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RESEARCH ARTICLE

Exposure to heavy metals in blood and risk perception of the population living in the vicinity of municipal waste incinerators in Korea

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Abstract
Background, aim, and scope The purpose of this study was to monitor and present the heavy metal concentrations in the blood of residents of areas near municipal waste incinerators (MWIs), who are more prone to environmental pollution. We also sought to compare and analyze the residents' perception of environmental pollution as one of the factors affecting heavy metal concentrations in the blood using a survey about the perceived damage caused by the facilities. Since heavy metal levels in the blood can be affected not only by local environmental pollution but also by personal and occupational factors, heavy metal levels in the blood need to be verified and consistently monitored.
Methods Residents who live within 300 m of MWIs in Seoul are acknowledged to be under indirect influence according to the Waste Disposal Act. A survey was given to 841 residents living within 300 m of a MWI from 2006 to 2009. The concentrations of heavy metals (lead, cadmium, and mercury) in the blood were measured in the 841 surveyed residents and in 105 residents in reference areas. Additionally, the perception of the damage caused by municipal waste incinerators was investigated using scores from 1 to 5 on a Likert scale.
Results The measurements of the heavy metal concentrations in the blood showed that the mean concentrations of lead, cadmium, and mercury were 43.1, 1.7, and 1.3 ug/L, respectively. The blood levels of lead and cadmium were slightly higher in the group of the subjects who had resided the longest near the municipal waste incinerators. When compared with the domestic investigation by the Ministry of Environment, the concentrations of lead and cadmium were a little higher, while that of mercury was a little lower. Overall, there was no significant difference in the distribution of heavy metal levels in the blood among age groups. Additionally, the investigation of the perceived damage from municipal waste incinerators showed that the subjects

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1 Introduction

Rapid industrialization aimed at economic growth has brought about many social changes, which have caused not only various political and social problems but also environmental problems (Lo and Chen 1990; Park et al. 2009). The especially rapid industrialization of Korea led to the proliferation of mass production and mass consumption, which inevitably led to mass disposal of waste. Waste incineration has been selected as the primary method of disposal due to the realistic limitations of conventional landfill methods: the price of land and rising cost of construction for these facilities, as well as environmental pollution from the effluent foul smell, a serious social problem that had been raised in the past regarding some unsanitary landfills (Environment Ministry of Korea 2004). Since the early 1990s, incineration treatment has been considered as the primary method of treating large amounts of domestic waste that is composed of varied materials (Park et al. 2009). However, incineration has its own problems, which include a costly initial investment for the construction of an incinerator and high operating costs. Moreover, since pollution including dioxin, which is harmful to human body, can be produced by the incineration of waste, environmental organizations and residents sometimes strongly oppose the construction of incinerators (Okuda and Thomson 2007; Cordier et al. 2010).

Municipal waste facilities can release toxic pollutants such as heavy metals during incineration. Lead (Pb), cadmium (Cd), and mercury (Hg) are among the elements associated with municipal waste incinerators (MWI) stack emissions that bioaccumulate in the food chain and have been shown to cause a wide range of adverse impacts on human health (Clevrly et al. 1989; Agramunt et al. 2003; Llobet et al. 2003). With the exception of mercury, the levels of these heavy metals released in the stack gasses have decreased considerably over the past decade thanks to improvements in air pollution abatement technology (Allsopp et al. 2001; Pekárek et al. 2003). Nevertheless, the quantities in which they are emitted from modern incinerators have the potential to add to the current background levels in the environment and in humans (Allsopp et al. 2001). The influence on the environment as well as on populations residing in the vicinity of incinerators still prompts public and scientific surveillance programs to assess the risk of the potential impact of these processes (Pekárek et al. 2003; Fátima Reis et al. 2007). For the heavy metals Pb, Cd, and Hg, biomonitoring by determining blood metal concentrations is often used (Skerfving et al. 1999). Although not providing information on health effects a priori, within the continuum “source emissions–environmental concentrations–exposure–human biomonitoring–health effects”, human biomonitoring is much closer to health effects than environmental monitoring (Llobet et al. 2003; Casteleyn et al. 2007; Rucandio et al. 2011).

As a result, although municipal waste facilities are necessary, they are hated by nearby residents. Accordingly, antipathy toward the facilities has spread as fast as the term NIMBYS (not in my backyard syndrome), which has now gained widespread usage (Lima et al. 2005; Greenberg 2009). As the perception of individual property rights becomes more positive and owners become increasingly interested in their surrounding residential environment, as they have in recent years, conflicts have arisen regarding the establishment of municipal waste facilities.

Taking all this into consideration, incineration facilities that can cause environmental pollution are an important risk factor to modern society. The concept of risk perception can be used as a core concept for the social perception of environmental pollution. In order to enforce an appropriate environmental policy, there should be harmony between the technological assessments and social perceptions of environmental pollutants (Barker 1990; Kröger et al. 1999; Zint 2001; Michael and Slimak 2006). Studies of the perception of environmental problems are useful in developing and determining an environmental policy since they encourage understanding of public response and offer insight into the way public opinion is formed with respect to risk (Slovic 1987; Sokolowska and Tyszka 1995). It also enables the understanding of risk observation and preference related to the behavior of the general population (Golding et al. 1992; Witten et al. 2000). We need to know the attitudes of those who would live near MWIs in order to understand their point of view on these issues (EI-Zein et al. 2006).

The purpose of this study was to monitor and present the heavy metal levels in the blood of residents of areas near municipal waste incinerators, and to compare and analyze their perceptions of environmental pollution as one of the influencing factors on heavy metal concentrations in the blood. Since the environmental perception of residents near municipal waste incinerators reflected the negative view that incinerators can cause environmental pollution, we propose a method in our discussion that could effectively manage municipal waste incinerators based on the results of our investigation of the concentrations of hazardous substances in the blood.

2 Methods

2.1 Study area and sampling group

The subject areas of this study were three municipal waste incinerators in Seoul that have been operating for over 10 years. At the moment, there are 37 MWIs installed and operating around the country; in Seoul, they are installed and operating in the Gangnam, Nowon, Yangcheon, and Mapo areas. Thirty-seven plants can combust 95% of wastes, which is about 3 million tons annually. The MWIs in Gangnam, Nowon, and Yangcheon can combust 72% of wastes from Seoul, which is about 495,000 t annually. The amount of incinerated waste treated at each plant daily is 900, 800, and 400 t, respectively. This research was conducted on residents 20 years of age or older who live within 300 m of one of the MWIs located in

Gangnam, Nowon, and Yangcheon in Seoul. Residents within 300 m of MWI are acknowledged as being under indirect influence of the facilities and receive support for their heating bills according to the Waste Disposal Act (Fig. 1). The heavy metal concentrations in the discharge gas of the incinerators were measured; lead was detected in the discharge of the Nowon and Yangcheon plants but not in the Gangnam plant. The concentration was much lower than the permissible discharge limit of 0.2 mg/m^3. Cadmium was detected in the discharge of the Nowon plant but not in the Gangnam and Yangcheon plants. Again, the concentration was much lower than the permissible discharge limit of 0.02 mg/m^3. Mercury (which has permissible discharge limit of 0.1 mg/m^3) was not detected in any of the areas (Table 1).

A questionnaire was given to 877 residents living within 300 m of an incinerator between 2006 and 2009, and the levels of heavy metals (Pb, Cd, Hg) in their blood were measured to investigate the influence of proximity to an MWI on their health. The surveys of 841 residents were analyzed, excluding the questionnaires with no responses. One hundred and five residents of areas not influenced by MWI were also investigated to compare results. This research protocol was approved by the institutional review board of Clinical Trials Center, Yonsei University Medical Center.

2.2 Heavy metals contents in blood sample analytical procedures

After collection, venous blood samples were divided into prepared vacutainer tubes in order to obtain serum and whole blood samples. For heavy metals analysis, approximately 5 ml of blood were collected using a 6-ml vacutainer tube with an anticoagulant and kept frozen at −20°C until the analysis. The Pb and Cd concentrations in the blood were determined by atomic absorption spectrophotometry with a graphite furnace (GF-AAS, Shimadzu-6701F, Japan). The calibration curve used a standard addition method and

Fig. 1 Study of municipal waste incinerators area; **a** Gangnam MWIs, **b** Nowon MWIs, **c** Yangcheon MWIs

Table 1 Characteristics of selected municipal waste incinerators

Classification			Gangnam MWIs	Nowon MWIs	Yangcheon MWIs
Facilities scale			900 ton/day	800 ton/day	400 ton/day
Facilities area			63,818 m^2	46,307 m^2	14,627 m^2
Combustion characteristics			Stoker type	Stoker type	Stoker type
Heavy metal concentrations in discharge gas	Pb (mg/m^3)	2006	ND	0.011	0.002
		2007	ND	0.018	0.003
		2008	ND	0.013	ND
		2009	ND	0.009	0.004
	Cd (mg/m^3)	2006	ND	ND	ND
		2007	ND	ND	ND
		2008	ND	0.009	ND
		2009	ND	0.008	ND
	Hg (mg/m^3)	2006	ND	ND	ND
		2007	ND	ND	ND
		2008	ND	ND	ND
		2009	ND	ND	ND

ND not detected

hydrogen phosphate was used as a matrix modifiers. To analyze the concentration of Hg in blood, used cold vapor generation method, which check the chemical reaction of evaporated Hg. Sample preparation for total Hg analyses in blood included pretreatment and digestion of the samples through the addition of nitric–perchloric and sulfuric acid solution. The digested samples were then analyzed by hydride generation atomic absorption (Shimadzue HVG-1, Japan). The method detection limits were 10, 0.5, and 0.0005 μg/l, respectively, for Pb, Cd, and Hg. An internal quality control was performed using the certified standard reference materials of blood heavy metals (SRM: 955a-1 and 955a-2, NIST in USA). Recoveries of SRM were 93± 7.5% for all metals.

2.3 Risk perception survey instruments and statistical analysis

The data were gathered by a structured self-report questionnaire given to all subjects who had their blood's heavy metal concentrations measured. Sociodemographic characteristics were composed of 10 items regarding sex, age, marital status, economic status, etc. and seven items regarding perception of damaging effects from the municipal waste incinerator including air pollution, foul odor, noise, traffic jams, invasion of right to sunlight, neighborhood image, and damage to property. All the surveys for the perception of damage caused by the incinerators used a five-point scale: 1 point for the greatest damage and 5 points for the least damage.

The Korean version of World Health Organization Quality of Life(WHOQOL)-BREF assessment was used to measure quality of life (Skevington et al. 2004; Min et al. 2002). WHOQOL-BREF consists of a total of 26 questions in five categories: physical capacity (seven questions), psychological well-being (six questions), social relationships (three questions), environment (eight questions), and overall quality of life (two questions). Questions regarding quality of life and perception of damaging effects of the municipal waste incinerator all used scores from 1 to 5 on a Likert scale, where 1 point was "strongly disagree (very unsatisfactory or very risky)" and 5 points indicated "strongly agree (very satisfactory or not at all risky)". Questions about pain and discomfort, medication and reliance on medical support, and negative responses were set for lower scores to indicate a higher quality of life, so these responses were reversed prior to analysis: 1 became 5, 2 became 4, 4 became 2, and 5 became 1. Each categorical score was defined as the mean value of the responses to the questions included in the category.

Sociodemographic characteristics were expressed as a number and categorical characteristics as a percentage. Comparisons of concentration of heavy metals in the blood and perceptions of the municipal waste incinerator influence between groups were performed using the Mann–Whitney test. Comparisons of heavy metals levels in blood by age and duration of residence between groups were performed using the Kruskal–Wallis test.

Correlation analysis was conducted to understand the correlation between each of heavy metals in the blood and multiple regression analysis was conducted to analyze the factors that influence the levels of each heavy metal in the blood. Data were analyzed using the statistical program Predictive Analytics Software, version 18.0.

3 Results

3.1 Blood levels of heavy metals

Table 2 shows the demographics of the study population. Among the 841 subjects living in the vicinity, 707 (84.1%) were female. Age distribution was highest in the 40–49 (38.6%) age group and the mean age was calculated as 48.8, which was slightly higher than that of the reference group. When duration of residence was examined, the average duration was 11.2 years, and 31.6% had lived there for over 16 years. Investigations showed that most of the residents living in the vicinity were married and their educational level was slightly lower than the reference group. Monthly income level distribution was higher than in the reference group. A study on people's jobs revealed that 80% of women were housekeepers and men were mostly office workers (data not shown).

The results of measuring heavy metals in the blood of residents living in the vicinity showed 43.1 μg/l (median 41.9 μg/l) Pb, 1.7 μg/l (median 1.6 μg/l) Cd, and 1.3 μg/l (median 1.1 μg/l) Hg (Table 3, Fig. 2). In general, a lack of statistically significant differences between the group living in the influenced area and the reference group for any studied metal was found, with mean and median values being similar in the two population groups ($p>0.05$).

The heavy metal concentrations in the blood were analyzed, taking into consideration the age, duration of residence, and smoking status of each subject. The results show that lead concentration was the highest in subjects in their 50s at 43.84 μg/l; cadmium concentration was the highest in subjects in their 60s at 1.91 μg/l, and mercury concentration was the highest in subjects in their 20s at 1.51 μg/l. However, there was no significant difference in the distribution of heavy metal concentrations in the blood between age groups ($p>0.05$). The mean lead (45.80 μg/l; $p=0.008$) and cadmium (1.80 μg/l; $p=0.002$) concentrations were significantly higher in the subjects who resided in the influenced areas for more of 16 years of residence. Mercury concentrations were highest at 1.39 μg/l in subjects who had resided in the subject areas for less than 5 years. The overall mercury concentration was low and did not show a significant difference by age and duration of residence ($p>0.05$). The heavy metal concentrations in the blood were compared between smoking and nonsmoking individuals since smoking is one of the environmental exposure factors.

Table 2 Sociodemographic characteristics of the subjects

Variables	No. of subjects (%)	
	Influence area ($n=841$)	Reference area ($n=105$)
Gender		
Males	134 (15.9)	39 (37.1)
Females	707 (84.1)	66 (62.9)
Age		
20–29 years	19 (2.3)	40 (38.1)
30–39 years	104 (12.4)	32 (30.5)
40–49 years	325 (38.6)	14 (13.3)
50–59 years	301 (35.8)	17 (16.2)
60 years or more	92 (10.9)	2 (1.9)
Mean (±SD), years	48.8 (±9.0)	36.2 (±11.0)
Residence duration		
Up to 5 years	102 (12.1)	54 (51.4)
6–10 years	223 (26.5)	28 (26.7)
11–15 years	250 (29.7)	12 (11.4)
16 Years or more	266 (31.6)	11 (10.5)
Mean (±SD), years	11.2 (±5.4)	5.9 (±5.9)
Smoking status		
Nonsmokers	727 (86.4)	71 (67.6)
Nonsmokers (past smoking)	61 (7.3)	11 (10.5)
Smokers	53 (6.3)	23 (21.9)
Education level		
Up to high school	275 (32.7)	11 (10.5)
2-Year college	250 (29.7)	32 (30.5)
Graduate	181 (21.6)	32 (30.5)
Postgraduate	135 (16.1)	30 (28.6)
Monthly income level		
Up to 2,000 won	219 (26.0)	39 (37.1)
2,000–3,000 won	203 (24.1)	21 (20.0)
3,000–4,000 won	202 (24.0)	19 (18.1)
4,000–5,000 won	115 (13.7)	10 (9.5)
5,000 won or more	102 (12.1)	16 (15.2)

Table 3 The concentration of heavy metals in the subjects' blood

Heavy metal (μg/l)	Influence area($n=841$)	Reference area($n=105$)	p^a
Lead (Pb)			
Mean (SD)	43.1 (16.4)	40.9 (16.8)	0.156
Median	41.9	37.3	
Min–max	6.3–85.0	10.3–81.4	
Cadmium (Cd)			
Mean (SD)	1.7 (1.1)	1.5 (0.8)	0.226
Median	1.6	1.5	
Min.-Max.	0.1–7.0	0.1–3.2	
Mercury (Hg)			
Mean (SD)	1.3 (1.0)	1.5 (1.1)	0.303
Median	1.1	1.2	
Min–max	ND–6.3	ND–4.8	

ND not detected

[a] Mann–Whitney test

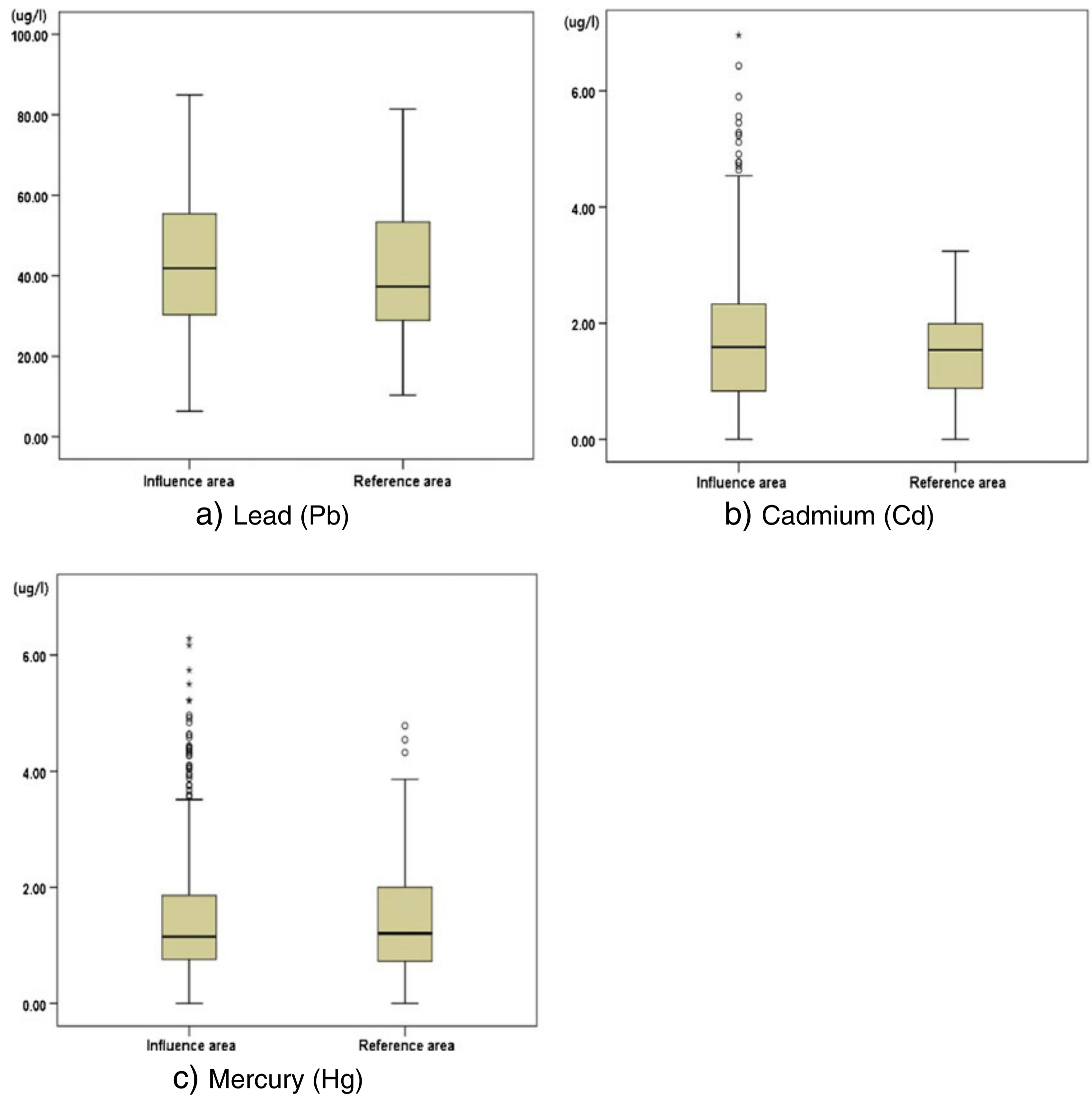

Fig. 2 Concentration of heavy metals in blood; **a** lead (Pb), **b** cadmium (Cd), **c** mercury (Hg)

The results show that the heavy metal concentrations in the blood were higher in subjects who had smoked before and in those who were smokers at the time of the investigation, with a significant difference in blood cadmium concentrations (p=0.042; Table 4). The correlation coefficient for blood lead, cadmium, and mercury concentrations was less than 0.2, indicating almost no correlation.

3.2 Perception of damaging effects from the municipal waste incinerator

Table 5 shows the residents' perceptions of the damaging effects on health and quality of life caused by the MWIs. The scores for the perception that residents experienced damage to their physical health, mental health, and economic status were 2.92, 2.50, and 2.68, respectively, indicating that the perception that people are negatively affected by the environmental pollution caused by municipal waste incinerators was significantly more prevalent among the residents of influenced areas.

The investigation of perceptions showed that residents believed that air pollution became worse, the bad smell increased, more noise was generated, traffic became severe, prospect rights were violated, the image of the town became worse, and real estate prices decreased because of the municipal waste incinerators. The investigation showed that the subjects felt more strongly about damage to the town's image than about environmental damage related to air pollution, odor, and noise, followed by the perceived decrease in real estate prices. The investigation of the residents in the reference areas showed that they also felt more strongly about the town's image and decreased real estate than environmental pollution. Overall, the reference group showed a significantly different opinion in their

Table 4 Heavy metal concentrations in the blood analyzed from each subject

Variables	Pb (μg/l) Mean (SD)	Cd (μg/l) Mean (SD)	Hg (μg/l) Mean (SD)
Age			
20–29 years	42.80 (15.93)	1.39 (0.79)	1.51 (1.12)
30–39 years	40.64 (15.28)	1.56 (0.96)	1.29 (0.85)
40–49 years	43.23 (16.48)	1.67 (1.12)	1.38 (1.03)
50–59 years	43.84 (16.83)	1.72 (1.16)	1.28 (1.07)
60 Years or more	41.56 (17.25)	1.91 (1.19)	1.46 (1.16)
p^a	0.350	0.132	0.402
Residence duration			
Up to 5 years	40.81 (17.43)	1.39 (0.89)	1.39 (1.01)
6–10 years	42.07 (15.90)	1.61 (1.08)	1.32 (0.98)
11–15 years	41.77 (16.07)	1.77 (1.22)	1.32 (0.97)
16 years or more	45.80 (16.54)	1.80 (1.10)	1.37 (1.16)
p^a	0.008	0.002	0.844
Smoking condition			
Nonsmokers	42.90 (16.21)	1.67 (1.13)	1.31 (1.02)
Nonsmokers (past smoking)	44.77 (18.14)	1.69 (0.95)	1.36 (1.03)
Smokers	44.10 (17.72)	2.13 (1.32)	1.58 (1.22)
p^a	0.682	0.042	0.309

[a]Kruskal–Wallis test

perception of the air pollution, odor, damage to the town's image, and decreased real estate prices as caused by municipal waste incinerators.

The results of the evaluation of quality of life showed that physical capacity was highest with a score of 3.52; followed by psychological well-being, 3.38; social relationships, 3.36; and overall quality of life was lowest with a score of 3.01 (Table 6). The quality of life measured for the residents living in the vicinity were slightly lower than the comparison group, but there were no statistically significant differences. The overall average quality of life score for those in the influenced area was 3.28, which was slightly lower than the 3.33 found in the reference group.

3.3 Relationship between blood levels of heavy metals and risk perception

A multiple regression analysis was done to investigate factors that were related to heavy metal concentrations in the blood (Table 7). The results show that factors related to blood lead concentration were gender ($p<0.05$) and duration of residence ($p<0.05$). The blood lead concentration was higher in male subjects and in subjects with a longer duration of residence.

The factors related to the blood cadmium concentration were duration of residence ($p<0.05$), marital status ($p<0.05$), monthly income ($p<0.05$), and perception of health ($p<0.05$) and mental ($p<0.05$) damage caused by the

Table 5 Perception of damaging effects from the municipal waste incinerator

	Influence area (n=841)	Reference area (n=105)	
	Mean (SD)	Mean (SD)	P^a
Healthy	2.92 (1.04)	4.09 (0.78)	<0.001
Psychological	2.50 (1.13)	4.18 (0.79)	<0.001
Economical	2.68 (1.22)	4.19 (0.78)	<0.001
Air pollution	2.13 (0.88)	2.66 (0.72)	<0.001
Foul odor	2.42 (0.98)	2.77 (0.81)	<0.001
Noise	2.94 (0.99)	3.05 (0.91)	0.546
Traffic jam	2.90 (0.99)	2.88 (0.92)	0.352
Invasion of right to sunlight	3.29 (1.06)	3.31 (0.92)	0.557
Neighborhood value	1.61 (0.88)	2.47 (0.93)	<0.001
Property	1.80 (0.98)	2.50 (0.93)	<0.001

[a]Mann–Whitney test, score from 1 to 5: 1(very risky) ~5(not at all risky)

Table 6 Score distributions of WHOQOL-BREF

	Influence area (n=841) Mean	Reference area (n=105) Mean
Overall quality of life and general health	3.01	3.11
Physical capacity	3.52	3.53
Psychological well-being	3.38	3.41
Social relationships	3.36	3.40
Environment	3.12	3.20

municipal waste incinerators. Blood cadmium concentration was higher in subjects with a longer duration of residence as was the case for the blood mercury concentration, and in subjects who were married. Blood cadmium concentration was also higher in subjects whose monthly income was lower and who perceived that their health had been greatly damaged by the municipal waste incinerators. However, blood cadmium concentrations were higher in subjects who perceived they had experienced less mental damage from the incinerators.

Factors related to the blood mercury concentration were gender ($p<0.05$) and the perception of health damage caused by the municipal waste incinerators ($p<0.05$). The blood mercury concentration was higher in subjects who were male and who perceived that their health had been greatly damaged by municipal waste incinerators.

There was no consistent trend between the various factors and heavy metal concentrations in the blood. Even though the local residents perceived that their physical bodies were greatly affected by the municipal waste incinerators, the municipal waste incinerators did not actually have a significant effect on heavy metal concentrations in the blood. Moreover, the multiple regression analysis showed a low descriptive power for these factors on heavy metal concentrations in the blood. The explanatory power of the results is weak, but there were no problems with multicollinearity between the independent variables.

4 Discussion

This study was done to objectively assess the effects of municipal waste incinerators on the environment and on heavy metal levels in the blood of residents of areas nearby. We investigated the long-term health effects of municipal waste incinerators on local residents in order to provide fundamental data to help establish a reasonable management plan for municipal waste incinerators. The chosen subject

Table 7 Multiple regression analysis of heavy metals in blood

Variable	Pb			Cd			Hg		
	B	β	t	B	β	t	B	β	t
Gender	−5.833	−0.137	−3.212*	0.040	0.014	0.334	−0.325	−0.120	−2.817*
Age	−0.548	−0.034	−0.816	−0.031	−0.029	−0.691	−0.021	−0.021	−0.494
Residence duration	1.557	0.100	2.736*	0.086	0.083	2.278*	0.005	0.006	0.150
Smoking condition	−2.011	−0.071	−1.729	0.121	0.064	1.571	0.018	0.010	0.241
Marital status	−0.369	−0.008	−0.206	0.231	0.074	1.944	0.030	0.010	0.262
Education level	−0.197	−0.015	−0.395	−0.057	−0.063	−1.710	0.016	0.018	0.489
Monthly income level	0.232	0.021	0.573	−0.088	−0.119	−3.279*	−0.026	−0.037	−1.004
Municipal waste incinerator effect									
Healthy	−0.043	−0.003	−0.059	0.108	0.105	2.229*	0.122	0.127	2.648*
Psychological	−1.391	−0.103	−1.916	−0.169	−0.186	−3.508**	−0.033	−0.038	−0.714
Economical	0.475	0.037	0.809	0.041	0.047	1.045	−0.026	−0.032	−0.691
Air pollution	1.317	0.070	1.551	0.023	0.018	0.407	−0.073	−0.062	−1.358
Foul odor	−0.903	−0.053	−1.163	0.026	0.023	0.500	−0.009	−0.008	−0.183
Noise	−0.117	−0.007	−0.156	−0.026	−0.023	−0.533	0.007	0.007	0.151
Traffic jam	0.547	0.033	0.742	0.061	0.054	1.239	0.070	0.066	1.486
Invasion of right to sunlight	1.115	0.071	1.791	−0.020	−0.019	−0.496	−0.043	−0.044	−1.099
Neighborhood value	0.174	0.010	0.195	−0.030	−0.025	−0.513	0.037	0.033	0.653
Property	0.116	0.007	0.142	−0.043	−0.039	−0.797	−0.052	−0.050	−1.000
F value		2.093			3.676			1.685	
Adjusted R^2		0.037			0.063			0.030	

* $p<0.05$, ** $p<0.001$

areas were areas near waste incinerators (Gangnam-gu, Nowon-gu, and Yangcheon-gu), and reference areas (without municipal waste incinerators). The subjects in the exposed areas were the residents living near the municipal waste incinerators within a 300 m radius, and the subjects in the reference areas were the residents living in areas of Seoul where there were no municipal waste incinerators.

The results of the measurements of heavy metal concentrations in the blood did not show a distinctive difference between the local residents in the subject areas (mean± standard deviation concentration: 43.1±16.4 μg/l for lead, 1.7±1.1 μg/l for cadmium, and 1.3±1.0 μg/l for mercury) and the residents in the reference areas (mean±standard deviation concentration: 40.9±16.8 μg/l for lead, 1.5± 0.8 μg/l for cadmium, and 1.5±1.1 μg/l for mercury). The heavy metal concentrations in the blood of residents near the subject areas were higher to a certain extent than the results of the National Investigation into the Current Status of Hazardous Substances in the Human Body by the Ministry of Environment for lead (mean concentration of 17.2 μg/l) and cadmium (mean concentration of 1.02 μg/l; Environment Ministry of Korea 2008). However, the blood lead concentration in this study was lower than the blood lead level recommended for children by the World Health Organization (WHO) or the US Centers for Disease Control and Prevention (CDC), which is 100 μg/L (Tong et al. 2000; CDC 2005), and none of the subjects had a blood lead concentration higher than the reference value. Lead in the blood can affect the development of the digestive tract, nervous system, and kidneys and cause anemia if a person is exposed for an extended period of time. Since lead in blood can also cause toxic effects to the genital organs, it is dangerous if it accumulates in the human body (Tong et al. 2000; Khan et al. 2010; Zhu et al. 2011).

Blood cadmium concentrations in this study were also considerably lower than the levels recommended by the WHO at 5 μg/l with only 0.9% of the subjects having blood cadmium concentrations higher than the reference value. Cadmium can also affect the central nervous system and kidneys and cause disorders of cognition and language with long-term exposure (Shen et al. 2005; Poręba et al. 2011). Cadmium in the blood indicates current exposure, while cadmium in the urine indicates past exposure. Thus, it is necessary to identify the cause by investigating urine cadmium concentration and reviewing environmental exposure factors and dietary habits (Llobet et al. 2003; Haddam et al. 2011). In general, cadmium levels are high in people from Asian countries, which is assumed to be because of differences in local factors and dietary habits (Higashikawa et al. 2000; Ikeda et al. 2011).

The blood mercury concentration in this study was lower than the level determined by the Ministry of Environment (3.80 μg/l). None of the subjects had blood mercury concentrations higher than 15 μg/l, which is the HBM II standard recommended by the Centre Hospitalier Belfort-Montbéliard as the level that can affect sensitive persons. Mercury, with continuous exposure over a long period of time, can have a serious effect on the lungs and cause proteinuria, renal dysfunction, and cancers in the human body (Stasinakis et al. 2003; Kim et al. 2011). Mercury in the blood is often organic mercury originating from food (mainly fish and shellfish), while mercury in the urine is inorganic mercury, most of which comes from environmental exposure (Friberg and Mottet 1989; Miranda et al. 2011). Since the mercury concentration is relatively high in the blood rather than in the urine in the case of the Korean population (Environment Ministry of Korea 2008), it is necessary to conduct further study on urine mercury concentrations and dietary habits.

Among the factors related to personal habits, smoking had the greatest effect on the concentrations of lead, cadmium, and mercury in the blood, but only cadmium showed a significant difference. However, there were no consistent trends between personal factors such as duration of residence, education level, monthly income, and perception of damage caused by the municipal waste incinerators and heavy metal concentrations in the blood. Also targeted people's occupational property and personal diet observation was needed to check their heavy metal concentration in blood. Additionally, the measured concentrations of atmospheric dioxin, particulate matter, and heavy metals were similar those of other areas in Seoul (data not shown). But continuous monitoring is necessary, and surroundings like traffic and pollution need to be observed.

These results indicate that heavy metal concentrations in the blood can be affected not only by local environmental pollution but also by personal and occupational factors, and thus, continuous monitoring and deeper analysis may be necessary in the future to identify these factors.

The questionnaire regarding risk perception showed that local residents near the municipal waste incinerators were less satisfied with the environmental conditions and were more aware of pollution than residents of the reference areas. This may be because they had greater anxiety about environmental pollutants or contamination due to lack of information and knowledge about their surroundings (Hermand et al. 2003; Bickerstaff 2004). Also, this indicates that improvement in overall quality of life is urgent, and our results are lower than those from the existing research (WHO 1997), so measures for improving the quality of life of the residents of the MWI vicinity of are necessary.

However, this was not strictly observed in this research, so the average age and the ratio of female residents were high. Although the influence of age and gender could not be accurately revealed, many subjects who had lived in the area for a long time participated; the results may still very important towards establishing ways of managing the quality of life of local residents. There were limitations to making direct comparisons due to the lack of existing research results regarding the perception of the damaging effects to residents living near these facilities.

Overall, the results show that proximity to a municipal waste incinerator had no distinctive effects on heavy metal concentrations in the blood of local residents or in the surrounding atmosphere. Neither change in the air quality nor hazardous health effects were found in the areas near the municipal waste incinerators.

Although the results of the investigation have many realistic limitations, it is assumed that there are no health effects caused by the operation of the municipal waste incinerators in the three districts of Seoul. However, there was a difference in the perception of health risks among the residents near the municipal waste incinerators, although this varied by area. The study clearly showed that the residents held an unfavorable attitude toward the municipal waste incinerators themselves.

It may be necessary for the management of the municipal waste incinerators to provide information about the incinerators to the public, and there should be organic communication between the residents of areas near municipal waste incinerators and the relevant city authorities. As a means of preventing and minimizing various problems that may arise in the future, the current results should be reviewed carefully and the effects of municipal waste incinerators on the environment should be continuously monitored and investigated.

5 Conclusion

Municipal waste incinerators are indispensable for modern life but may cause many problems in the future if they are not properly managed. Hence, the Seoul Metropolitan Government needs to provide proper support and management so that municipal waste incinerators can be operated safely with consistent maintenance and repair of active facilities and appropriate replacement of decrepit facilities. Additionally, an environmental monitoring system should be established near municipal waste incinerators and the health effects on residents of nearby areas should be continuously monitored. The proper and optimal operation of municipal waste incinerators is a good method in minimizing pollution in the nearby areas.

It is also necessary to change the perception of municipal waste incinerators into a friendlier one by adjusting the look of the facilities to be more pleasing. Improving and remodeling the outer appearance and establishing scenic areas around them would have the desired effect. Since there is no particular alternative for municipal waste incinerators, there is no choice but to accept them as a part of life. Because some of them are located near residential areas, those who live near them must accept them as part of the cityscape. Nevertheless, they are considered unpleasant facilities in many aspects because they have an outer appearance that reminds people of factories. In other developed countries, efforts have been made to give municipal waste incinerators a pleasing outer appearance, giving the impression of a beautiful sculpture accompanied by a resting space for pedestrians and taking into consideration harmony with the nature. Equal effort should be made in Korea so that the complaints of the residents of these areas may be resolved. In this way, problems such as the imbalanced land price may also be solved.

The current municipal waste incinerators can avoid being perceived as unpleasant or causing health problems only if they are properly managed and consistently investigated. It is necessary to develop channels through which the residents of the MWI-adjacent areas can be educated about the waste incinerators and make sure that their opinions on the subject are heard. In this way, it will be possible to change public opinion about municipal waste incinerators.

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