Heavy metal exposures among residents in an abandoned metal mine area, Goseong, Korea

[1]K Choi, [2]HJ Kwon, [3]HK Chung, [4]JY Jang, [1]YC Hong, [5]DS Kim, [6]DH Paek, [7]WH Yang, [8]HM Lee [3]IJ Chung [1]KG Kim

[1]Seoul National University, [2]Dankuk University, [3]Sungkyunkwan University, [4]Ajou University, [5]National Institute for Environmental Research, [6]Seonam University, [7]Daegu Catholic University, [8]Korea Food and Drug Administration

1. Backgrounds

There was a report suspecting a cadmium related health symptoms among the residents near an abandoned copper mine in Byungsan-ri, Goseong-gun, Gyeongsangnam-do In the study area, there were three abandoned copper mines, i.e., Samsan Jeil, Samsan Jeil-2, and Sambong mines. The incidences of so called "Itai-itai"-like symptom among the residents were hinted in mass-media, which raised nation-wide public concerns. This investigation was initiated to understand the levels of environmental exposure to the heavy metal contaminants among the residents. That is, the extents of heavy metal contamination in various agricultural products and sea foods, as well as environmental media such as soil, surface water, groundwater, and air were investigated. The information gleaned from this study may be employed for development of appropriate risk management strategies.

2. Method

Samples collected and contaminants of potential concern

Three environmental media, including air, drinking water, and soil were collected. In addition, six agricultural products, i.e., rice, barley, pepper, bean, stems of sweet potato, and sesame leaves were collected. Oysters were also harvested from near by mud flat (tideland).

Five heavy metals were chosen as contaminants of potential concern, based on the reports from other old copper mines in Korea. These heavy metals include cadmium, lead, arsenic, copper, and zinc.

Selection of reference sites

Two reference sites were chosen in near by rural areas, Songchun-1-gu, and Daepyung-ri where the effects from the metal mines could be ruled out.

Soil, drinking water, and air samples

A total of 40 surface soil samples were collected from residential areas and road sides of the study area. From reference sites, five and six surface soil samples were collected from Songchun-1-gu and Daepyung-ri, respectively. Samples were analyzed by EPA 3050B and 6010B. Nine groundwater wells were sampled from the study area. Three groundwater samples were collected from the reference sites. Water samples were analyzed by appropriate standard methods. For air samples, three locations were chosen from the study area and two reference sites, where the influence of

traffics could be ruled out. PM10 and total suspended particulates (TSP) were analyzed. In addition PM2.5 was collected in the study area. From the PM10 samples, heavy metal contents were analyzed. Samples were quantified using an ICP.

Agricultural products

Several agricultural products which were available in the study and reference area between July and October, 2004, including pepper, bean, sesame leaves, and stem of sweet potato were chosen because they were produced in high amount. Rice and barley samples were collected from each household since these products were already harvested. In addition, oyster samples, which are a major household income, were collected from the study area and Songchun-1-gu during two sampling events. Samples were analyzed using an ICP-MS and an AAS.

Table 1. Sampling locations and number of agricultural samples and oyster

	Study area					Reference area						Total
	A	B	C	D	Other	S-1	D	J	W	DS	M	
Rice	12(10) 9(9)	7(7) 8(8)	9(9) 4(4)	25(15) 6(6)	5(5)	7(5)	5(5)	5(4)	5(5)	-	5(5)	112(97)
Barley	-	-	2(2)	2(2)	3(3)	4(4)	-	-	-	5(5)	3(3)	19(19)
Pepper	6(5)	5(5)	-	6(5)	-	5(5)	5(5)	-	-	-	-	27(25)
Bean	5(5)	-	-	5(5)	-	5(5)	1	-	-	-	-	16(15)
Sesame Leaves	5(5)	-	-	5(5)	-	4(4)	5(5)	-	-	-	-	19(19)
Stem of sweet potato	3(3)	-	-	5(5)	-	5(5)	5(5)	-	-	-	-	18(18)
Oyster (Aquacultured)	5(5)					5(5)					5(5)	29(29)
Oyster	9(9)					5(5)						

* Numbers indicate sample collected. Numbers in parenthesis are the samples analyzed

-: No sampling was made

Exposure assessment

Heavy metal exposure was estimated for the residents in the study area, using the equation below. Average amounts of consumption of each agricultural products and oyster were obtained from Exposure Factors Handbook (US EPA 1997) and Korean National Survey (2001).

$$\exp osure(mg/kg\_d) = \sum_{i=1}^{n} \frac{Ci \times CRi}{BW}$$

C_i : Heavy metal concentration in exposure media i (mg/kg)

CR_i : Daily contact rate of exposure media i

- air, 13 m^3/day; drinking water, 2 L/day; soil, 50 mg/day

BW : average body weight of Korean adults, 60 kg

3. Results and discussion

Heavy metal contamination in the study and reference areas

Surface soil in the study area showed 2-10 times higher levels of heavy metals compared to the reference sites. However, only lead exhibited a statistically significant differences. However, groundwater and air did not show any notable differences in heavy metal concentrations.

With rice and barley, cadmium levels were significantly higher in the study area. Among rice samples collected from the study area, three samples exceeded the regulatory limit of 0 2 mg/kg. All of the three samples were collected from locations near the metal mines or from the area influenced by mine drainage. Table 2 summarizes the levels of contamination of environmental media and agricultural products collected from the study and reference areas.

Heavy metal exposure among residents in the study and the reference areas

Table 3 summarizes the daily heavy metal exposure among residents in the study and the reference areas through contact with environmental media and various agricultural products. While the amount of cadmium exposure was 0.101 ug/kg_d in the reference population, the Byungsan-ri residents were exposed to 0.190 ug/kg_d of cadmium. Major source of cadmium exposure was through consumption of rice, which accounts for 96.5% of total cadmium uptake. The main route of exposure for the other metals such as copper, zinc, arsenic, and lead is also through the consumption of rice. At least 70% of total heavy metal exposure was explained by such route.

4. Conclusion

Soil and agricultural products collected from the Byungsan-ri area were contaminated with heavy metals. Human exposure to heavy metals in the study area was mainly through the consumption of rice. Especially with cadmium, copper, and zinc, rice accounts for >90% of heavy metal exposure. Rice harvested in rice paddy near the abandoned copper mines showed relatively higher levels of heavy metals, which strongly suggest the source of heavy metal contamination in the study area.

Table 2. Heavy metal levels of environmental media and agricultural products collected from the study and reference (B: Byungsan-ri (Study area), Ref: Reference area)

	Unit	n	Cd		Cu		As		Pb		Zn	
			B	Ref	B	Ref	B	Ref	B	Ref	B	Ref
rice	mg/kg	87	0.048	0.025	3.510	2.450	0.154	0.157	0.061	0.052	17.45	16.61
barley		7	0.021	0.011	3.599	2.802	0.005	0.006	0.054	0.040	16.48	15.25
bean		10	0.006	0.008	2.972	4.045	0.01	0.015	0.023	0.035	16.92	21.83
Sesame leaves		10	0.005	0.001	1.966	1.458	0.015	0.017	0.148	0.078	8.308	5.651
pepper		15	0.015	0.017	1.576	0.77	0.003	0.002	0.056	0.08	1.607	1.888
Stem of sweet potato		8	0.002	0.001	0.941	0.518	0.201	0.007	0.611	0.081	3.345	2.279
Oyster		14	0.224	0.210	63.15	25.54	1.169	1.329	0.243	0.154	137.7	103.9
Air	ug/m^3	11	0	0	0.075	0.063	0	0	0.11	0.06	0.15	2.14
Soil	mg/kg	38	0.35	0.18	268.2	66.37	22.53	7.3	62.71	23.33	249.2	119.3
Drinking water	mg/L	10	0	0	0.001	0	0.007	0.002	0	0	0.029	0.001

Table 3. Total daily heavy metal intake (ug/kg_d) among the Byungsan-ri and the reference populations through contact with environmental media and agricultural products and their relative contribution (per cent)

	Cd		Cu		As		Pb		Zn	
	B	Ref	B	Ref	B	Ref	B	Ref	B	Ref
Total exp*	0.190	0.101	15.13	10.32	0.860	0.691	0.335	0.250	72.24	68.09
Rice	96.5%	94.3%	88.6%	90.7%	68.5%	86.8%	69.6%	79.5%	92.2%	93.1%
Barley	0.9%	0.9%	1.9%	2.2%	0.0%	0.1%	1.3%	1.3%	1.8%	1.8%
Bean	0.2%	0.4%	1.0%	2.1%	0.1%	0.1%	0.4%	0.7%	1.2%	1.7%
Sesame leaves	0.1%	0.0%	0.5%	0.6%	0.1%	0.1%	1.7%	1.2%	0.5%	0.3%
Pepper	0.8%	1.7%	1.0%	0.7%	0.0%	0.0%	1.7%	3.2%	0.2%	0.3%
Stem of S. potato	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	1.7%	0.3%	0.0%	0.0%
Oyster	1.4%	2.5%	5.1%	3.0%	1.7%	2.3%	0.9%	0.8%	2.3%	1.9%
Air**	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	7.1%	5.2%	0.0%	0.7%
Soil	0.2%	0.1%	1.5%	0.5%	2.2%	0.9%	15.6%	7.8%	0.3%	0.1%
D. water	0.0%	0.0%	0.2%	0.0%	27.2%	9.7%	0.0%	0.0%	1.3%	0.0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%