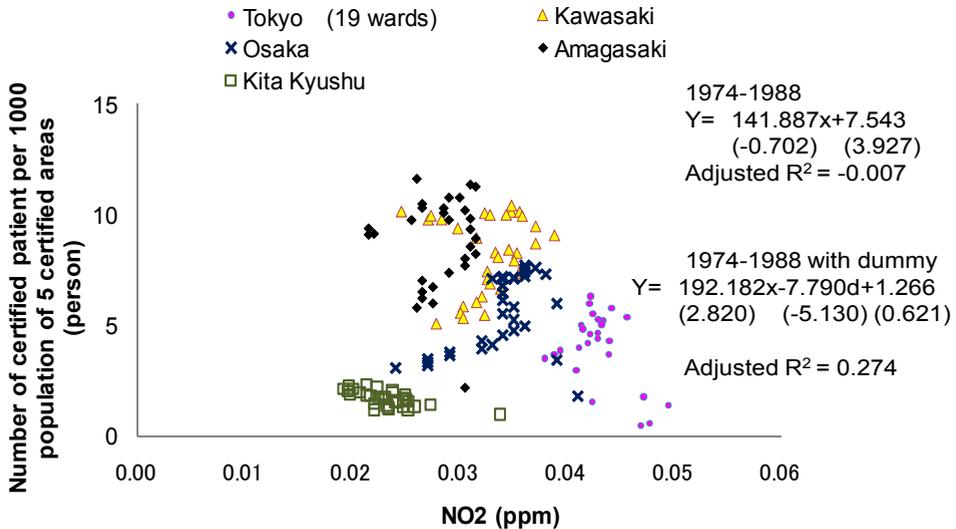


Fig. 8. Correlation: NO₂ and certified patients in Tokyo (19 wards), Kawasaki-city, Osaka-city, Amagasaki-city and Kita Kyushu-city (1974-2007)

Figure 9 shows NO_x and mortality values of certified patients in Kawasaki, Osaka, Amagasaki, and Kita Kyushu. The air quality is between 0.02 ppm and 0.04 ppm. The range of annual mortality numbers per 1000 certified patients is 4–32 in Kawasaki. There were 4 per 1000 certified patients in 1974 in Osaka. The number increased to 11 per 1000 certified patients in 1975. The mortality rate became stable at approximately 30 per 1000 certified patients after 1976. Osaka has three outlier years: 1974, 1975, and 1976. The Amagasaki data from 1983 to 1999 are missing. The mortality figure was 33 per 1000 certified patients in 1974. The number stabilised to around 20 from 1975 to 1982. The range of mortality increased from 27 to 33 between 2001 and 2007. The mortality figures were between 13 and 24 in Kita Kyushu. When the dummy variables were introduced for the three Osaka outliers from 1974 to 1988, the R² and t-values improved and the correlation estimation reached a significant level.

Figure 10 shows NO_x and recovery values of certified patients in Kawasaki, Osaka, Amagasaki, and Kita Kyushu. The recovery rates increased from 2 people per 1000 certified patients in 1975 to 47 people per 1000 certified patients in 1976 in Kawasaki. The number of recovery cases decreased, reaching 6 recoveries in 1997. The number of recoveries went up (to 22 recoveries) and down (to 2 recoveries) after 1998. There were 29 recovery cases in 1974 in Osaka. The number decreased to 6 in 1975. The number increased to 80 recovery cases per 1000 patients in 1980. There is no 'recovery' data in Amagasaki. It includes only non-renewal of registration and retirement cases. Recovery decreased from 30 people in 1970 to 0 in 2002. The data exhibit a significant reduction—from 74 people in 1974 to 10 people in 2004 in Kita

Kyushu. A dummy variable was introduced when the recovery figure was more than 40 and the level of NO₂ was more than 0.035 ppm (Osaka, 1979, 1980, 1981, and 1982; Kita Kyushu, 1977, 1980, and 1983). The R² and t-values improved when the dummy variable was applied.

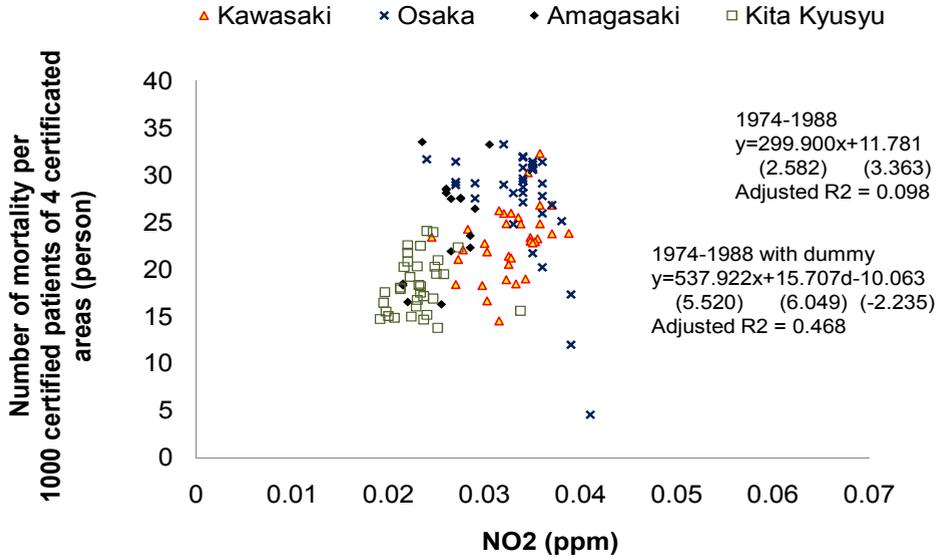


Fig. 9. Correlation: NO_x and mortality in Kawasaki-city, Osaka-city, Amagasaki-city and Kita Kyushu-city

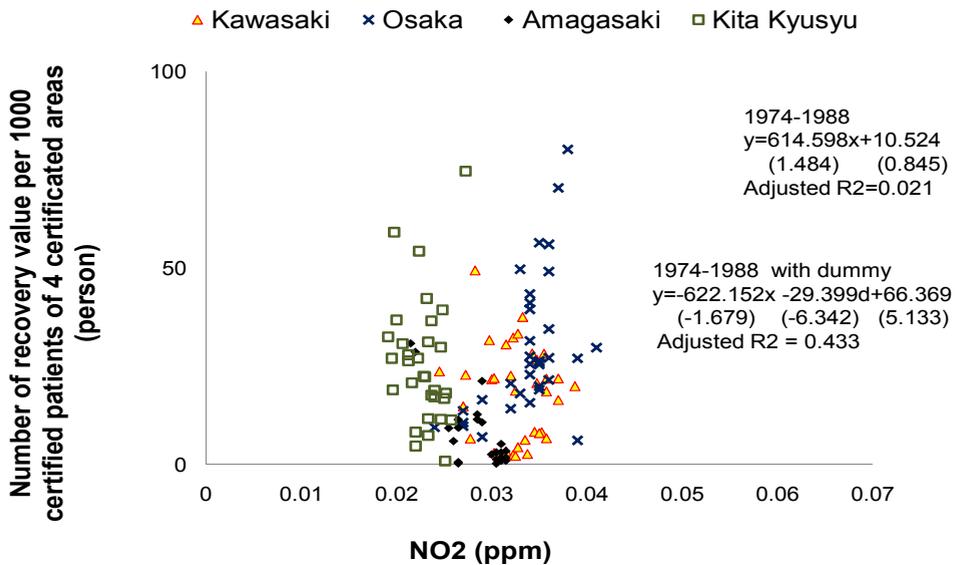


Fig. 10. Correlation: NO₂ and recovery in Kawasaki-city, Osaka-city, Amagasaki-city and Kita Kyushu-city (1974–2007)

Figure 11 shows NO₂ levels and the number of new patients. The number of newly certified patients tended to increase before the compensation law was amended in 1989. In Kawasaki, Osaka, and Amagasaki, new patients decreased from 1974 to 1986. There were sharp increases in new patients in 1987 and 1988. A dummy value is applied for Kawasaki 1975, Osaka 1976, Osaka 1989 and Amagasaki 1975. R² and t-values improve when the dummy value is applied.

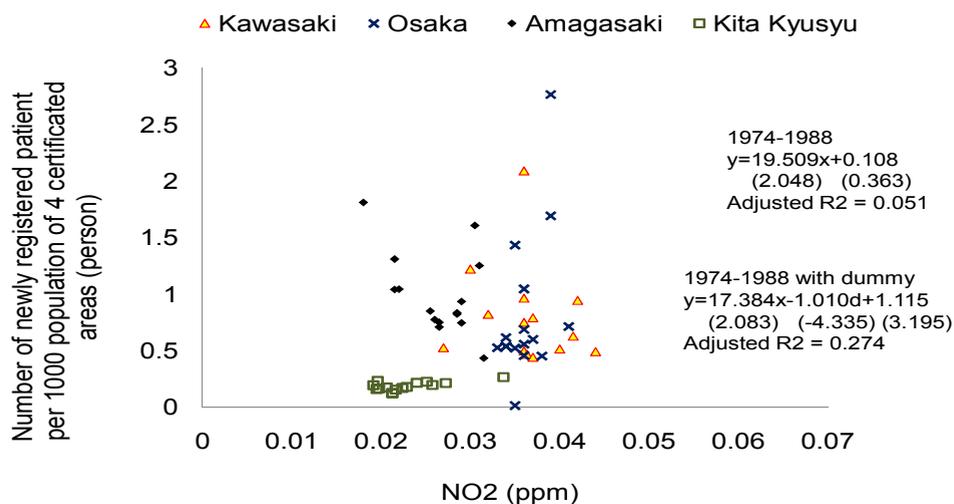


Fig. 11. Correlation: NO₂ and newly certified patients in Kawasaki-city, Osaka-city, Amagasaki-city and Kita Kyushu-city (1974–1988)

5. Results

5.1. Hypothesis 1 (Correlation between emission volume and air quality)

Table 2 shows the results from Eq 1. Without adjustment by dummy, NO_x concentrations related to NO_x emission are estimated to be significant. Without adjustment by dummy, PM concentrations related to PM emission are estimated to be significant.

		NO _x	PM
1974–2007	Constant	0.009	0.001
	NO ₂ /PM pollutant	0.005	0.009
	t value	5.660***	2.225**
	Adjusted R ²	0.525	0.300

Significance at * 20%, **5%, ***1%

Table 2. Result of correlation (Eq 1)

5.2 Hypothesis 2 (Correlation between air quality and health effects)

Table 3 shows the results from Eq. 2 to Eq. 5 for the whole period 1974–2007. R² tends to be low without adjustment with the dummy value. The correlation between the air quality and the

number of certified patients is not estimated to be significant. There is an inverse relationship between recovery rates and air quality owing to the large variance. The number of newly registered patients increased before the amendment of the compensation law in 1988.

Table 4 represents the results from Eq. 2 to Eq. 5 for the period before and the period after the system amendment (1974–1988 and 1989–2007, respectively). When the data are separated, the relationship between NO₂ and the number of certified patients is indicated clearly, even though the t-value is still low. The number of recovered patients may affect the number of certified patients. Mortality rates and the numbers of newly registered patients are estimated to be significant.

Table 5 represents the result from Eq 4 to Eq 7 with a dummy variable in separate periods (1974–1988). All explanatory variables are estimated significantly.

		Certified patients	Newly registered	Mortality	Recovery
1974–2007	Constant	5.426		11.763	13.819
	NO ₂	-10.115		386.387	242.825
	t value	-0.652		4.439***	0.889
	Adjusted R ²	-0.001		0.138	-0.002

Significance at * 20%, **5%, ***1%

Table 3. Results of correlation 1974–2007 (Eq 2-Eq5)

		Certified patients	Newly registered	Mortality	Recovery
1974–1988	Constant	6.600	-42.715	11.781	10.524
	NO ₂	-14.396	5396.263	299.900	614.598
	t value	-0.371	2.768***	2.582***	1.484*
	Adjusted R ²	-0.007	0.105	0.098	0.021
1988–2007	Constant	4.417		10.011	19.177
	NO ₂	5.926		517.227	-150.001
	t value	0.484		4.862***	-0.553
	Adjusted R ²	-0.002		0.261	-0.010

Significance at * 20%, **5%, ***1%

Table 4. Results of correlation 1974–1988 and 1989–2007 (Eq 2-Eq5)

		Certified patients	Newly registered	Mortality	Recovery
1974–1988	Constant	1.317	1.115	-10.063	66.369
	NO ₂	68.730	17.384	537.922	-622.152
	t value	1.466*	2.083**	5.520***	-1.679*
	Dummy	3.071	-1.010	15.707	-29.399
	t value	2.981***	-4.335***	6.049***	-6.342***
	Adjusted R ²	0.052	0.274	0.468	0.433

Significance at * 20%, **5%, ***1%

Table 5. Results of correlation 1974–1988 with dummy variable (Eq 2-Eq5)

6. Resume of the chapter

The correlation between air pollution and health effects in the large Japanese cities presents a great challenge owing to the limited availability of data on the exposure to air pollution, health effects and the uncertainty of mixed causes. In this paper, methodology for quantitative relationships (between emission volume and air quality, and air quality and health effects) is analyzed with a statistical method: the correlation of air pollution reduction policy in Japan from 1974 to 1988.

6.1 Hypothesis 1 (Correlation between emission volume and air quality)

Hypothesis 1 states that the total volume of emissions affects the air quality. Emissions volume data from stationary and mobile sources were collected only from the 23 Tokyo wards, Kawasaki (2 wards), and Osaka whole city. Amagasaki were not available. Kita Kyushu was not covered by the NO_x-PM certified area. The emission volumes data from mobile sources were not available in Kita Kyushu.

For air quality data, the annual averages were collected from environmental white papers of the areas of hypothesis 1. The health effect data—Tokyo (23 wards), Kawasaki (2 wards), Osaka, Amagasaki, and Kita Kyushu—was collected.

The relationship between emission volumes and air quality was clarified using data on emission volumes and air quality in Tokyo, Kawasaki, and Osaka. The air quality (NO_x, SPM) tended to worsen with increases in emission volumes (from both stationary and mobile sources). The relationship between total emissions and air quality was found to be significant, which supports hypothesis 1. The correlation analysis of emission volume, and air quality suggests that NO_x levels worsen according to increases in NO₂.

6.2 Hypothesis 2 (Correlation between air quality and health effects)

Hypothesis 2 states that the air quality influences the number of certified patients. The health effect data are adopted from the compensation system for two reasons. First, local governments issue environmental white papers which indicate the number of certified, deceased, newly registered, and recovered patients in the compensation system. These consistent data are useful for checking the reliability of the calculations. Second, to be a certified patient, a patient must be a non-smoker. The data include classified patients with one of the four certified diseases. In addition, the data include classified patients affected by diseases caused by air pollution.

In the compensation system, patients who suffer from one of the four certified respiratory diseases in a certified area can be registered with the local government. For air quality data, the annual averages were collected from environmental white papers of each local government. The health effect data—Tokyo (19 wards), Kawasaki (2 wards), Osaka whole city, Amagasaki, and Kita Kyushu—was collected. The annual averages were collected from environmental white papers of the areas of hypothesis 2 for air quality data.

Based on previous literature and on its strong relationship to health effects, NO_x was selected for the analysis. In order to include all the pollutants, the Air Quality Index (AQI) data were also revised. The results of the AQI data confirm that PM and NO_x are the main indicators for the assessment of the health effects of air pollution.

An amendment in the compensation system (1988) clearly affects the data trends, so this period is divided into two stages: 1974–1988 (before the amendment) and 1989–2007 (after the amendment). To increase accuracy, the coefficients were re-examined by separating the period into two stages, namely, 1974–1988 and 1989–2007.

The correlation is estimated by using a simple linear model to support hypothesis 2. Most of the coefficients would be expected to be positive; however, there were some inverse relationships. Estimates based only on air quality data may lead to overestimation or underestimation of the number of certified, of mortality, recovered patients, or newly registered patient rates.

The relationship between certified patients and NO₂ was estimated to be significant. The relationship between NO₂ and the number of death was also estimated to be significant. When the air quality worsens, mortality increases. When the three outliers of Osaka were excluded, R² and the t-value improved. The recovery data exhibited a large variance among the four areas; therefore, the relationship between NO₂ and recovery rate was not significant. When the outliers of Osaka and Kita Kyushu from the end of the 1970s and the beginning of the 1980s were excluded, the estimate was significant. The recovery data may have affected the number of certified patients. The relationship between NO₂ and the number of new certified patients was estimated to be significant.

The relationship between air quality (NO₂) and health effects was found to be significant, which support hypothesis 2. When NO₂ worsens, certified patients, mortality rates and newly certified patients increase, according to the data from 1989 to 2007 with dummy variable analysis.

6.3 Conclusion and further issues

The discussion focuses on how to choose the methodology for correlation analysis of the area, time period, pollutants, air quality data, emission volume, and health effects in the large Japanese cities. In order to capture the data related to health problems caused by air pollution, we focused on the data from the Japanese compensation system because these data represent respiratory diseases caused by air pollution.

This chapter establishes a methodology by paying attention to historical events of the compensation system. The previous studies suggest that the data set of respiratory disease caused by air pollution were not separated from the other risks. This research collected existent data of health effects caused by air pollution. The methodology is designed for application to large Asian cities.

This research also indicates some improvement points. The further issues are the followings.

- Only outlier was detected for revision of data. It also needs to check all the data.
- The area used for analysis should cover all the compensation areas in Japan. Increasing the analysis area can also raise the accuracy of the coefficients.
- Air Quality Index (AQI) is an index for reporting air quality with regard to public health [USEPA <http://www.airnow.gov/>]. A lower AQI indicates better air quality. PM and NO₂ values were converted to AQI values in all five regions.
- For the correlation analysis, it must be required adjustment on health effect data by age, gender and population.

- Inverse relationships are observed in the data from Japan, but the replacement of outliers by dummy variables yields significant estimation results. These results suggest the possibility of introducing other variables—such as weather, lifestyle, and age—for further analysis. The area used for analysis should cover all the compensation areas in Japan. Increasing the analysis area can also raise the accuracy of the coefficients for large Asian cities.

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