



## Risk Assessment of Arsenic

Arsenic (As) is a metalloid that has both metal and nonmetal properties and is widely distributed in soils, water, air, and rocks. As is absorbed by inhalation and oral ingestion, and is rarely absorbed through the skin. The absorption rate through the digestive organs is about 90%, which is relatively higher than that of other heavy metals. In particular, trivalent and pentavalent inorganic As compounds are quickly absorbed through the digestive organs and have a high absorption rate. The absorbed As binds to red blood cells *in vivo* and is deposited in the liver, kidneys, muscles, bones, hair, skin, and nails. The absorption of As particles in air through inhalation has high correlations with particle size and solubility.

As has wide-ranging toxicity depending on its chemical form. Pure metal As and organic As have low toxicity, but soluble inorganic As causes acute toxicity. Ingestion of As in large quantities causes dysfunction in the gastrointestinal tract, cardiovascular system, and nervous system, and eventually leads to death. Survivors of As poisoning were found to have bone marrow degeneration, hemolysis, hepatomegaly, melanosis, polyneuropathy, and encephalopathy.

This risk assessment was conducted in the following four stages in accordance with the Regulations on Risk Assessment Methods and Procedures as well as the Risk Assessment Guide: hazard identification, hazard characterization, exposure assessment, and risk characterization. The maximum allowable daily body load of 50  $\mu\text{g}/\text{kg}$  bw/day, which was suggested by the World Health Organization (WHO)<sup>1</sup> in 1967, was applied as the safety standard for human exposure to As in Korea.

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<sup>1</sup>WHO, 1967. Technical Report Series No. 373

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Target foods were selected from the 2008–2010 (three years) Integrated Database, and this study covered 89% of the total food intakes of Koreans. Food commodities were purchased across Korea between 2012 and 2015. A total of 33,148 cases (agricultural: 11,297, livestock: 9,397, fishery: 6,630, and processed foods: 5,824) for 403 items (agricultural: 136, livestock: 20, fishery: 106, and processed foods: 141) were collected.

The analysis of As in food was performed using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), and an absence of As in the analyte indicated that the As concentration was lower than the detection limit of the assay. In risk assessment, half of the detection limit was applied to the undetected results (GEMS/Food-Euro, 1995).

The As detection rate in the agricultural products was 80.6%. The As concentration was  $<0.1$  mg/kg in most agricultural products, and As levels of  $\geq 0.3$  mg/kg were detected in some cereals, nuts and seeds, vegetables, and mushrooms. The average As level in the agricultural products was  $0.018 \pm 0.194$  mg/kg.

The As detection rate in the livestock products was 82.4%. The As concentration was  $<0.05$  mg/kg in most livestock products, and the average As concentration in the livestock products was  $0.009 \pm 0.031$  mg/kg.

The As detection rate in the fishery products was 99.1%. The average As concentration in all fishery products was  $3.216 \pm 5.690$  mg/kg.

The As detection rate in the processed foods was 79.8%. The As concentration in most processed foods was  $<2.0$  mg/kg, and the average As pollution level in all processed foods was  $0.575 \pm 3.012$  mg/kg.

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**Table 1.** As concentration

Categories	Items	Cases	Concentration levels (mg/kg)							
			No detection cases	Detection rate (%)	Average	Deviation	Min	P50	P95	Max
Agricultural products	136	11,297	2,194	80.6	0.018	0.194	<0.000	0.004	0.072	15.217
Livestock products	20	9,397	1,656	82.4	0.009	0.031	<0.000	0.005	0.024	2.200
Fishery products	106	6,630	61	99.1	3.216	5.690	0.003	1.595	11.175	90.926
Processed foods	141	5,824	1,177	79.8	0.575	3.012	<0.000	0.018	1.417	55.412
<b>Total Foods</b>	<b>403</b>	<b>33,148</b>	<b>5,088</b>	<b>84.7</b>	<b>0.753</b>	<b>3.105</b>	<b>&lt;0.000</b>	<b>0.008</b>	<b>3.629</b>	<b>90.926</b>

\* If there is a value below the third decimal point, it is indicated as <0.000.

Risk assessment showed that dietary exposure to As remained at safe levels within the health-based guidance values (HBGVs). Average daily exposures in Korean population to As was 3.650  $\mu\text{g}/\text{kg}$  bw/day. The As contribution rates of fishery products was 60% (2.184  $\mu\text{g}/\text{kg}$  bw/day), that of processed foods was 31% (1.130  $\mu\text{g}/\text{kg}$  bw/day), that of agricultural products was 9% (0.328  $\mu\text{g}/\text{kg}$  bw/day), and that of livestock products was <1% (0.008  $\mu\text{g}/\text{kg}$  bw/day), respectively.

The risk level of As exposure was approximately 7%. Among the food groups, the risk level of As was 0.6% through agricultural products, <0.0% through livestock products, 4.4% through fishery products, and 2.3% through processed foods.

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**Table 2.** As exposure from food

Categories		Exposure Levels (µg/kg bw/day)							
		All ages	≤2 years	3–6 years	7–12 years	13–19 years	20–64 years	≥65 years	
Agricultural products	Cereals	0.301	0.670	0.601	0.445	0.286	0.277	0.365	
	Root and tuber crops	0.001	0.003	0.002	0.001	0.001	0.001	0.001	
	Beans	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
	Seeds and nuts	Peanuts or nuts	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
		Seeds	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
		Sum	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
	Fruits	Kernel fruits	0.003	0.008	0.005	0.003	0.001	0.003	0.003
		Citrus fruits	<0.000	0.002	0.002	0.001	0.001	<0.000	<0.000
		Stone fruits	<0.000	0.001	0.001	0.001	<0.000	<0.000	<0.000
		Berries	<0.000	0.005	0.003	0.002	<0.000	0.001	<0.000
		Tropical fruits	<0.000	0.001	0.001	<0.000	<0.000	<0.000	<0.000
		Sum	0.003	0.017	0.012	0.007	0.002	0.004	0.003
	Vegetables	Green head vegetables	0.001	0.001	0.001	0.001	0.001	0.002	0.002
		Green vegetables	0.006	0.003	0.003	0.003	0.002	0.006	0.009
		Leaf and stem vegetables	0.004	0.003	0.004	0.004	0.003	0.004	0.003
		Root vegetables	0.004	0.007	0.007	0.004	0.003	0.004	0.004
		Cucurbitaceous fruit vegetables	0.003	0.003	0.004	0.002	<0.000	0.003	0.002
		Others than cucurbitaceous fruit vegetables	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000
		Sum	0.018	0.017	0.019	0.014	0.009	0.019	0.020
	Mushrooms	0.004	0.006	0.005	0.004	0.003	0.004	0.001	
	Livestock products	Beef	0.002	0.003	0.003	0.003	0.003	0.002	0.002
Pork		0.002	0.002	0.004	0.003	0.003	0.002	<0.000	
Other edible meats		<0.000	0	0	0	0	<0.000	<0.000	
Chicken		0.003	0.004	0.004	0.004	0.004	0.003	0.001	
Other poultry		<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	
Chicken eggs		0.001	0.003	0.003	0.002	0.001	0.001	<0.000	
Other eggs		<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	
Other animals		<0.000	0	0	0	0.001	<0.000	0	

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Categories			Exposure Levels (µg/kg bw/day)							
			All ages	≤2 years	3–6 years	7–12 years	13–19 years	20–64 years	≥65 years	
Fishery products	Fish	Freshwater fish	Freshwater fish	0.005	0.006	0.005	0.005	0.017	0.018	
		Migratory fish	Migratory fish	0.002	<0.000	0.001	0.005	0.005	0.003	
		Marine fish	General fish	0.819	1.001	0.814	0.686	0.424	0.895	0.702
			Deep sea fish	0.011	0	0.019	0.011	0	0.013	0.009
			Tuna and billfish	0.031	0.035	0.007	0.018	0.013	0.037	0.016
			Sum (Marine fish)	0.861	1.036	0.840	0.715	0.437	0.945	0.727
		Sum	Sum	1.043	0.846	0.721	0.447	0.967	0.748	
	Fish eggs	<0.000	<0.000	0.002	<0.000	<0.000	<0.000	<0.000		
	Invertebrates	Crustaceans	0.152	0.056	0.253	0.125	0.066	0.173	0.091	
		Mollusks	Shellfish	0.279	0.311	0.227	0.281	0.180	0.313	0.162
			Cephalopods	0.444	0.253	0.558	0.498	0.473	0.480	0.135
			Other mollusks	0.001	0.001	0.001	<0.000	<0.000	0.001	<0.000
			Sum (mollusks)	0.724	0.565	0.786	0.779	0.653	0.794	0.297
		Echinoderms	0.004	0.001	0	<0.000	<0.000	0.006	0.002	
		Tunicates	0.012	<0.000	0.002	0.008	0.005	0.014	0.006	
		Sum	0.892	0.622	1.041	0.912	0.724	0.987	0.396	
	Seaweeds	0.412	1.077	0.999	0.574	0.319	0.403	0.397		
	Processed foods	Cookies	0.014	0.085	0.076	0.048	0.033	0.009	0.003	
		Bread or rice cakes	0.008	0.019	0.022	0.015	0.011	0.008	0.006	
		Sugar	0.001	<0.000	<0.000	<0.000	<0.000	0.001	<0.000	
Fish meat products		0.016	0.038	0.039	0.026	0.019	0.016	0.003		
Tofu or jellied foods		0.003	0.004	0.004	0.003	0.002	0.003	0.002		
Cooking oils		<0.000	<0.000	<0.000	<0.000	<0.000	<0.000	<0.000		
Noodles		0.019	0.016	0.017	0.024	0.022	0.020	0.011		
Teas		0.002	0.001	<0.000	<0.000	0.002	0.003	0.001		
Coffee		0.002	<0.000	<0.000	<0.000	<0.000	0.003	0.002		
Drinks		0.001	0.006	0.004	0.002	0.002	0.001	<0.000		
Special foods		<0.000	0.001	0	0	0	0	<0.000		
Fermented soy products		0.045	0.041	0.050	0.045	0.034	0.047	0.043		
Seasonings and dressings		0.004	0.006	0.009	0.009	0.007	0.004	0.001		
Kimchi	0.064	0.035	0.052	0.057	0.047	0.067	0.072			

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	All ages	$\leq 2$ years	3–6 years	7–12 years	13–19 years	20–64 years	$\geq 65$ years
Salted fish products	0.058	0.016	0.037	0.039	0.033	0.062	0.065
Salted foods	0.009	0.005	0.009	0.007	0.007	0.010	0.007
Braised foods	<0.000	<0.000	0.001	0.001	0.001	<0.000	<0.000
Liquors	0.005	<0.000	<0.000	<0.000	0.001	0.006	0.004
Dried fish and shells	0.048	0.027	0.075	0.070	0.067	0.050	0.007
Other foods	0.764	2.452	2.205	1.487	0.954	0.711	0.390
Nonstandard general processed foods	0.064	0.096	0.119	0.127	0.108	0.058	0.026
Dairy products	0.001	0.027	0.014	0.005	0.004	0.001	0.001
Processed meat products	0.002	0.007	0.009	0.005	0.005	0.001	<0.000

As has a wide-ranging degree of toxicity depending on the form. Thus, an analytical method that can distinguish As species in foods needs to be established, and exposure assessment should be conducted based on As species using this method. Additionally, the risks of each As species should be assessed in future studies because the toxicity of inorganic As has been found to be correlated with carcinogenesis or specific skin diseases.

This report is based on published research reports. Therefore, the data in this report will be reassessed when new information is identified or sufficient monitoring data are available.

**Key words:** Arsenic, Analysis, Food, Source of exposure, Exposure level, Risk Assessment, Toxicity, Maximum Allowable Daily Level