The aim of this study is to examine the relation between mortality and the existence of incineration plants and dioxin released from the plants in 590 municipalities across Japan. The concentration of dioxins in emissions from incineraors, the amount of dioxins per population, the cumulative amount of dioxins, and the cumulative amount per land area were used as dioxin-related municipal indices. Age-adjusted mortality rates from all causes and five major disease categories by municipality in 1995 were used as health indices. The relation was examined using t-test, analysis of covariance (ANCOVA), correlation coefficients and multiple linear regression analysis, considering the effects of cities’ socioeconomic conditions.

Although municipalities with plants had significantly higher mortality from female stroke and lower mortality from male cancer at all site and lung than municipalities without plants, these differences were not significant in ANCOVA with socioeconomic indicators. The significant relation between mortality and dioxin indices in correlation coefficient was ruled out when the socioeconomic conditions were adjusted in multiple regression analysis. This study did not show the statistical relation between increased mortality from major causes and the existence of incineration plants and dioxins from the plants at the municipal level.

Key words: Dioxins, Incineration plant, Mortality, Epidemiology

Introduction

The health risk caused by dioxins, including polychlorinated dibenzo-p-dioxin, polychlorinated dibenzo-p-dioxin and related substances, have become an important public health concern. In addition to chloracne as a classical manifestation, systemic, immunologic, neurological, developmental, reproductive, and carcinogenic effects have been reported as adverse effects in humans. In previous studies on populations who were accidentally or occupationally exposed to dioxins, the marked increased risks were found in mortality from sarcoma and lymphotropic malignancy. In addition, recent findings of several cohort studies suggested the effects to other kinds of malignant and non-malignant health including circulatory disease, diabetes, and cognitive functioning, as well as the effects of perinatal exposure such as modification of sex ratio at birth, and cognitive and motor abilities.

In industrialized countries, dioxins are mainly produced from chlorinated materials and aromatic carbohydrates by burning trash in incineration plants. According to the Japanese Environmental Agency’s estimation of the amounts of dioxins released, over 90% of dioxins was originated from municipal solid waste incineration plants. The results of studies measuring the dioxin concentrations in the blood of residents living near incineration plants demonstrated that the concentrations were not high enough to cause a health hazard. Conversely, some studies
have demonstrated that substantially high concentrations of dioxins are present in the blood of individuals working in incineration plants\textsuperscript{7,20}. Therefore, it is necessary to examine health effects of dioxins not for specific populations but for general population exposed in everyday life.

The population-based study that focuses on the comparison of groups or regions makes it possible to investigate the relation between health levels of the population and environmental measures of the place\textsuperscript{21}. This method has rational advantages especially in environmental epidemiology, because it is difficult to measure the relevant exposure at the individual level for large number of subject accurately\textsuperscript{21}.

It is well known that the health status is associated with regional socioeconomic conditions such as education, income, employment, and living environments\textsuperscript{22-24}. A previous study in England demonstrated that the apparent increase of cancer mortality related to incineration plants was result of the confounding by regional socioeconomic conditions\textsuperscript{25}. Thus, in an investigation of the relation between dioxins released from incineration plants and the health status of the population, the influence of regional socioeconomic conditions as potential health determinants should be taken into consideration.

The aim of this study was to examine the relations between the existence of incineration plants and dioxins release from plants and mortality rates in municipalities from major diseases, considering cities’ socioeconomic conditions as potential confounders.

**Materials and Methods**

In Japan, municipalities are defined as Tokyo special ward-cities, cities designated by ordinance, cities, towns, and villages. The cities designated by ordinance are further categorized into wards for the purposes of administrative services. The subjects of this study were Tokyo special ward-cities, wards of cities designated by ordinance and cities. In 1995 there were 803 municipalities as study subjects and the following statistical data were compiled at the municipal level.

Dioxin-related municipal indices were based on the database of the Ministry of Health and Welfare in Japan, obtained in measurement of dioxin concentrations in emissions from 98% of total incineration plants in 1996-1997\textsuperscript{26}. Using the data on the dioxin concentrations and the census population and land area in 1995\textsuperscript{27}, we formulated four dioxin-related municipal indices: the concentration of dioxins (DC), the amount of dioxins per population (DA/P), the cumulative amount of dioxins (CA), and the cumulative amount of dioxins per land area (CA/A). In the case of municipalities with plural plants, DC represented the average concentration adjusted for the incineration capacity. DA/P, CA, and CA/A were estimated as DC × incineration capacity (t/day) / 10,000 population, DC × incineration capacity (t/day) × operation period (from the year of construction to 1995: day), and CA / land area of municipality (ha), respectively.

Seven municipal indicators related to cities’ socioeconomic conditions: population, population density, per capita income, unemployment rate, age-adjusted educational level, square kilometer of city park per total land, and average area of dwelling unit per person, were selected and calculated using statistics from 1990 Population Census of Japan\textsuperscript{28}, 1993 Housing Survey of Japan\textsuperscript{29}, 1991 Established Census of Japan\textsuperscript{30}, and 1991 Indicators of Citizens’ Income\textsuperscript{31}. Population was used for the consideration of the effects of differences in the population size among municipalities, especially urban and rural differences. Other indicators were selected because of their critical relation with health level at the municipal level\textsuperscript{24}.

For calculating the age-adjusted mortality rates, the population in 1995\textsuperscript{27} and the number of deaths from all causes and five disease categories: stroke, ischemic heart disease, cancer at all sites, stomach cancer, and lung cancer, by municipalities, and sex and age categories in 1994, 1995, and 1996 were individually compiled. Using a 1985 model population of Japan and the average number of deaths in three consecutive years in individual municipalities, the sex-specific and age-adjusted mortality rates were calculated.

The municipalities with incineration plants constructed after 1995 were excluded from the study. The DC, DA/P, CA, CA/A, population and population density were converted to a logarithmic scale to follow the normal distribution.

Mortality rates were compared according to the existence of incineration plants using Student’s t-test. To adjust for the influence of cities’ socioeconomic conditions on the mortality rates for which a significant (P < 0.05) relation was evident in the uni-variate analysis (t-test), analysis of covariance (ANCOVA) was conducted using the mortality rate as a dependent variable, the existence of plants as an independent variable and the socioeconomic indicators as covariates. The relations among the dioxin indices, age-adjusted mortality rates, the socioeconomic indicators and the capacity of
incineration plants were examined using uni-variate cor-
relation coefficients (Pearson’s). To exclude the influ-
ence of cities’ socioeconomic conditions, multiple linear 
regression analysis was conducted with the mortality 
rate as a dependent variable, and the dioxin indices 
and the socioeconomic indicators as independent vari-
able. This multi-variate analysis was performed for 
the cases in which a significant ($P < 0.05$) relation 
was evident in the uni-variate analysis (correlation coefficient) 
between mortality and dioxin indices. First, each 
socioeconomic indicator was individually included as 
independent variable in the regression model in addition 
to a dioxin index. Next, all seven socioeconomic indica-
tors were simultaneously included as independent variables. The SPSS10.0 statistical package was 
used for the statistical analysis.

## Results

The mean ± S.D. of DC, DA/P, CA, and CA/A for all 
subject municipalities were 28.3 ± 60.1 (ng-TEQ/ 
Nm$^3$), 413.8 ± 860.2 (ng-TEQ/Nm$^3$×t/day/10,000), 
10,691 ± 17,056 (mg-TEQ/Nm$^3$), and 1.5 ± 3.7 
(mg-TEQ/Nm$^3$×t/ha), respectively.

Table 1 shows the comparison of mortality rates 
between municipalities with and without incineration 
plants. Significant lower mortality rates from male 
cancer at all sites and male lung cancer were 
observed in municipalities with plants. Conversely, 
municipalities with plants had a significant higher 
female stroke mortality rate. Regarding the socioeco-
nomic indicators, there was no significant difference 
between municipalities with and without plants except 
larger population in the municipalities with plants.

ANCOVA was conducted for mortality rates from 
male cancer at all sites, male lung cancer, and female 
stroke. A significant relation between the female 
stroke mortality rate and the existence of incineration 
plants was not evident when population density and 
unemployment were used as covariates. As well, pop-
ulation density, per capita income, unemployment rate 
and age-adjusted education level were identified as sig-
nificant confounders affecting the relation with the 
male mortality rate from cancer at all sites. However, 
the relation between the male lung cancer mortality rate 
and the existence of plants was significant even after 
adjustment for the influence of the socioeconomic 
indicators.

The correlation coefficients of the dioxin indices 
and mortality rates are shown in Table 2. DC and DA/P 
were significantly positively correlated with stroke 
mortality rates. Conversely, these indices were signifi-
cantly negatively correlated with mortality rates from 
cancer at all sites. There was no significant correlation 
between CA and mortality. CA/A was significantly 
associated with mortality from all causes and 
ischemic heart disease for males.

### Table 1. Age-adjusted mortality rates (mean±S.D., per 100,000) in municipalities with and without incineration 
plants across Japan in 1995.

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>Municipalities with plants (N=426)</th>
<th>Municipalities without plants (N=164)</th>
<th>$p*$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All causes</td>
<td>587.0 ± 53.8</td>
<td>593.1 ± 56.4</td>
<td>0.22</td>
</tr>
<tr>
<td>Stroke</td>
<td>75.5 ± 14.3</td>
<td>73.6 ± 13.5</td>
<td>0.14</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>41.3 ± 9.8</td>
<td>41.0 ± 10.1</td>
<td>0.77</td>
</tr>
<tr>
<td>Cancer at all sites</td>
<td>187.4 ± 22.5</td>
<td>191.6 ± 22.2</td>
<td>0.048</td>
</tr>
<tr>
<td>Stomach cancer</td>
<td>38.2 ± 7.8</td>
<td>39.0 ± 8.8</td>
<td>0.29</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>39.0 ± 6.7</td>
<td>41.6 ± 9.1</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All causes</td>
<td>429.9 ± 36.3</td>
<td>428.5 ± 40.5</td>
<td>0.67</td>
</tr>
<tr>
<td>Stroke</td>
<td>73.3 ± 14.8</td>
<td>70.5 ± 15.6</td>
<td>0.04</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>31.4 ± 8.2</td>
<td>31.5 ± 8.8</td>
<td>0.24</td>
</tr>
<tr>
<td>Cancer at all sites</td>
<td>118.0 ± 13.0</td>
<td>118.5 ± 13.2</td>
<td>0.68</td>
</tr>
<tr>
<td>Stomach cancer</td>
<td>20.7 ± 5.0</td>
<td>20.7 ± 5.8</td>
<td>0.92</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>13.7 ± 3.8</td>
<td>14.3 ± 4.6</td>
<td>0.11</td>
</tr>
</tbody>
</table>

*$p*$: probability value in Student’s t-test
Table 3 shows the correlation between dioxin indices and socioeconomic indicators. DC and DA/P were significantly negatively correlated with the socioeconomic indicators except an indicator of average area of dwelling units per population, which was significantly positively correlated. CA showed the significant correlation only with population. Capacity of incineration plant had significant correlation with DC, DAP and population density: r = -0.23, r = -0.34 and r = 0.64, respectively.

Multiple regression analysis was performed for the cases in which there was a significant correlation between mortality and the dioxin indices: male cancer at all sites with CA, male and female stroke with DC and DA/P, male ischemic heart disease with CA, male cancer at all site with DC and DA/P, and female cancer at all site with DC. The results were shown in Table 4. In the model where only one socioeconomic indicator was included as independent variable, several cases showed significant relation between mortality and...
dioxin indices. However, regression model with all socioeconomic indicators as independent variables found no significant correlation between the dioxin indices and mortality rates from all disease categories.

**Discussion**

In this study, uni-variate analysis showed a significant relation between mortality in municipalities and the existence of incineration plants or indices related to dioxin concentration in the emissions from plants. However, after excluding the effect of cities' socioeconomic conditions, there was no evidence of increased mortality of the population due to the existence of plants and the dioxin indices.

Uni-variate correlation coefficients demonstrated a significant positive relation with the dioxin indices for stroke mortality for males and females, and male ischemic heart disease. In contrast, mortality rates from cancer at all sites for males and females, and male all causes were significantly negatively correlated with the dioxin indices. If possible confounders was not taken account of, the findings might imply that the municipalities with higher dioxin concentrations in emissions from their incineration plants had higher mortality from stroke and ischemic hear disease and lower mortality from cancer at all sites and male all causes.

Previous studies have indicated that the health status of individuals and populations is influenced by the socioeconomic and environmental factors. The difference in health status by municipality was considerably related to a wide range of health determinants such as education, economy, employment, infrastructure, and others. This is the reason why the indicators related to cities' socioeconomic conditions were adjusted as candidates for possible confounding factors in the relation between mortality in municipalities and the existence of incineration plants and the dioxin indices.

The results of multi-variate analysis of the relation between the dioxin indices and mortality after adjusting for the effect of the socioeconomic indicators indicated that the significant relation in uni-variate analysis was confounded by socioeconomic indicators. According to
the results of multi-variate analysis, we concluded that this study did not demonstrate evidence for the influence on the increased mortality in municipalities from major causes due to higher dioxin concentration from the incineration plants.

Regarding the difference in the relation between the dioxin indices and cause-specific mortality, the regional distribution and risk factors for each cause should be discussed. In the case of Japan, a higher mortality from stroke has been found in northern regions, most parts of which are rural. Conversely, there is a tendency for cancer mortality to be higher in urban areas, though there is variation according to the site of cancer. A positive relation between cancer mortality and socioeconomic factors related to urbanization was found in previous studies. In this study, the analysis of the relation between the dioxin indices such as DC and DA/P and mortality showed a negative relation for the causes with lower mortality in urban areas, and a positive relation for the causes with higher mortality in rural areas. The result indicated that relation was largely influenced by the urban and rural differences in socioeconomic conditions.

The relation between the dioxin indices and the indicators related to cities’ socioeconomic conditions support this hypothesis. Population and population density, an indicator associated with urbanization, was significantly negatively correlated with the DC and DA/P. Other socioeconomic indicators that showed a negative correlation with these indices (per capita income, unemployment rate, education level and city park facilities) are related to urban clutter. In contrast, average dwelling area, which is related to non-urban living conditions, showed a significant positive correlation with DA and DA/P. These findings imply that incineration plants located in urban areas had a lower concentration in their emissions.

It is likely that this situation was due to the quality of incineration plants. Municipalities in urban areas have large-scale incineration plants. In our data, there was a significant negative correlation between DA and DA/P and the plant capacity, and a significant positive correlation between population density and the capacity.

This study adopted a cross-sectional study design because of the limited availability of data of dioxin concentration related to incineration plants, and the population mobility between municipalities was not taken account of. In general, there are long latency periods from exposures of health hazards to occurrences of chronic diseases as the consequences, for example a few decades in the case of smoking and lung cancer. Since late 1990s, the intensive measures have been taken for the reduction of dioxins emission in Japan. As a result, the amount of dioxins emission and the exposure to dioxins was estimated to be markedly decreased. However, considering the long latency periods, carefully prospective epidemiological studies are required for the population suspected to be exposed to some level of dioxins in their earlier life.

In this study, municipal level data for mortality and the dioxins indices was used, because municipality is the smallest unit for availability of most statistical data sources including mortality and socioeconomic indicators. It seems that the municipal level is still too large to elucidate the health effects of dioxins related to incineration plants to the population. Thus, longitudinal and long-term analysis using data of smaller areas than the municipal level will contribute to elucidate the health effects of dioxins in general population more accurately.

In conclusion, after controlling the effects of cities’ socioeconomic conditions, there was no statistically significant association between the existence of incineration plants and dioxins release from the plants and increased mortalities from major causes by municipalities across Japan.

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References


