

# Ingestion risk assessment of heavy metals in the marine and agricultural products

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## Introduction

According to several news reports on food contamination in Korea, the general population is exposed to potential ingestion of heavy metals from marine and agricultural products on the domestic market. Koreans' dietary habits of consuming internal organs and raw vegetables increase their dietary ingestion risk of heavy metals.

The objectives of this study were to estimate the intake doses of heavy metals(Pb, Cd, Hg, As, Al) and to assess potential health risks posed by agricultural and marine products on the Korean market, considering food consumption patterns by age groups. The ultimate aim is to identify dietary patterns that may reduce the risk of ingestion of heavy metals.

## Materials and methods

### 1. Selection and sampling of food products and analysis of heavy metals

For selection of surveyed food products, this study was based on data obtained from the Korea National Health and Nutrition Examination Survey(KNHANES 2008-2010) of consumption of marine and agricultural products, in addition to domestic reports and papers on products with a high concentration of heavy metals. The study focused on foods commonly consumed in Korea. The levels of heavy metals(Pb: Lead, Cd : Cadmium, Al : Aluminum, Hg : Mercury, Me-Hg : Methyl-mercury, As : Arsenic, I-As : Inorganic arsenic) were measured of marine food(134 species) and in agricultural food (136 species) samples collected from local markets in Korea(Seoul, Metropolitan area, Gangneung, Daejeon, Daegu, Gwangju, Busan).

Marines products groups were classified fishes(60 species), shellfishs(19 species), crustaceans(14 species), mollusks(10 species), seaweeds(9 species), echinoderms & chordates(4 species), deep sea fishs(18 species), respectively. The marine products were classified as ordinary fish or dried fish. Inspection part is a byproduct and muscle. Agriculturals products groups were classified cereals(13 species), beans(7 species), bulbous(4 species), nuts & seeds(11 species), vegetables(72 species), fruits (22 species), mushrooms(7 species), respectively. The number of purchase quantity was 22,476 sample.

After being digested in HNO<sub>3</sub>-H<sub>2</sub>O<sub>2</sub> solution, the concentrations of Pb, Cd, As and Al in the food products were determined using inductively coupled plasma mass spectrometry (ICP-MS) or inductively coupled plasma optical emission spectrometry (ICP-OES).The concentrations of Hg in food products were determined using gold amalgamation. Instrumental analysis and quality assurance/quality control(QA/QC) were carried out the Kist, ANAPEX and Chosun University.

### 2. Estimation of average daily intakes and risk assessment

To identify dietary patterns, target items listed in the Korean nutrient database were categorized into eight groups(≤2 age, 3-6 age, 7-12 age, 13-19 age, 20-64 age, ≥65 age, ≥20 age, All age). This study included 26,041 participated in the Korean National Health and Nutrition Examination Survey (KNHANES 2008-2010). Food content and consumed amounts were obtained by the one day 24-h recall method; then, the nutrient intake was analyzed. Food intakes of total marines products and total agriculturals products were calculated 58.3g and 850.1g, respectively. Statistical analysis was performed using SPSS version 9.2.(Table 1).

PTWIs(The provisional tolerable weekly intake) for Pb, Cd, Al, Hg, As, Me-Hg and I-As were cited by the International representative institutions (Table 2). The equation of the average daily dose(ADD) for heavy metals in food used in as follows :

$$ADD = \frac{(C_{\text{food}} \times IR_{\text{food}})}{BW}$$

- ADD : average daily dose (ug/kg -day)
- C<sub>food</sub> : heavy metals concentration in food (ug/g)
- IR<sub>food</sub> : ingestion rate of food (g/day)
- BW : average body weight(kg)

## Results and discussion

### 1. Average daily intakes and health risks

The total average daily intake of Pb in marine&agricultural products was 0.203 µg/kg-day, and the total average daily intake of Cd was 0.302 µg/kg-day, and the total average daily intake of Al was 5.996 µg/kg-day, and the total average daily intake of Hg was 0.068 µg/kg-day, and the total average daily intake of As was 3.636 µg/kg-day (Table 3.).

The highest level of Cd was found in marine products, and the highest level of Al was found in agricultural products. Children's intake of %PTWI was higher than that of the other age groups (Figure 1.).

Among the marine food groups, mollusks were primarily responsible for the ingestion of Pb, Al, and Cd, and cereals were the major contributing food group of Cd, As, and Hg among the agricultural products. Looking at trends in marine products by age, seaweed was mainly responsible for exposure to heavy metals in those younger than 2 years and older than 65 years. Looking at trends in agricultural products by age, cereal was mainly responsible for exposure to heavy metals in all age groups. When looking at the contribution of the overall food group to expose, Al was mainly found in vegetables, Hg in fish, and I-As in cereals(Figure 2.).

### 2. Top ranks of heavy metal exposure from marines and agricultural products

The intake of Pb, Cd, Al, and As via ingestion of marine products was high, with seaweed and mollusk mainly responsible for the high intake. And the intake of Cd, As, and Hg via ingestion of agricultural products was high, with Cereal and Vegetable mainly responsible for the high intake. The percent of intake to the PTWI of Pb, As(includ Inorganic As), Hg and methyl-Hg were below about 20%. However, in case of Cd, marines products(specially mollusks) and agriculturals products have the slightly high contribution rate. And in case of Al, agriculturals products(specially vegetables) have the slightly high contribution rate.

### 3. Comparison risk of heavy metal and suggestion of management method for heavy metal

The concentration of Cd and Al in food were higher than that of other metals. The daily ingestion doses of Pb, Hg and As in food were below 20% of the PTWIs, respectively. And the concentration of Al in food were higher than that of other metals from the agriculturals products. Steps are needed to prevent the ingestion of heavy metals via consumption of marine and agricultural products. In the marine products group, consumption of mollusks was mainly responsible for exposure to heavy metals. Caution is needed with regard to the intake of food by sensitive groups. In the case of agricultural products, rice is primarily responsible for exposure to heavy metals due to characteristic Korean dietary habits. A mixed diet containing various cereals is recommended to ensure an adequate intake of nutrients.

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Table 1. Food intake for marines and agriculturals products according to age groups in Korea(based on 2008-2010)

Age group	Total (g/day)	Marines products (g/day)	Agriculturals products (g/day)	Body weight (kg)
≤2 age	316.5	14.5	302.0	12
3-6 age	393.6	21.6	372.0	19
7-12 age	505.8	34.3	471.5	37
13-19 age	499.2	38.2	461.0	58
20-64 age	678.2	59.1	619.1	63
≥65 age	615.8	36.6	579.2	58
Adult(≥20 age)	677.3	55.8	613.5	62
All age	621.7	48.9	572.8	55

\* table 1 data are included to analysis of foods only

Table 2. Intake recommendation standard of heavy metals

Heavt metal	international standard (PTWI)	Reference
Lead(Pb)	25 ug/kg-week	RIVM(2000)
Cadmium(Cd)	25 ug/kg-month(PTMI)	JECFA(2013)
Aluminum(Al)	2,000 ug/kg-week	JECFA(2013)
Mercury(Hg)	4 ug/kg-week	JECFA(2013)
Arsenic(As)	350 ug/kg-week	JECFA(2000)
Methyl-mercury(Me-Hg)	1.6 ug/kg-week	JECFA(2003)
Inorganic arsenic(I-As)	2 ug/kg-day(PTDI)	JECFA(2011)

Table 3. Average daily intakes of heavy metals in marines and agriculturals products(ug/kg-day)\_ All age

marines products	Heavy metal	Total	Fishes & deep sea fishes (78species)	Shellfishs (19species)	Crustaceans (14species)	Mollusks (10species)	Seaweeds (9species)	Echinoderms & Chordates (4species)
	Pb	0.103	0.013	0.007	0.004	0.044	0.033	0.001
	Cd	0.202	0.006	0.023	0.007	0.109	0.056	0.000
	Al	0.374	0.019	0.041	0.013	0.198	0.102	0.000
	Hg	0.055	0.048	0.001	0.001	0.005	0.001	0.000

	As	3.281	1.081	0.260	0.140	0.492	1.292	0.016	
	Me-Hg	0.020	0.020	-	-	-	-	-	
	I-As <sup>1</sup>	0.003	0.000	-	-	-	0.003	-	
agricultural products	Heavy metal	Total	Cereals (13species)	Beans (7species)	Bulbous (4species)	Nuts & Seeds (11species)	Vegetables (72species)	Fruits (22species)	Mushrooms (7species)
	Pb	0.100	0.017	0.003	0.008	0.001	0.047	0.025	0.001
	Cd	0.100	0.056	0.003	0.008	0.002	0.025	0.003	0.003
	Al	59.586	9.184	0.917	6.898	0.657	26.689	15.157	0.083
	Hg	0.013	0.009	0.000	0.000	0.000	0.002	0.001	0.000
	As	0.355	0.321	0.001	0.001	0.000	0.023	0.005	0.003
	Me-Hg	-	-	-	-	-	-	-	-
I-As <sup>2</sup>	0.230	0.230	-	-	-	-	-	-	

1. Only calculate in fishes and seaweeds
2. Only calculate in rice and brown rice

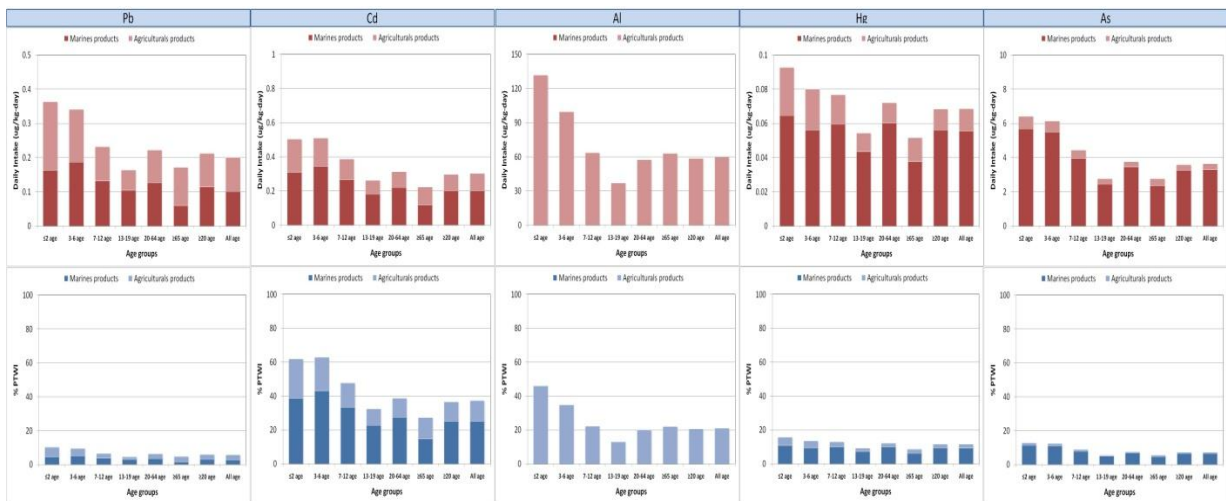


Figure 1. Average daily intake and %PTWI of heavy metal

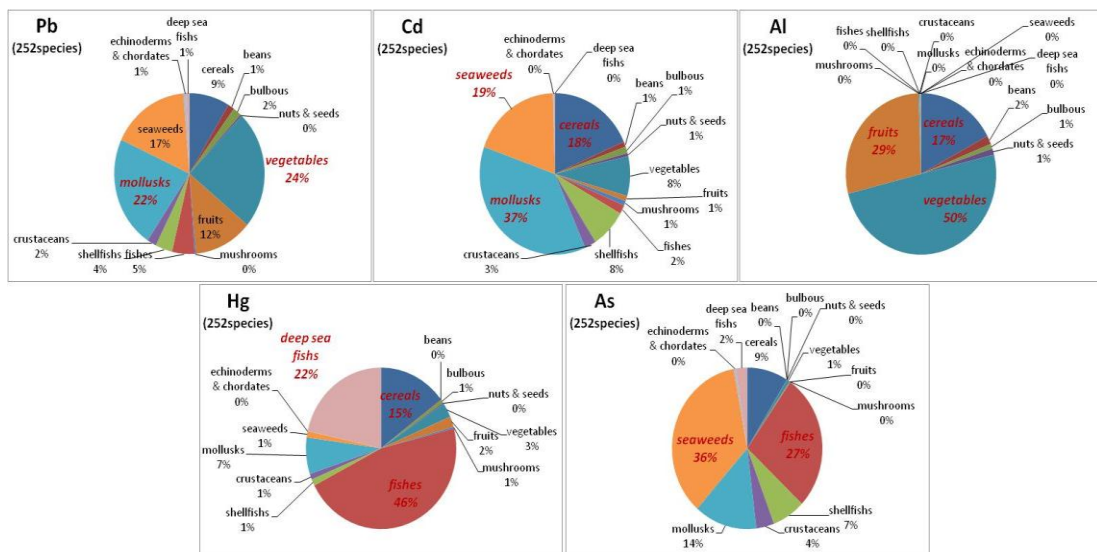


Figure 2. contribution rate of Heavy metal (all food groups)