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## Abstract

### Blood Pb, Urine Cd and Health Assessment of Residents in the Vicinity of Abandoned Mines in Gyeongsangbuk-do

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**Objectives:** The objective of this health assessment is to evaluate the health risks that may result from exposure to abandoned mine tailings in Gyeongsangbuk-do. The tailings are remnants from an earlier flotation mill and mining operation that was in business from the early 1930's until 1970.

**Methods:** The soil, stream water, and drinking water in and around three abandoned mine areas, Soochul, Gumjang, Darock, and three control areas located in Gyeongsangbuk-do were analyzed for level of Cd, Pb, Cu, As, and Hg. Potential chronic health effects were evaluated by interview and medical examination.

**Results:** Some soil and stream samples exceeded the Korean standard for soil contamination in farmland and the Korean standard of water contamination in streams respectively. Blood lead (5.37  $\mu\text{g}/\text{dl}$ ) and urine cadmium (2.79  $\mu\text{g}/\text{g Cr}$ ) levels of the residents in the vicinity of the abandoned mine sites were significantly higher than of the residents in the control areas (blood lead, 4.34  $\mu\text{g}/\text{dl}$ ; urine cadmium, 1.62  $\mu\text{g}/\text{g Cr}$ ). There were no significant differences between the mining and control areas in terms of blood pressure, Hb, BUN, creatinine, SGOT, SGPT, fasting blood sugar, and the prevalence of potential chronic diseases.

**Conclusions:** The results of the assessment suggested that the three abandoned mine sites do not pose an apparent health risk to nearby residents. Nevertheless, the elevated blood lead and urine cadmium levels in the residents of the abandoned mine site suggested that it might be an important source of heavy metals contamination. Therefore, a nationwide evaluation program is needed to assess the potential health risks of residents living in the vicinity of abandoned mine sites.

**Key Words:** Abandoned mine, Blood lead, Urine cadmium, Health assessment

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**Table 2.** Average concentration (mg/kg) of heavy metals in top and sub-soil at abandoned mine sites

Heavy metal (mg/kg)	Limit of concern (mg/kg)	Soochul							Gumjang							Darock						
		SP1	SP2	SP3	SP4	SP5	SP6	SP7	CP1	SP1	SP2	SP3	SP4	SP5	CP1	SP1	SP2	SP3	SP4	SP5	CP1	
pH	-																					
Top-soil		7.87	7.43	7.30	6.67	5.87	5.62	6.05	5.63	5.80	5.97	5.83	5.83	5.87	6.23	5.6	5.9	6.1	5.9	6.2	6.5	
Sub-soil		7.67	6.93	6.53	6.63	6.15	6.17	6.52	5.87	6.00	6.00	6.47	6.07	6.27	6.00	5.8	6.2	6.3	6.3	6.5	6.7	
Cd	1.5																					
Top-soil		0.18	0.20	0.05	0.03	0.26	0.32	0.10	0.07	0.55	0.26	0.21	0.25	0.30	0.05	5.860	0.450	0.245	0.170	0.225	0.190	
Sub-soil		0.09	0.11	0.02	0.04	0.40	0.36	0.09	0.05	0.36	1.44	0.15	0.35	0.71	0.05	4.415	0.220	0.190	0.100	0.320	0.135	
Pb	100																					
Top-soil		1.06	3.18	2.49	6.19	54.57	6.00	9.44	4.49	31.60	23.28	26.58	20.14	12.78	2.76	29.75	20.05	7.65	4.50	4.80	2.85	
Sub-soil		5.06	3.41	2.17	5.89	31.51	5.93	11.16	4.17	17.41	55.67	14.00	27.98	573.32	2.02	15.90	9.40	4.55	2.85	4.30	2.20	
Cu	50																					
Top-soil		4.63	3.83	1.12	1.06	57.75	8.58	3.47	3.98	11.94	5.27	4.38	4.24	2.12	2.40	7.810	3.790	4.210	5.540	5.405	5.085	
Sub-soil		7.41	4.28	0.68	1.23	37.00	8.82	4.18	2.98	3.67	6.77	2.68	2.90	43.00	1.93	16.200	2.330	4.000	3.840	5.085	1.585	
As	6																					
Top-soil		0.14	0.22	0.12	0.07	1.19	0.30	0.69	0.17	0.27	0.44	0.37	0.45	0.42	0.47	0.113	0.862	0.432	0.300	0.440	0.683	
Sub-soil		0.06	0.24	0.02	0.14	2.69	0.26	0.77	0.18	0.14	0.50	0.39	0.46	1.24	0.40	0.077	0.304	0.272	0.268	0.681	0.884	
Hg	4																					
Top-soil		0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.12	0.06	0.03	0.02	0.02	0.01	0.013	0.014	0.007	0.004	0.005	0.005	
Sub-soil		0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.07	0.04	0.04	0.02	0.02	0.01	0.018	0.014	0.004	0.006	0.009	0.009	

At Soochul AMS, SP1, just below of mine tailings waste site; SP2, 100 m from mine tailings waste site; SP3, 200 m from mine tailings waste site; SP4, 300 m from mine tailings waste site, SP5, farm land in front of mine tailings waste site; SP6, farm land 1.5 km east from SP5; SP7, farm land 1.5 km east from SP6; CP1, control site.

At Gumjang mining site, SP1, just below of mine tailings waste site; SP2, 50 m north from mine tailings waste site; SP3, 100 m north from mine tailings waste site; SP4, 200 m north from mine tailings waste site; SP5, 400 m north from mine tailings waste site; CP1, control site.

At Darock AMS, SP1, just below of mine tailings waste site; SP2, 200 m south from mine tailings waste site; SP3, 400 m south from mine tailings waste site; SP4, 600 m south from mine tailings waste site; SP5, 1 km south from mine tailings waste site; CP1, control site.

AMS: abandoned mine site.

**Table 3.** Average concentration (mg/kg) of heavy metals in water at abandoned mine sites

Heavy metal (mg/l)	Guideline (mg/l)	Soochul						Gumjang						Darock							
		WP1	WP2	WP3	WP4	WP5	WP6	WP1	WP2	WP3	WP4	WP5	CP1	CP2	WP1	WP2	WP3	WP4	WP5	CP1	CP2
pH	-	5.80	7.58	7.78	7.83	8.23	7.45	7.03	7.00	7.10	6.90	6.97	7.47	7.27	5.1	6.6	7.7	6.8	7.7	7.1	7.5
Cd	0.01	0.08	ND	ND	ND	ND	ND	ND	0.01	0.01	0.02	0.01	ND	ND	0.34	ND	ND	ND	ND	ND	ND
Pb	0.1	0.13	ND	ND	ND	ND	ND	ND	0.02	ND	ND	ND	ND	ND	0.96	ND	ND	ND	ND	ND	ND
Cu	-	6.44	0.02	ND	0.03	0.01	ND	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.30	0.01	ND	0.01	ND	0.02	0.03
As	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

At Soochul AMS, WP1, just below of mine tailings waste site; WP2, stream of Dalsan 2-ri; WP3, joining point of stream from Dalsan 2-ri and stream from mine tailings waste site; WP4, 3 km from joining point; WP5, drinking water of Dalsan 1-ri; WP6, drinking water of Dalsan 2-ri.

At Gumjang AMS, WP1, upper stream from mine entrance; WP2, 300 m north from mine entrance; WP3, 600 m north from mine entrance; WP4, 1 km from mine entrance; WP5, drinking water of Sungu-ri; CP1, drinking water of control site; CP2, stream of control site.

At Darock AMS, WP1, just below of mine tailings waste site; WP2, stream of bridge; WP3, stream 200m from mine tailings waste site; WP4, stream joining point; WP5, drinking water of Songae-ri.

AMS: abandoned mine site.

ND: not detected.

**Table 4.** Blood lead concentration ( $\mu\text{g/dl}$ ) of the subjects of abandoned mine and control sites

Age group (yrs)	Abandoned mine site												Control site							
	Soochul				Gumjang				Darock				Total			Mean	SD	Median	Range	
	Mean	SD	Median	Range	Mean	SD	Median	Range	Mean	SD	Median	Range	Mean	SD	Median					Range
~49	3.83	0.82	3.58	2.97~5.22	5.84	3.04	5.00	2.92~13.84	7.27	-	-	-	5.12	2.52	4.48	2.92~13.84	4.58	1.33	4.37	3.16~9.47
50~59	4.56	1.21	4.40	2.87~6.78	5.67	1.46	5.42	3.10~7.54	5.64	1.63	5.05	3.60~8.49	5.10	1.44	5.01	2.87~8.49	4.52	1.42	4.43	2.81~10.30
60~69	5.58	2.85	4.76	2.99~14.86	5.68	2.64	5.36	2.83~15.08	5.41	1.35	5.15	3.53~8.75	5.58**	2.48	4.97	2.82~15.08	4.30**	1.43	3.97	2.74~9.80
70~	4.88	2.46	4.38	2.87~18.33	5.79	2.23	5.37	2.64~10.42	5.41	1.35	5.36	3.67~8.27	5.30**	2.24	4.74	2.65~18.33	4.21**	1.17	3.90	2.66~8.03
Total	5.00	2.42	4.42	2.87~18.33	5.74	2.42	5.32	2.64~15.08	5.48	1.38	5.25	3.53~8.75	5.37**	2.28	4.89	2.65~18.33	4.34**	1.33	4.10	2.66~10.30

SD: standard deviation.

\*\*  $p < 0.01$ , tested between average of abandoned mine sites and control sites.**Table 5.** Adjusted urine cadmium concentration ( $\mu\text{g/g Cr}$ ) of the subjects of abandoned mine and control sites

Age group (yrs)	Abandoned mine site												Control site							
	Soochul				Gumjang				Darock				Total			Mean	SD	Median	Range	
	Mean	SD	Median	Range	Mean	SD	Median	Range	Mean	SD	Median	Range	Mean	SD	Median					Range
~49	4.07	4.01	2.99	0.12~11.12	0.17	0.01	0.18	0.01~0.28	0.01	-	-	-	1.72	3.13	2.23	0.01~11.12	1.89	2.13	1.26	0.16~8.98
50~59	2.66	2.67	2.01	0.14~8.20	1.43	2.64	0.56	0.01~8.72	2.44	1.31	2.61	0.62~4.05	2.26	2.45	1.71	0.01~8.72	1.51	1.94	0.62	0.06~8.87
60~69	3.15	3.20	1.84	0.05~12.80	1.80	2.81	0.73	0.04~12.44	4.41	2.58	3.59	0.62~10.83	2.89**	3.06	1.74	0.04~12.80	1.23**	2.06	0.53	0.03~10.55
70~	3.23	3.14	2.19	0.04~11.37	1.45	2.44	0.72	0.02~12.18	5.97	4.39	4.49	0.89~12.76	3.09*	3.51	1.55	0.02~12.76	2.07*	3.23	0.61	0.01~13.86
Total	3.17	3.12	2.07	0.04~12.80	1.46	2.52	0.54	0.01~12.44	4.58	3.41	3.68	0.01~12.76	2.79**	3.18	1.61	0.01~12.80	1.62**	2.51	0.66	0.01~13.86

SD: standard deviation.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , tested between average of abandoned mine sites and control sites.



**Table 7.** Linear regression modeling of relations of blood lead ( $\mu\text{g}/\text{dl}$ ) concentration and urine cadmium ( $\mu\text{g}/\text{g Cr}$ ) concentration with AMS, age, sex, smoking and alcohol

Dependent variable	Independent variables	coefficient	SE	p-value	95% CI
Blood lead ( $\mu\text{g}/\text{dl}$ )	Soochul	0.74	0.21	0.00	0.33~1.15
	AMS Gumjang	1.47	0.22	0.00	1.04~1.90
	Darock	1.29	0.28	0.00	0.73~1.85
	Age (10 yrs)	0.02	0.09	0.85	0.19~0.16
	Sex (Male=1, Female=0)	1.31	0.17	0.00	0.99~1.65
	Smoking (Yes=1, No=0)	0.46	0.31	0.17	1.11~0.37
	Alcohol (Yes=1, No=0)	0.38	0.26	0.15	0.16~0.69
Urine cadmium ( $\mu\text{g}/\text{g Cr}$ )	Soochul	1.15	0.33	0.00	0.88~2.15
	AMS Gumjang	-0.18	0.34	0.06	-0.84~0.49
	Darock	2.91	0.44	0.00	2.05~3.78
	Age (10 yrs)	0.23	0.14	0.92	0.04~0.50
	Sex (Male=1, Female=0)	0.04	0.26	0.88	0.48~0.56
	Smoking (Yes=1, No=0)	0.03	0.12	0.78	-0.29~0.25
	Alcohol (Yes=1, No=0)	0.18	0.11	0.15	0.36~0.06

AMS: abandoned mine site; SE: standard error; CI: confidence interval.

**Table 8.** Result of medical examination of abandon mine and control sites

Medical Examinations	Soochul	Gumjang	Darock	Control site
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Systolic BP (mmHg)	149.0 $\pm$ 21.1 <sup>a</sup>	150.1 $\pm$ 20.2 <sup>a</sup>	138.8 $\pm$ 14.1 <sup>b</sup>	146.4 $\pm$ 19.2 <sup>a</sup>
Diastolic BP (mmHg)	86.4 $\pm$ 11.9 <sup>ab</sup>	93.0 $\pm$ 11.4 <sup>bc</sup>	84.6 $\pm$ 7.0 <sup>a</sup>	88.8 $\pm$ 9.8 <sup>bc</sup>
Hemoglobin (g/dl)	12.8 $\pm$ 1.4	12.8 $\pm$ 1.2	12.9 $\pm$ 1.2	13.0 $\pm$ 1.4
Hematocrit (%)	38.6 $\pm$ 4.3	39.2 $\pm$ 4.1	38.9 $\pm$ 4.1	39.1 $\pm$ 4.0
BUN (mg/dl)	15.8 $\pm$ 4.2 <sup>ab</sup>	16.0 $\pm$ 5.4 <sup>b</sup>	14.3 $\pm$ 4.3 <sup>a</sup>	15.8 $\pm$ 5.5 <sup>ab</sup>
Creatinine (mg/dl)	0.83 $\pm$ 0.17 <sup>a</sup>	0.87 $\pm$ 0.16 <sup>a</sup>	0.78 $\pm$ 0.12 <sup>b</sup>	0.84 $\pm$ 0.16 <sup>a</sup>
SGOT (IU/l)	25.0 $\pm$ 11.7 <sup>a</sup>	30.9 $\pm$ 12.0 <sup>b</sup>	26.8 $\pm$ 10.9 <sup>ab</sup>	29.3 $\pm$ 15.1 <sup>b</sup>
SGPT (IU/l)	14.8 $\pm$ 9.2 <sup>a</sup>	23.0 $\pm$ 14.8 <sup>b</sup>	17.7 $\pm$ 8.9 <sup>ab</sup>	21.8 $\pm$ 15.7 <sup>b</sup>
FBS (mg/dl)	100.7 $\pm$ 61.6	101.4 $\pm$ 35.8	101.9 $\pm$ 28.6	97.6 $\pm$ 30.9

BP: blood pressure, SGOT: serum glutamic oxaloacetic transaminase, SGPT: serum glutamic pyruvic transaminase.

<sup>a,b,c</sup> The values of same indication have not significant difference.

**Table 9.** Relative risk of diseases of abandoned mine and control sites

Diseases	AMS	Control site	Odds ratio (95% CI)	Adjusted odds ratio (95% CI)
	No.(%)	No.(%)		
Hypertension	96 (37.3)	81 (37.8)	0.98 (0.48~1.32)	0.92 (0.46~1.27)
Cardiac disease	18 (7.1)	25 (11.5)	0.59 (0.21~1.13)	0.51 (0.18~1.12)
Anemia	17 (6.5)	9 (4.3)	1.56 (0.49~4.03)	1.74 (0.44~3.91)
Liver disease	18 (7.1)	16 (7.3)	0.97 (0.32~2.12)	1.21 (0.40~2.80)
Kidney disease	5 (1.8)	12 (5.5)	0.31 (0.07~1.13)	0.30 (0.06~1.04)
Diabetes	20 (7.9)	19 (8.8)	0.88 (0.25~2.10)	0.94 (0.27~2.32)
Asthma	2 (0.8)	4 (1.8)	0.44 (0.03~4.63)	0.53 (0.04~6.13)
Arthritis	45 (17.3)	36 (16.8)	1.04 (0.43~2.01)	1.01 (0.41~1.78)

Adjusted odds ratio was the odds ratio controlled for age, sex, smoking and alcohol.

AMS: abandoned mine site, SE: standard error, CI: confidence interval.



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 4.34  $\mu\text{g/dl}$  ( 4.10  
 $\mu\text{g/dl}$ )  
 (p<0.01)  
 2.79  $\mu\text{g/g Cr}$  ( 1.61  $\mu\text{g/g Cr}$ )  
 1.62  $\mu\text{g/g Cr}$  (p<0.01)  
 0.66  $\mu\text{g/g Cr}$ )

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