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Relationship between distance of schools from the nearest municipal waste incineration plant and child health in Japan

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Abstract. In Japan, the main source of dioxins is incinerators. This study examined the relationship between the distance of schools from municipal waste incineration plants and the prevalence of allergic disorders and general symptoms in Japanese children. Study subjects were 450,807 elementary school children aged 6–12 years who attended 996 public elementary schools in Osaka Prefecture in Japan. Parents of school children completed a questionnaire that included items about illnesses and symptoms in the study child. Distance of each of the public elementary schools from all of the 37 municipal waste incineration plants in Osaka Prefecture was measured using geographical information systems packages. Adjustment was made for grade, socioeconomic status and access to health care per municipality. Decreases in the distance of schools from the nearest municipal waste incineration plant were independently associated with an increased prevalence of wheeze, headache, stomach ache, and fatigue (adjusted odds ratios [95% confidence intervals] for shortest vs. longest distance categories = 1.08 [1.01–1.15], 1.05 [1.00–1.11], 1.06 [1.01–1.11], and 1.12 [1.08–1.17], respectively). A positive association with fatigue was pronounced in schools within 4 km of the second nearest municipal waste incineration plant. There was no evident relationship between the distance of schools from such a plant and the prevalence of atopic dermatitis or allergic rhinitis. The findings suggest that proximity of schools to municipal waste incineration plants may be associated with an increased prevalence of wheeze, headache, stomach ache, and fatigue in Japanese children.

Key words: Fatigue, Headache, Incineration, Japanese children, Stomach ache, Wheeze

Abbreviations: CI = confidence interval; OR = odds ratio; PCDD = polychlorinated dibenzo-*p*-dioxin; PCDF = polychlorinated dibenzofuran

Introduction

In Japan, the main source of dioxins is incinerators because of ineffective measures to prevent the generation of these chemicals. About 80% of solid waste is incinerated in municipal waste incinerators in Japan while about 2% and 10% of such waste is incinerated in the USA and the UK, respectively [1–4]. For example, in 1997, the proportions of dioxin emissions from municipal and industrial waste incinerators to total dioxin emissions were estimated to be 68% and 21%, respectively, in Japan [5]. A national survey of concentrations of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in exhaust gas from municipal waste incinerators showed that 105 of 1641 plants emitted more than 80 ng toxicity equivalent/Nm^3 [6]. Other incinerator emissions that have gained attention include organic chemicals, particulate matter, heavy metals, and acid gases [7, 8]. A case-crossover study in Australia and New Zealand demonstrated that there were statistically significant increases in hospital admissions for respiratory conditions in children in the presence of increased levels of particulate matter less than 2.5 μm and less than 10 μm in diameter, coefficient of light-scattering by nephelometry, nitrogen dioxide, and sulfur dioxide, but not carbon monoxide or ozone [9]. Trasande and Thurston reviewed recent epidemiologic studies among children and found statistically significant associations between multiple individual pollutants and a wide range of significant adverse and preventable sequelae at present-day pollutant levels in the United States [10]. This situation sometimes existed even in areas with pollution levels less than current air pollution standards [10].

The prevalence of allergic disorders and general symptoms such as headache and fatigue has been increasing in Japanese children [11, 12]. Changes in life style and living conditions are generally believed to be responsible for the increase in these symptoms

[13, 14]. Although there is not a great deal of evidence regarding the effects of incinerators on health in the general population, some studies have addressed this issue [3, 4, 15–17]. Proximity to municipal waste incinerators was positively related to both childhood and adult cancer in Great Britain [4, 15, 16]. However, the prevalence of asthma and atopy determined by skin prick tests did not differ significantly between Australian children living in a region with high-temperature sludge-burning incinerators and those living in a control region [17]. The aim of our present study was to examine the relationship between the distance of schools from the nearest municipal waste incineration plant and the prevalence of allergic disorders and general symptoms among 450,807 Japanese children.

Methods

Participants

Of the 1030 public elementary schools in Osaka Prefecture, which is a metropolis in Japan with 44 municipalities, 1016 participated in surveys of general medical history and subjective symptoms in school children conducted by the Osaka Medical Association and Osaka Prefectural Board of Education in 1997. These surveys had been performed at 2-year intervals since 1971 [11, 12]. Parents of school children completed a questionnaire anonymously that included items about illnesses and symptoms in the study child. Questions were concise and did not request specific information on number and times of events for a certain period so that parents could easily complete the questionnaire. According to the questionnaire, wheeze was defined as present if the parents often recognized episodes of wheezing without cold; atopic dermatitis was considered present if the child had been diagnosed by a physician as having atopic dermatitis at some time since birth; allergic rhinitis was defined as frequent nasal discharge or blockage after sneezing without cold; and headache, stomach ache, and fatigue were defined as present if the child had often complained of the respective symptoms. The questionnaires were collected at each elementary school where the number of participants and children with each of the allergic disorders and general symptoms were compiled.

Measurements

Distance of each school from all of the 37 municipal waste incineration plants (6 plants with intermittently burning incinerators and 31 plants with continuously burning incinerators) in Osaka Prefecture was measured using geographical information systems packages (ArcView version 3.2 and ArcInfo version 8.1). Twenty schools were excluded because the digital map did not include their addresses. Study subjects were 450,807 of 481,788 elementary school children aged 6–12 years from 996 schools (92.1%).

The average local inhabitant's tax per family, based on the 1998 census [18], in each municipality was used as a proxy for socioeconomic status. The total number of clinics and hospitals per 100,000 people in each municipality from the 1997 census [19] served as a proxy for access to health care. A previous study of school children in Osaka Prefecture found a significant positive correlation between the prevalence of atopic dermatitis and the income index according to municipalities [12]. We hypothesized that access to health care was inversely associated with the prevalence of allergic disorders and general symptoms under investigation. Thus, these factors were selected as potential confounding factors. Gender of subjects was not available in the current study.

Statistical analysis

Distances of schools from the nearest municipal waste incineration plant were categorized into five groups (0 to <1, 1 to <2, 2 to <3, 3 to <4, and $4+$ km). The potential confounding factors (average local inhabitant's tax per family and total number of clinics and hospitals per 100,000 people) were categorized into tertiles. All computations were done by the PC-SAS version 8.2 (SAS Institute, Inc., Cary, NC, USA). Logistic regression analysis was used to compare the prevalence of symptoms under study in relation to the distance of schools from the nearest municipal waste incineration plant. We took into consideration clustering within schools via the PROC GENMOD procedure. In addition, multiple logistic regression analysis was used to control for the potential confounding effects of the selected factors. Trend of association was assessed by a logistic regression model that assigned scores to the levels of the independent variable. *P*-values (two-sided) less than 0.05 were regarded as statistically significant.

Results

Table 1 shows the distribution of 996 public elementary schools according to distance from the nearest municipal waste incineration plant in Osaka Prefecture. The distribution was skewed to the right. The proportions of public elementary schools in the range of 0 to <1, 1 to <2, 2 to <3, 3 to <4, and $4+$ km from the nearest municipal waste incineration plant were 5, 21, 28, 25, and 22%, respectively. The median (90% central range) was 2.9 (1.0–5.3) km.

The relationship between the distance of schools from the nearest municipal waste incineration plant and the prevalence of allergic disorders in terms of crude and adjusted odds ratio (OR) and 95% confidence interval (CI) was assessed (Table 2). Crude

Table 1. Distribution of public elementary schools according to distance from the nearest municipal waste incinerator, Osaka Prefecture, Japan

Distance (km)	Number of public elementary schools (%)
0–<1	50 (5.0)
1–<2	210 (21.0)
2–<3	276 (27.7)
3–<4	246 (24.6)
4–<5	139 (13.9)
5–<6	61 (6.1)
6–<7	10 (1.0)
7–<8	3 (0.3)
8–<9	0 (0.0)
9–<10	1 (0.1)

prevalence of wheeze was 0.3% higher in schools within 0–1 km of the nearest municipal waste incineration plant than in those located 4 km or more away (crude OR = 1.07, 95% CI: 1.00–1.14). After adjustment for grade, socioeconomic status, and access to health care, the relationship was slightly evident and a significant linear trend was demonstrated across the five categories of distance from the nearest municipal waste incineration plant (*P* for linear trend = 0.03). Schools within 1–2 km and within 2–3 km of the nearest municipal waste incineration plant were significantly associated with a decreased prevalence of atopic dermatitis and allergic rhinitis. However, these inverse associations were completely attenuated by adjusting for the potential confounding factors under study.

Regarding general symptoms, little difference was found between crude and adjusted ORs for each symptom (Table 3). After controlling for grade, socioeconomic status, and access to health care, there was an independent positive association between schools within 0–1 km of the nearest municipal waste incineration plant and the prevalence of headache although the trend fell just short of significance (adjusted OR = 1.05, 95% CI: 1.00–1.11, *P* for linear trend = 0.06). Shorter distances of schools from the nearest incineration plant were independently associated with an increased prevalence of stomach ache and fatigue (adjusted ORs for shortest vs. longest distance categories = 1.06, 95% CI: 1.01–1.11 and 1.12, 95% CI: 1.08–1.17, respectively), showing a highly positive exposure-related relationship (*P* for linear trend = 0.002 and < 0.0001, respectively).

The median distance of schools from the second nearest municipal waste incineration plant (90% central range) was 4.9 (2.3–7.4) km. Schools within 4 km of the nearest municipal incineration plant were categorized according to the distance from the second nearest such plant (< 4 and 4+ km). An increased prevalence of wheeze, headache, stomach ache, and fatigue associated with proximity of schools to the nearest municipal waste incineration plants was generally more evident in schools within 4 km of the second nearest municipal waste incineration plant

Table 2. Odds ratios for allergic disorders according to distance from the nearest municipal waste incinerator, Osaka Prefecture, Japan

		Children with any of the allergic disorders			
Distance (km)	Number of children	Number	Prevalence (%)	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)[a]
Wheeze					
0–<1	22,945	1118	4.9	1.07 (1.00–1.14)	1.08 (1.01–1.15)
1–<2	94,172	4491	4.8	1.05 (1.00–1.09)	1.05 (1.01–1.10)
2–<3	122,673	5673	4.6	1.01 (0.97–1.05)	1.01 (0.97–1.06)
3–<4	114,498	5435	4.7	1.04 (1.00–1.08)	1.04 (1.00–1.08)
4+	96,519	4408	4.6	1.00	1.00
P for linear trend				0.05	0.03
Atopic dermatitis					
0–<1	22,945	5196	22.6	0.97 (0.94–1.01)	1.00 (0.97–1.03)
1–<2	94,172	21,375	22.7	0.98 (0.96–1.00)	1.01 (0.99–1.03)
2–<3	122,673	27,703	22.6	0.97 (0.95–0.99)	0.98 (0.96–1.00)
3–<4	114,498	26,671	23.3	1.01 (0.99–1.03)	1.02 (1.00–1.04)
4+	96,519	22,319	23.1	1.00	1.00
P for linear trend				0.0004	0.51
Allergic rhinitis					
0–<1	22,945	5573	24.3	1.00 (0.97–1.04)	1.03 (1.00–1.07)
1–<2	94,172	22,300	23.7	0.97 (0.95–0.99)	1.00 (0.98–1.02)
2–<3	122,673	28,890	23.6	0.96 (0.94–0.98)	0.98 (0.96–1.00)
3–<4	114,498	27,648	24.1	1.00 (0.98–1.02)	1.01 (0.99–1.03)
4+	96,519	23,396	24.2	1.00	1.00
P for linear trend				0.005	0.80

[a]Adjusted for grade, socioeconomic status, and access to health care.

Table 3. Odds ratios for general symptoms according to distance from the nearest municipal waste incinerator, Osaka Prefecture, Japan

Distance (km)	Number of children	Children with any of the general symptoms			
		Number	Prevalence (%)	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)[a]
Headache					
0–<1	22,945	2246	9.8	1.07 (1.02–1.12)	1.05 (1.00–1.11)
1–<2	94,172	9032	9.6	1.04 (1.01–1.08)	1.03 (1.00–1.06)
2–<3	122,673	11,478	9.4	1.02 (0.99–1.05)	1.00 (0.98–1.03)
3–<4	114,498	10,825	9.5	1.03 (1.00–1.06)	1.02 (0.99–1.05)
4+	96,519	8906	9.2	1.00	1.00
P for linear trend				0.004	0.06
Stomach ache					
0–<1	22,945	2958	12.9	1.07 (1.02–1.11)	1.06 (1.01–1.11)
1–<2	94,172	11,908	12.6	1.04 (1.01–1.07)	1.04 (1.01–1.06)
2–<3	122,673	15,353	12.5	1.03 (1.00–1.06)	1.03 (1.00–1.05)
3–<4	114,498	14,240	12.4	1.02 (1.00–1.05)	1.02 (0.99–1.05)
4+	96,519	11,771	12.2	1.00	1.00
P for linear trend				0.0004	0.002
Fatigue					
0–<1	22,945	2992	13.0	1.14 (1.09–1.19)	1.12 (1.08–1.17)
1–<2	94,172	11,671	12.4	1.08 (1.05–1.11)	1.05 (1.03–1.08)
2–<3	122,673	14,869	12.1	1.05 (1.02–1.08)	1.04 (1.01–1.06)
3–<4	114,498	13,959	12.2	1.06 (1.03–1.09)	1.05 (1.02–1.08)
4+	96,519	11,200	11.6	1.00	1.00
P for linear trend				<0.0001	<0.0001

[a]Adjusted for grade, socioeconomic status, and access to health care.

than in those further away. However, positive associations between schools within 0–1 km of the nearest municipal waste incineration plant and the prevalence of wheeze, headache, and stomach ache were more pronounced in schools located 4 km or more from the second nearest plant than in those within 4 km of such a plant (Table 4).

Discussion

In the present study, we showed that among the schools studied, a shorter distance from the nearest municipal waste incineration plant was independently associated with an increased prevalence of wheeze, headache, stomach ache, and fatigue. There was, however, no evident relationship with the prevalence of atopic dermatitis or allergic rhinitis. To our knowledge, this is the first study to investigate the potential effects of municipal waste incinerators on wheeze and the general symptoms under study. Information was obtained from parents of almost all pupils attending elementary schools in Osaka Prefecture. Moreover, all of the municipal waste incineration plants in Osaka Prefecture were taken into consideration. Thus, selection bias was

Table 4. Adjusted odds ratios for wheeze and general symptoms according to the nearest and the second nearest municipal waste incinerator, Osaka Prefecture, Japan

Distance (km)	Adjusted odds ratio (95%CI)[a]			
	Wheeze	Headache	Stomach ache	Fatigue
Within 4 km of the second nearest municipal incineration plant (n = 133,236)				
0–<1	1.04 (0.95–1.13)	1.05 (0.99–1.12)	1.06 (1.00–1.12)	1.14 (1.09–1.21)
1–<2	1.06 (1.01–1.12)	1.05 (1.01–1.09)	1.06 (1.02–1.09)	1.09 (1.06–1.13)
2–<3	1.01 (0.96–1.07)	1.02 (0.98–1.06)	1.05 (1.02–1.09)	1.08 (1.05–1.12)
3–<4	1.03 (0.97–1.10)	1.03 (0.98–1.08)	1.06 (1.02–1.11)	1.09 (1.04–1.13)
4 km or more from the second nearest municipal incineration plant (n = 221,052)				
0–<1	1.14 (1.03–1.26)	1.06 (0.98–1.14)	1.07 (1.00–1.14)	1.10 (1.03–1.17)
1–<2	1.04 (0.99–1.10)	1.01 (0.97–1.04)	1.02 (0.98–1.05)	1.02 (0.99–1.06)
2–<3	1.01 (0.97–1.06)	1.00 (0.96–1.03)	1.01 (0.98–1.04)	1.01 (0.98–1.04)
3–<4	1.04 (1.00–1.09)	1.02 (0.99–1.05)	1.01 (0.98–1.04)	1.04 (1.01–1.07)

[a]Adjusted for grade, socioeconomic status, and access to health care.

not likely to be a major problem. It may be difficult to generalize the present findings, however, because the study subjects were likely to have an urban lifestyle.

We used a proxy for exhaust gas from a municipal waste incinerator based on proximity to the nearest municipal waste incineration plant and took no account of factors affecting emissions from a particular incinerator such as meteorological conditions, disposal capacity of the plant and location. An investigation of the soil around the municipal waste incinerator in Toyono, which scattered a large amount of high concentrations of fumes and dust containing PCDDs and PCDFs, showed an obvious gradient for PCDD/PCDF levels according to the distance from the incinerator [20, 21]. Elliott and colleagues demonstrated a statistically significant excess of cancers within 3.0 km and within 7.5 km of 72 municipal solid-waste incinerators in England [4]. Thus, it seems probable that proximity is a reasonable surrogate for outdoor concentrations of most pollutants from an incineration plant. The present study included the plant in Toyono operations of which were suspended in June 1997. The inclusion of this plant may have impacted on results of the study, but such influence was likely to be negligible because only three elementary schools were located within 4 km of the plant.

We did not use validated diagnostic criteria for allergic disorders, such as those reported in the International Study of Asthma and Allergies in Childhood. The definitions of symptoms of headache, stomach ache, and fatigue were crude, which may have resulted in overestimation of the number of children with these symptoms because of the unreliable nature of children's complaints. Thus, misclassification may have created information bias. The magnitude of any such hypothetical bias was unlikely to differ among all five categories of distance from the nearest municipal waste incineration plant. The consequence would have been underestimation of values in our results.

This study incorporated information on socioeconomic status and access to health care in each municipality, using multiple logistic regression analysis. However, the ability to control for the effects of these confounding factors was limited because data on these confounders were from a municipality level not an individual school level. Moreover, information on variations in the distribution of the other confounding factors, such as distance of the children's homes from the nearest incinerator, as well as parental smoking, pets, pollen, household stress, and single parent families were not available. The area of an elementary school district was small in Osaka Prefecture. For example, in Osaka City, the largest municipality, the crude area, which was calculated by dividing the total area of Osaka City by the number of elementary schools in Osaka City was 0.73 km^2 in 1997 whereas the area of Tajiri Town, which is the smallest municipality and has only 1 elementary school, is 3.86 km^2. Probably, schoolchildren spend more time at or near home than at school. However, because of such small school districts, it did not seem necessary for our investigation to separate the effects of the distance of the residence and the school from the nearest plant.

The effect of industrial waste incinerators was not taken into account in the present study. The volume of incinerated waste at an industrial waste incineration plant is much lower than that at a municipal waste incineration plant. Moreover, exposure to combustion effluents from industrial waste incinerators may be ubiquitous in Osaka Prefecture, because these plants are likely to be scattered throughout the entire prefecture. Including these plants would not have affected estimation of the true exposure effect.

Shimizu and Yura reported the correlation coefficient between the air pollutant levels and the prevalence of symptoms under study in school children who were also the subjects of our investigation and who lived around 36 measurement stations [11]. The nitrogen dioxide concentration was significantly positively correlated with headache and fatigue whereas a significant inverse correlation between the suspended particulate matter concentration and atopic dermatitis was found. There was no significant correlation between sulphur dioxide concentration and allergic disorders or the general symptoms under investigation [11]. Traffic density is likely to be greater in Osaka and Sakai City where 11 municipal waste incineration plants and 372 schools existed. There were 20 plants and 584 schools in the other cities and 6 plants and 40 schools in the towns. The distance of schools from the nearest major road was not available for this study. Results of our previous study suggested that the residence, but not the school, within 100 m of a major road may be associated with an increased prevalence of allergic disorders, headache, stomach ache, and fatigue among junior high school students in Osaka [22]. However, in elementary schoolchildren, the proximity of elementary schools to major roads may be related to an increased prevalence of allergic disorders and general symptoms under study. If traffic density was a negative confounder, the reported ORs would have been underestimated.

Data by gender were not available in the present study. If there were differences in health effects of incinerators by gender, hormonal differences may have been cited as a cause. However, since our study examined young children, this effect would not have been as relevant as examination of junior and senior high school students. Our recent study among junior high school students in Osaka showed that male gender was independently associated with an increased prevalence of wheeze and a decreased prevalence of atopic dermatitis [23]. Also,

information on siblings was not available. In a previously cited study, a significant inverse relationship between the number of older siblings and the prevalence of rhinoconjunctivitis, but not wheeze or atopic dermatitis, was observed among junior high school students in Osaka [23]. We were unable to take migration into consideration. The effect of migration is greater for diseases with longer latent periods. The disadvantage could lead to bias toward the null. Parents of these study children filled out the questionnaire after the mass media featured news about high dioxin levels from a municipal waste incineration plant in Toyono. Thus, some parents may have been aware of the possible ill effects of proximity to municipal waste incineration plants. If parents living anywhere near one of these plants recalled health symptoms or problems in their children more easily than parents living further from these plants, this type of misclassification of outcomes could bias the estimates of the association in a positive direction.

We have no immediate explanation as to underlying mechanisms for the positive association between shorter distances of schools from the nearest municipal waste incineration plant and the prevalence of wheeze, headache, stomach ache, and fatigue. It is difficult to explain the current findings by factors other than those in relation to municipal waste incineration plants. The nature of the present study prevents conclusions from being drawn about causality. Moreover, an association at the aggregated level may be due to complex biases and may not apply at the individual level, since proximity to municipal waste incineration plants may reflect socioeconomic or environmental differences. We had no data on the characteristics of the areas close to incinerators compared with those further away, however. In this study, the positive associations with headache, stomach ache, and fatigue were generally more pronounced in schools within 4 km of the second nearest municipal waste incineration plant than in those further away. This would be likely to strengthen our hypothesis that an increased prevalence of general symptoms under study may be partly ascribed to the effects of emissions from these incineration plants. Alternatively, the findings may simply be a chance phenomenon. Although municipal waste incineration plants seem to have a relatively small impact on wheeze and the general symptoms under study, our observations may be of more importance from a public health point of view as an approximation of the general risk to the childhood population exposed to waste incinerators. A more complete understanding of the potential toxicity of emissions from an incinerator and the possible exposure pathway is required. This study is an important starting point for further investigation of the health effects of exposure to factors in relation to incinerators.

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