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중금속의 위해성 평가에 관한 연구

A Study on Risk Analysis of Heavy Metals

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Abstract

Typical levels of heavy metal exposure for humans may be attributed to four components in the environment : food, inhaled air, various types of dust, and drinking water. To assess the health risk of lead, it is necessary to estimate the blood lead levels in the populations of concern under various air lead concentrations.

The blood lead levels of the population in Seoul and Yeoju are estimated by Biokinetic model for the risk assessment in this study.

The differences in blood lead levels between areas of different land use are not dominant but some differences show among different age groups and sex. Blood lead levels of the population show log normal distribution.

The geometric standard deviation values of blood lead levels are in the range of 1.25～1.39, it is somewhat smaller than the values in the general U.S pollution which are determined to be from 1.31 to 1.41 by the U.S. EPA.

1. Introduction

In general, typical levels of heavy metal exposure for humans may be attributed to four components in the environment : food, inhaled air, various types of dust, and drinking water. These sources and pathways of human heavy metals expoures are diagramed in Figure 1. A baseline of potential exposure for the average Korean individual is studied, eating a typical diet and living in an urban community. Beyond this level, additive exposure factors have not yet been determimed for other environments(e.g. occupational, rural), for certain habits and activities(e.g. pica, smoking, drinking and hobbies) and for variations due to age, sex, or socioeconomic status.

Considering various environmental standards, recommendation values, and present levels of lead in environment media(Table 1), e,.g. the present national air quality standard of 1.5μg/m^3, the drinking water quality standard of 60μg/l, the food standard of 300μg/day, the present air quality level from 0.18μg/m^3 to 0.34μg/m^3, intake from diet 90μg/day and intake from drinking water 60μg/l.

Table 1. Various environmental standards for lead.

	Air				Food	Water
	Environment	Work Place				
		Inorganic	Acenate	Chromic		
Conc	1.5$\mu g/m^3$ (national air quality standard)	0.05$\mu g/m^3$	0.05$\mu g/m^3$	0.05$\mu g/m^3$	300μg/day	60μg/l

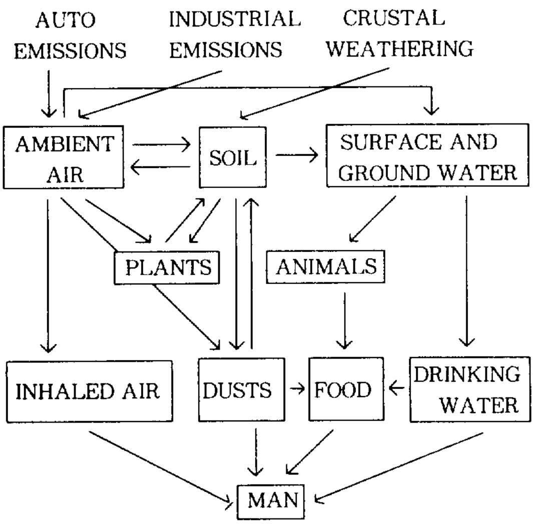

Fig. 1. Principal pathways of lead from the environment to human consumption.

2. Material and Methods

To assess the health risk associated with alternative air lead concentrations, it is necessary to estimate the blood lead levels that would exist in the populations of concern under various air lead concentrations.

Several models for the estimation of blood lead levels have been used in environmental exposure of lead. The blood lead levels of the population in Seoul and Yeoju are estimated for different areas of land use, different ages, and sex. The data on blood lead and the lead content in environmental media such as diets and drinking water, for the population of Seoul and Yoju, are used as input to obtain the Korean Biokinetics model for the general Korean population using equation(1).

The following mathematical formula (1) is derived from compartment analysis and is also used as the Biokinetics model. Under conditions of constant lead exposure, blood lead concentrations change from one level to another apparent equilibrium level over a period of several months. The model assumes that lead in the body is held in some number of homogeneous and well mixed pools or compartments.

$$Xe = It/(Koi \times Vi) \quad (1)$$

Here,

Xe ; blood lead level, $\mu g/dl$
It ; total intake of lead a day, μg/day
Vi ; total volume of blood, dl.

3. Results and Discussion

3. 1 Heavy Metal Levels in Ambient Air

Widely varying amounts in heavy metals have been detected in air in both rural and urban areas of Korea. Natural background levels of the heavy metals Pb, Cd, Cr, and Ni in ambient air are .006$\mu g/m^3$, .0001$\mu g/m^3$ or none .008$\mu g/m^3$ and .006$\mu g/m^3$, respectively.

The annual average values for Korean cities listed fall mainly within the range of .0957$\mu g/m^3$ to .3093$\mu g/m^3$ for Pb .0033$\mu g/m^3$ to .0057$\mu g/m^3$ for Cd, .0182$\mu g/m^3$ to .0207$\mu g/m^3$ for Cr, and .0160$\mu g/m^3$ to .0313$\mu g/m^3$ for Ni with a number of averages being below the limit of detection in 1991.

3. 2 Food

Ingestion of food probably represents the single most important source of heavy metals, particularly for non-smokers, except Cd(smoking is important for Cd). In general, daily dietary heavy metal intake may be estimated on the basis of a standard diet, drinking water, and inhalation.

Varying levels of heavy metals have been found from analysis of typical Korean foods. In Korea, as in other oriental countries where rice is the main dish, rice is an important environmental medium susceptible to the exposure of heavy metals such as Pb, Cd, and Ni. In the Korean rice, the average level of Pb is 0.85$\mu g/g$, for Cd it is 0.11$\mu g/g$, and for Ni it is 2.33$\mu g/g$(Table 3). These values are relatively high when compared with those found in other foods. In the typical Korean diet, which mainly consists of rice it appears that an average daily dietary heavy metal intake can be reasonably estimated.

3. 3 Drinking Water

Heavy metals in uncontaminated rural streams are derived from natural sources and generally contain less than 1 ppm or 1$\mu g/L$ of heavy metals. In some cases, however, the naturally-derived heavy metals are augmented by those from industrial and commercial sources. Such contamination can occur, for example, as result of : (1) mining and smelting operations ; (2) other manufacturing processes utilizing mainly Pb, Cd, Cr and Ni(as in the galvanizing of steel) ; (3) or the leaching of heavy metals from land fill or disposal sites with industrial wastes ; and (4) the use of phosphate fertilizers, and the spreading of sewage sludge(containing heavy metals) on agricultural land.

The average levels of heavy metals in Korean streams are 59ppm for Pb, 3ppm for Cd, 6ppm for Cr, and 50ppm for Ni. The average levels of heavy metals in a drinking water are little lower than

Table 2. Annual average values of heavy metals in major cities in Korea(1991).

(Unit : $\mu g/m^3$)

City	Seoul		Pusan		Kwangju	
	average	range	average	rangde	average	range
Pb	0.3093	0.1077~0.7470	0.2367	0.0490~0.8437	0.0957	0.0137~0.4133
Cd	0.0057	0.0010~0.0100	0.0044	0.0013~0.0093	0.0033	0.0002~0.0112
Cr	0.0207	0.0013~0.1060	0.0182	0.0017~0.0500	0.0195	0.0042~0.0885
Ni	0.0313	0.0083~0.0903	0.0160	0.0000~0.0563	0.0174	0.0063~0.0622

Table 3. Heavy metal content in sampled raw crops.

(Unit : $\mu g/l$)

	Cd	Cu	Ni	Zn	Pb
Rice	0.11±0.03	1.46±0.53	2.33±1.14	5.86±3.02	0.85±0.47
Cucumber	0.02±0.01	1.30±0.26	0.22±0.07	1.30±0.99	0.11±0.26
Chinese cabbage	0.01±0.03	2.69±2.82	0.29±0.16	2.41±1.92	0.14±0.10
Raddish	0.01±0.04	2.54±2.75	0.26±0.24	1.33±1.01	0.08±0.11
Apple	0.02±0.01	0.66±0.25	0.14±0.13	0.67±0.52	0.09±0.13
Pear	0.03±0.01	1.83±1.55	0.21±0.14	0.71±1.51	0.04±0.06
Grape	0.03±0.01	1.23±0.37	0.25±0.16	0.97±0.72	0.22±0.32
Orange	0.01±0.01	0.43±0.15	0.24±0.06	0.97±0.29	0.31±0.27

Table 4. The average levels of heavy matal in water in Korea.

(Unit : mg/l)

		Fe	Cd	Pb	Mn	Cu	Hg
Stream Water (Han Kang	RW	0.47	0.008	0.066	0.508	0.038	0.002
	TW	0.53	0.008	0.063	0.508	0.02	0.002
Drinking Water	Paldang	0.002	–	0.03	0.01	0.01	ND
	Kimpo	0.01	–	0.03	0.01	0.01	ND

*RW : Raw Water TW : Treated Water

stream water(Table 4). For Koreans, the average quantity of drinking water is estimated to be 1 to 1.5 liters per day, from which the average amount of heavy metal intake can be estimated.

3. 4 Exposure from Environmental Media

The concentrations of heavy metals in the average diet, in the drinking water, through inhalation, as well as data on heavy metals composition in each environmental medium and absorption coefficents of each heavy metal in different organs in the human body have been determined. Therefore, an average daily average of total heavy metals intake ranges from 80μg to 95μg per day for Pb, 50μg to 60μg per day for Cd, 70μg to 75μg per day for Cr, and 900μg to 950μg to per day for Ni. An example of daily lead exposure can be broken down as follows : 59percent from food, 38 percent from drinking water, 2 percent from inhalation of air and the remaining 1 percent from other sources(Table 5d).

3. 5 Total Uptake from Environmental Exposure

The total intake of heavy metals from environmental exposure is absorbed into human body. The total amount of heavy metals absorbed in various tissues of the body is defined as total uptake. Uptake depends on the coefficient of absorption of every organ in the body, which varies with age, sex, and race. In estimating of heavy metal uptake, various assumptions and data are used. The absorption coefficients for inhaled lead in the lungs lie between 42% to 50% and in the GI tract between 7% to 20% for food and drinking water depending upon age and sex.

3. 6 The Blood Lead Levels

Several models for the estimation of blood lead levels have been used in environmental exposure of lead. "The amount of lead measured in whole blood is an index of the rapidly diffusible fraction of the total body burden of absorbed lead and is generally used as the dosage, or index of exposure, in investigating the various human health effects associated with lead."The blood lead levels of population in Seoul is estimated for different areas of land use, different ages, and sex. The data on blood lead and the lead content in enviro nment media such as diets and drinking water, for the population of Yeoju(Table 6), are used as input data to obtain the Korean Biokinetics model for the general Korean population.

The blood lead levels are estimated for five different age groups(7>, age of middle school, 20−30, 40−50, and over 50), for each type of land use(i.e.residential, commercial, industrial, and park), and for male and female, and for the year of 1990, the levels of lead in the air in Seoul were between 0.236μg/m^3(in the park area) and 0.384μg/m^3(in the commercial area) as shown in table 7. The difference in blood lead levels between areas of different land use are not dominant, but some differences exist among different age groups and sex.

For males between the ages of 20−29 years, the arithmetic average (AM)blood lead level is 13.4μg/dl with a geometric mean(GM) of 13.1μg/dl and a geometric standard deviation(GSD)of 1.24 ; for males between the ages of 30−49 years, the AM is 12.8μg/dl with a GM of 12.5μg/dl and a GSD of 1.25 ; and for males in the group over 50 years of age, the AM is 16.7μg/dl with GM of 16.1μg/dl and a GSD of 1.30(Table 9). For females between the age of 20−29 years, the AM of blood lead level is 11.9μg/dl with a GM of 11.2μg/dl and a GSD of 1.25 ; for females between the age of 30−49, the AM is 9.1μg/dl with a GM of 10.6μg/dl and a GSD of 1.21 ; and for females in the group over 50 years of age, the AM is 10.7μg/dl with a GM of 10.3μg/dl and a GSD of 1.31. The data of blood lead levels for Koreans by different institutions show differ-ences : 13.7μg/dl for the age group over 50 years to 14.3μg/dl for the age group 20 to 29 years by NIER in 1989 ; 24μg/dl for the age group of 30 to 50 years by university laboratory in 1988 ; and 18.7 μg/dl for unknown age group by assoc iation in 1986(Table 10).

If the estimated blood lead levels are assumed to represent values for the population of Seoul, they

Table 5. An example of daily lead exposure(%).

Food	Drinking water	Inhalation of air	Other source
59	38	2	1

Table 6. Lead contents in environmental media in Yeoju and Seoul.

(unit : $\mu g/m^3$)

			7>	middle	20−29	30−40	50<
Yeoju	male	air	0.027	0.13	0.11	0.11	0.08
		food	3	5.94	5.4	5.4	3.3
		water	3	9	9	6	3.5
		uptake	6.027	15.07	14.51	11.51	6.88
	female		7>	middle	20−29	30−40	50<
		air	0.027	0.09	0.08	0.08	0.06
		food	3	5.4	4.965	0.31	3
		water	3	9	9	6	3.5
		uptake	6.027	14.49	14.045	9.39	6.56
Seoul	male		7>	middle	20−29	30−40	50<
		air					
		resi	0.031	0.2	0.18	0.12	0.08
		comm	0.044	0.28	0.25	0.17	0.12
		indu	0.036	0.23	0.2	0.14	0.07
		park	0.027	0.17	0.15	0.1	0.05
		food	9	15.84	14.55	9.7	6.16
		water	9	10.62	10.62	7.8	4.123
	female		7>	middle	20−29	30−40	50<
		air					
		resi	0.031	0.14	0.16	0.13	0.06
		comm	0.044	0.27	0.22	0.18	0.08
		indu	0.036	0.16	0.18	0.15	0.07
		park	0.027	0.12	0.13	0.11	0.05
		food	9	14.4	13.2	8.8	5.6
		water	9	10.62	10.62	7.8	4.123

Table 7. Airborne heavy metal concentrations in Seoul and Yeoju(1990).

	Seoul($\mu g/m^3$)	Yeoju($\mu g/m^3$)
risidential	0.35	0.25
industrial	0.63	0.25
commercial	0.75	0.25
park	0.29	0.25

* data of Yeoju are estimated from vicinity city (chung ju)

are a little higher than those found in the United States. However, they are also lower than those in Africa and the same as those in Japan. In Korea, food and drinking water containing lead are the primary causes of high concentrations of lead in the blood in the population.

3. 7 Risk Analysis of Lead for Population

The distribution of blood lead levels of the population are log normal. The GM and GSD values are used to plot the distribution graph of blood levels for the population in Seoul.

The GM and GSD used here are measured in the population in Yeoju, 1988 by the university institution. The GSD values of blood lead levels which lie from 1.2 to 1.3 are somewhat smaller than the values of standard geometric deviation of blood lead levels in the general U.S. population, which are determined to be from 1.31 to 1.41 by the U.S EPA judging from the distribution graphs obtained, for males, the percent of population which has blood lead levels higher than 20 μg/dl is 9% for the age group 20 to 29 years, 6% for ages 30 to 49 years, and 36% for ages over 50 years. However, for females, 2% for ages 20 to 29 years, 0% for ages 30 to 49 years, and 3% for ages over 50 years were obtained(Fig 2,3). The population which has blood lead levels higher than 30 μg/dl is only 3% of the population of males over the age of 50 years and this population will be the population

Table 8. Blood lead level for different land uses(GM and GSD for Seoul).

(1) MALE

	Age	GM(50%)	84%	GSD
Residential	20-29	11.52	14.65	1.271701
	30-39	12.32	15.59	1.265422
	40-49	12.66	15.82	1.249605
	50-59	16.21	20.95	1.292412
	mean	15.06	19.02	1.262948
Industrial	20-29	11.79	14.99	1.271416
	30-39	12.62	15.96	1.264659
	40-49	12.97	16.2	1.249036
	50-59	16.59	21.44	1.292345
	mean	15.75	19.68	1.249524
Commercial	20-29	11.98	15.23	1.271285
	30-39	12.81	16.21	1.265418
	40-49	13.18	16.46	1.248862
	50-59	16.85	21.78	1.292582
	mean	15.99	20	1.250782
Park	20-29	11.31	14.37	1.270557
	30-39	12.09	15.3	1.265509
	40-49	12.44	15.53	1.248392
	50-59	15.9	20.55	1.292453
	mean	15.09	18.87	1.250497

(2) FEMALE

	Age	GM(50%)	84%	GSD
Residential	20-29	15.47	21.42	1.384615
	30-39	10.12	12.66	1.250988
	40-49	14.89	19.47	1.307589
	50-50			ERR
	mean	13.32	16.87	1.266517
Industrial	20-29	16.44	22.77	1.385036
	30-39	10.76	13.45	1.25
	40-49	15.83	20.7	1.307644
	50-59			ERR
	mean	14.16	17.94	1.266949
Commercial	20-29	16.38	22.68	1.384615
	30-39	10.72	13.4	1.25
	40-49	15.77	20.62	1.307546
	50-59			ERR
	mean	14.11	17.87	1.266478
Park	20-29	15.38	21.3	1.384915
	30-39	10.07	12.59	1.250248
	40-49	14.81	19.36	1.307225
	50-59			ERR
	mean	13.25	16.78	1.266415

Table 9. Blood lead statistics (AM, GM, and GSD) in Seoul.

Age	AM(male/female)	GM(m/f)	GSD(m/f)
20−29	13.4/11.9	13.1/11.2	1.24/1.25
30−49	12.8/ 9.1	12.5/10.6	1.25/1.21
50<	16.7/10.7	16.1/10.3	1.3 /1.31

* converting formula from Am to Gm is used.

Table 10. Comparison of blood lead levels in Seoul(1990).

	ESTIM	NIER	Tollgate	Others
20−29	13.4/11.9	14.3		
30−49	12.8/ 9.1	13.7	24	18.7
50<	16.7/10.7	13.85		

* blood lead levels in child for remote area(US) 3.5μg/dl blood lead levels in Japan 6.0μg/dl
 〃 in Newyork(US) 15μg/dl 〃 in Israele 8.2μg/dl
 〃 in entire population(US) 15μg/dl 〃 in US 7.5μg/dl

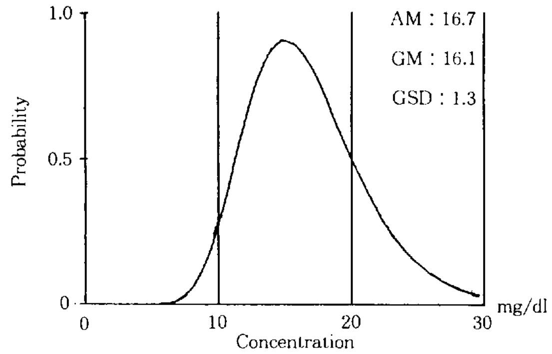

Fig. 2. Estimated blood lead level of male population of age over 50 years.

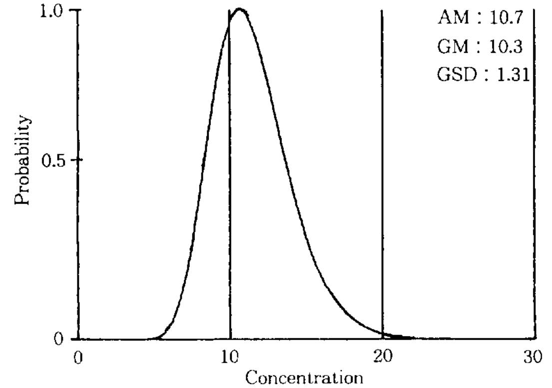

Fig. 3. Estimated blood lead level of female population of age over 50 years.

at risk because of their high blood pressure caused by high levels of lead in the blood. It has been reported that there are three important populations at risk with lead ; (1) the white adult male with risk of high blood pressure, (2) pregnant women, and (3) children with mental disorder and some other physiological disturbances.

Present air quality lead levels in major Korean cities are not high enough to cause serious risks from lead by themselves. However, airborne lead is the primary source of lead contamination in food, drinking water, and soils on most occasions. To reduce the risk caused by lead from all environmertal media, reduction in the use of leaded gasoline, which is the major source of airborne lead, In addition, enforcement of lower levels of lead in other countries where annual reduction programs for limiting the lead content in food and drinking water have been implemented.

4. Conclusion

The blood lead levels of the population in Seoul and Yeoju are estimated by Biokinetic Model for the risk assessment of lead.

The results were as follows ;

- The difference in blood lead levels between areas of different land use are not dominant, but some differences exist among different age groups and for sex.
- For males between the ages of 20∼29 years, the AM, GM, GSD values are 13.4 μg/dl, 13.1μg/dl, 1.24 ; the ages of 30∼49years, the AM, GM,

GSD are 12.8μg/dl, 12.5μg/dl, 1.25 ; the group over 50years of age are 16.7μg/dl, 16.1μg/dl, 1.30, respectively.

- For females between the age of 20～29 years, the AM, GM, GSD values are 11.9μg/dl, 11.2μg/dl, 1.25 ; the ages of 30～49 years, 9.1μg/dl, 10.6 μg/dl, 1.21 ; in the group over 50 years of age are 10.7μg/dl, 10.3μg/dl, 1.31 respectively.
- The distribution of blood lead levels of the population shows log normal. The GSD values of blood lead levels which lie from 1.2, to 1.3 are some what smaller than the values in the general U.S. pollution which are determined to be from 1.31 to 1.41 by the U.S. EPA.

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중금속의 위해성 평가에 관한 연구

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초록

인체에 영향을 미치는 중금속금은 대개 환경중에서 음식물, 공기, 먼지 및 음료수를 통하여 축적된다.

본 연구는 중금속중 납이 인체에 미치는 유해정도를 평가하기 위하여 서울과 여주 등 대기중 납농도가 차이가 나는 지역주민들의 혈액중 납농도를 측정하여 Bio kinetic Model을 이용 납에 대한 인체의 위해성 정도를 알아보았으며 그 결과는 다음과 같다.

－지역별로는 혈액중 납농도가 별다른 차이를 보이지 않았으나 나이와 성별에 따라서는 다소 차이가 나고 있다.

－또한 혈액중 납농도는 log normal 분포를 나타고 있음.

－기하표준편차는 1.2～1.3 정도의 값으로 미국 EPA에서 추정한 1.31～1.41의 값보다 약간 적은 값을 나타냈다.