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Geochemical Characterization of Acid Rock Drainage(ARD) in a Pyrophyllite Mine Area, Pusan: Preliminary Results

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1. Introduction

Metal- and sulfur-rich, acid rock drainage (ARD) can be harmful to the environment, due to the potential hazards to aquatic life, water contamination with toxic heavy metals, and little or no recreational value. Usually, ARD forms as a result of bacterial and chemical oxidation of sulfide minerals (mainly pyrite) in metallic mines. Recently however, ARD generation around non-metallic mines by oxidation of pyrite also has been reported.

A number of pyrophyllite deposits are distributed in the Pusan area, which were formed by hydrothermal alteration of andesitic volcanic rocks. Due to the low capacity of host rock for pH buffering, the generated ARD maintains low pH (down to 2.6), and therefore the high content of metals is contaminating the receiving Suyoung river to considerable downstream distance. This study aims to examine the distribution and variation of heavy metal contamination in surface water of a pyrophyllite mine area, and to investigate the geochemical processes controlling the fate of trace metals.

2. Study area

The study site is located in the northern part of Pusan City, covering the area ranging from 129°05′00″ E to 129°10′00″ E and from 35°21′00″ N to 35°15′00″ N. The major rocks in the area are andesite and granite (Park et al., 2000). Many pyrophyllite deposits occur in andesite and typically contain pyrite (up to 30 vol. %). Open-pit mining has exposed the pyrite-rich pyrophyllite deposits to the air condition. Furthermore, large amounts of waste rocks have been left untreated. Therefore, natural weathering of waste rocks produces acidic, metal-rich drainage. The precipitation of Fe, Al, and Mn hydroxides occurs in downstream area.

3. Sampling and analysis

For sampling, the streams were divided into two parts: Dongrae creek and Suyoung river. The stream water and stream-bed sediment samples were collected in the Dongrae creek (11 sites) and Suyoung river (19 sites) in December 2001 (Figure 1). Water samples consist of mine drainages, stream waters impacted by ARD, and unpolluted tributaries. Water samples collected for cation determination were filtered through a 0.45 µm cellulose nitrate membrane filter using a hand pump, and were immediately acidified in the field to pH < 2 by adding HNO_3. At the same sites of water sample collection, sediment samples were also collected with a plastic scoop and transferred into polyethylene bottles. Analysis of dissolved cations was performed using ICP-AES. Anions were analyzed using ion chromatography (IC). In order to determine the concentrations of electrochemically 'labile' metal species (Yun et al., 2001), the filtered and non-acidified water samples were also analyzed by Anodic Stripping Voltammetry (ASV).

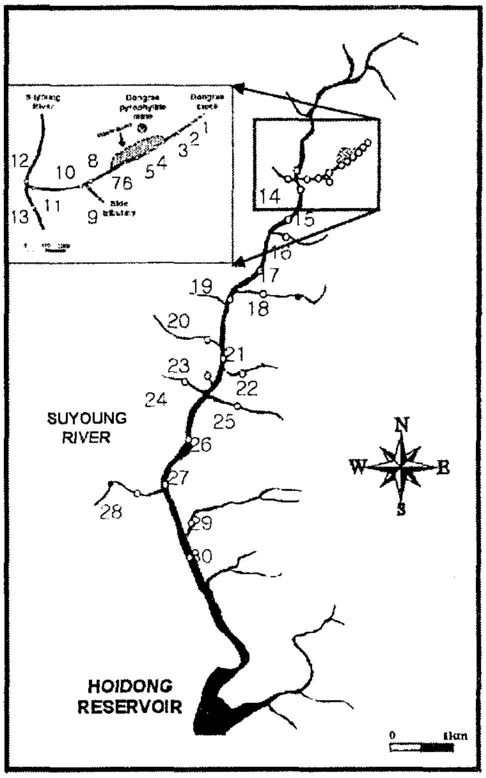

Fig. 1. Locality map showing the sampling site

4. Results

The Dongrae creek water generally show the characteristics of ARD or acid mine drainage (AMD), such as the minimum pH of 2.6 and the very high concentrations of dissolved metals. The maximum concentrations of Zn, Cu, Pb, and Cd were 4,419, 2,214, 8,002, and 54 ppb, respectively (Tables 1 and 2). However, the concentrations of heavy metals decrease down to detection limits at the confluence with Suyoung River. Most metals such as Al, Cd, Cu, Pb and Zn in the Dongrae creek and Suyoung river water generally decrease in amounts with increasing pH as the distance from the mine site increases. At the confluence of Dongrae creek with the mainstream of Suyoung river, characteristic phenomena of the mixing effect are observed, i.e., precipitation of white precipitates and the adsorption or coprecipitation of metals. Thereafter, pH of stream increases due to the mixing of unpolluted tributary, resulting in progressive decrease of heavy metals concentrations. Therefore, the stream waters in the Dongrae pyrophyllite mine area are contaminated by ARD, at least down to the confluence with the Suyoung river. We are now studying the removal of heavy metals by adsorption or coprecipitation with Fe and Al precipitates through laboratory neutralization experiments.

6. References

Park, M.E., Sung, K.Y., and Koh, Y.K. (2000) Formation of Acid Mine Drainage and Pollution of Geological Environment Accompanying the Sulfidation Zone of Nonmetallic Deposits: Reaction Path Modeling on the Formation of AMD of Tongrae Pyrophyllite Mine. Econ. Environ. Geol., v. 33, p. 405-415 (in Korean).

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Table 1. Physical parameter and major element composition (unit: ppm) of the Dongrae creek and Suyoung river in the study area

Sample No.	Distance (m)	Temp. (C)	pH	EC (µS cm-1)	Na	K	Ca	Mg	F	Cl	NO3	SO4	HCO3
							Dissolved constituents (mg/l)						
DR-1	0	11.1	6.51	59.6	5.3	0.4	4.4	0.9	0.3	4.2	2.9	3.6	18.3
DR-2	20	11.6	6.09	67.7	5.8	0.5	5.3	1.1	0.3	4.7	2.7	7.9	15.3
DR-3	80	11.2	4.21	175.8	7.9	1.9	13.0	2.7	5.1	7.3	3.9	74.2	0.0
DR-4	106	12.4	3.44	404	7.5	1.7	23.7	4.7	7.1	6.6	9.4	140.2	0.0
DR-5	113	13.2	2.59	3080	19.2	3.2	261.0	60.1	67.5	25.1	4.7	2193.2	0.0
DR-6	120	12.1	3.23	725	9.4	4.7	58.0	14.4	15.9	25.8	7.5	391.6	0.0
DR-7	320	15.3	2.25	6200	57.5	16.2	493.3	190.5	72.9	66.5	5.9	7916.1	0.0
DR-8	620	10.2	2.99	2160	11.9	3.6	151.5	45.8	33.9	21.7	3.7	1559.9	0.0
DR-9	620	10.7	6.16	81.6	5.4	0.6	6.2	1.7	0.5	4.8	3.3	15.2	15.3
DR-10	650	10.5	3.19	1521	15.4	3.9	104.9	32.7	8.6	11.3	2.2	1130.5	0.0
DR-11	920	12.5	3.44	939	24.5	4.8	59.9	20.0	5.5	11.9	3.3	626.0	0.0
DR-12	920	13.6	6.85	193.6	12.0	3.5	18.1	3.3	0.4	15.6	22.6	16.5	43.3
DR-13	920	12.3	6.59	150.3	9.0	3.4	12.5	2.3	0.3	11.4	10.5	8.4	45.8
DR-14	1070	14.1	5.62	225	11.3	3.4	21.7	4.8	1.5	14.3	23.9	60.7	11.0
DR-15	1270	15.9	6.27	223	10.3	2.8	22.4	4.1	1.2	14.1	20.9	55.9	6.1
DR-16	1770	10.5	6.95	230	12.5	3.2	19.8	4.0	1.7	24.6	21.6	42.9	8.5
DR-17	2770	13.2	6.17	243	10.9	5.5	24.1	4.6	0.9	18.2	31.4	52.0	18.9
DR-18	3020	9.7	6.84	388	47.5	3.6	20.3	2.2	0.6	19.8	17.6	105.4	35.4
DR-19	3270	11.3	6.91	218	10.5	4.2	20.8	3.8	0.8	21.6	24.7	33.5	23.2
DR-20	4020	10.5	7.69	190.5	10.5	4.1	20.6	3.8	0.8	21.1	23.9	31.4	26.2
DR-21	4020	13.4	6.82	206	9.6	4.6	19.5	3.8	0.7	15.1	18.8	38.6	28.1
DR-22	4300	8.7	7.23	281	18.9	8.9	23.9	4.3	0.6	31.0	17.9	45.9	35.4
DR-23	4550	11.3	7.1	220	10.9	4.2	20.4	3.9	0.8	21.6	24.2	36.5	20.7
DR-24	4770	8.0	7.39	288	26.9	8.2	19.7	4.5	0.4	44.1	20.5	21.4	58.0
DR-25	1770	10.2	6.86	68.9	4.7	1.0	4.4	0.9	0.3	5.3	3.1	4.2	17.1
DR-26	5700	10.1	6.97	285	20.3	4.8	25.4	4.3	0.7	19.6	26.8	47.7	41.5
DR-27	6520	13.3	9.98	155.1	56.6	7.2	40.4	4.6	0.6	100.2	28.9	21.3	106.8
DR-28	6520	11.1	6.5	241	16.1	5.4	24.2	4.5	0.9	21.8	28.1	33.0	44.5
DR-29	7270	11.0	6.6	490	37.0	10.4	46.2	8.0	0.6	52.7	17.0	63.1	126.9
DR-30	8070	11.8	6.7	252	17.8	5.2	25.5	4.6	0.6	23.3	17.8	36.5	65.9

Table 2. Trace element composition (unit: ppb) of the Dongrae creek and Suyoung river in the study area.

Sample No.	Al	Ba	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sr	Li	Zn
				Dissolved constituents (µg/l)									
DR-1	nd	16	nd	1	nd	nd	nd	4	nd	23	38	nd	nd
DR-2	nd	9	nd	1	nd	nd	5	5	1	67	38	nd	nd
DR-3	5364	27	1	31	nd	7	1025	387	15	94	149	9	39
DR-4	11900	38	2	79	nd	19	1693	2104	46	637	237	18	144
DR-5	225920	28	39	1399	19	649	76503	54965	845	3488	2025	318	2901
DR-6	34322	64	5	264	1	52	7966	7180	244	654	473	40	428
DR-7	678864	145	54	4527	109	2214	613701	40040	2826	8002	1638	1190	4419
DR-8	171311	42	17	918	4	181	22493	26843	599	911	882	170	1526
DR-9	226	8	nd	2	nd	4	61	82	1	nd	44	nd	nd
DR-10	116631	36	12	642	2	120	14247	18238	341	389	618	108	1107
DR-11	56097	39	5	346	5	54	2088	8452	236	129	327	52	651
DR-12	38	31	nd	1	nd	1	11	13	2	7	97	0	nd
DR-13	20	25	nd	1	nd	2	15	6	1	16	57	0	nd
DR-14	1275	40	nd	24	nd	3	100	649	20	12	111	3	18
DR-15	1057	39	nd	20	15	2	77	301	127	8	98	1	nd
DR-16	330	45	nd	18	nd	3	3	577	10	18	104	2	nd
DR-17	88	50	nd	1	nd	2	12	92	3	1	115	nd	nd
DR-18	73	13	nd	1	7	1	27	24	12	13	63	1	nd
DR-19	23	34	nd	1	nd	nd	nd	25	1	nd	98	nd	nd
DR-20	24	39	nd	1	nd	1	4	32	2	8	98	nd	nd
DR-21	30	31	nd	1	nd	2	40	39	1	nd	92	nd	nd
DR-22	22	308	nd	1	nd	3	31	46	1	nd	112	nd	nd
DR-23	36	47	nd	1	nd	1	nd	31	2	nd	97	nd	nd
DR-24	38	40	nd	nd	nd	1	2	11	nd	5	113	nd	nd
DR-25	6	13	nd	1	nd	nd	25	4	nd	4	26	nd	nd
DR-26	nd	31	nd	1	1	1	nd	65	2	1	116	nd	nd
DR-27	63	28	nd	1	16	3	39	9	2	2	150	10	nd
DR-28	182	29	nd	2	nd	2	208	31	2	1	120	nd	nd
DR-29	nd	71	nd	1	nd	4	15	137	2	10	198	nd	nd
DR-30	nd	26	nd	1	nd	1	10	70	1	6	127	nd	nd