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Distribution of heavy metal contamination in soils and sediments in the vicinity of the Hwacheon Au-Ag-Pb-Zn mine

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Abstract: In order to investigate the level of heavy metal contamination and the seasonal variation of metal concentrations in soils and sediments influenced by past mining activities, tailings, soil and sediment samples were collected from the Hwacheon mine in Korea. The main pollution sources in this mine site are suggested as tailings and mine waste rocks. Elevated levels of Cd, Pb and Zn were found in soils and sediments. In a study of seasonal variation on the heavy metals in soils and sediments, heavy metals were higher enriched collected from before rainy season (2nd sampling) than after rainy season (1st sampling). Also, in order to estimate the microbial effects on Cd speciation in sediments, bacteria which can adsorb Cd was isolated and Cd adsorption characteristics of isolated bacteria in Cd solution was evaluated. The Cd bioremoval efficiency in Cd solution (5 ppm) by bacteria was more than 90%. Bioremoval efficiency in single metal solution was higher than that in mixed metal solution of Pb and Zn.

1. Introduction

Mining is one of the most important sources of heavy metals in the environment. Mining and milling operations together with grinding, concentrating ores and disposal of tailings, along with mine and mill waste water, provide obvious sources of heavy metal contamination (Adriano, 1986). Therefore, large areas of agricultural land including paddy fields and stream sediments can be contaminated by heavy metals. Environmental surveys of the mining districts have been undertaken since the early 1990s, but further investigation is still needed to draw general conclusions about the fate and transport of toxic heavy metals in different environments, to treat or remove heavy metals from contaminated mining sites.

Microorganisms in sediments can alter metal mobility and can leach metals from sediments, adsorb metals on their cell wall and accumulate metals intracellular matrix. Thus, the microbial geochemical characteristics of isolated bacteria effecting on the behavior of heavy metal in sediments are very important.

The objectives of this study are to investigate the extent and degree of heavy metal contamination of soils and sediments around the Hwacheon Au-Ag-Pb-Zn mine, to examine the seasonal variations of heavy metals in soils and sediments and to estimate the microbial effects on Cd speciation in sediments in the vicinity of the Hwacheon mine.

2. Materials and methods

The study area is the Hwacheon Au-Ag-Pb-Zn mine, Korea. During the period of operation, mainly in the 1940s, the mine produced a thousand tons of Pb and Zn. The geology of the mine is mainly conglomerate, sandstone and black shale. The mine ceased production in 1989 and large amounts of mine wastes including tailings have been left without proper environmental treatment. Thus, these materials have been dispersed downslope by surface erosion, wind and rain action. Effulent discharged from the tailings flows into the main stream in this area.

Samplings of tailings, soils and sediments was carried out on October (after rainy season) in 2002 and on May (before rainy season) in 2003. The sampling locations is shown in Fig. 1.

After air-drying, soil and sediment samples were disaggregated, sieved to < 2 mm and then ground to a fine powder (< 180 μm). The finely milled soil and sediment samples were digested in 3:1 concentrated HCl and HNO_3 (aqua regia). The solutions were analysed by ICP-AES and AAS.

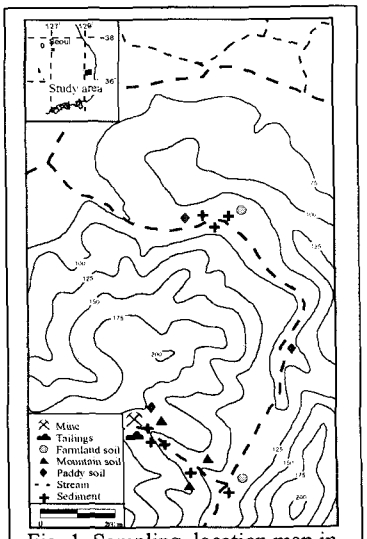

Fig. 1. Sampling location map in the Hwacheon mine area.

Cadmium is the target heavy metal in this study. Isolated bacteria from sediments were adapted to high concentrations of Cd. Microorganisms vary in their need and tolerance for oxygen. Thus, to get characteristics of different microorganisms according to terminal electron acceptor, this experiment was considered under aerobic conditions and anaerobic conditions, respectively.

3. Results and discussion

Geochemical characteristics of soils and sediments

The range and mean concentrations of As, Cd, Cu, Pb and Zn in surface soils extracted by aqua regia are shown in Table 1. Elevated levels of these were found in soils, 25.1 As mg/kg, 5.2 Cd mg/kg, 41.9 Cu mg/kg, 323 Pb mg/kg and 357 Zn mg/kg (2^{nd} samples). These levels in soils are significantly higher than those in uncontaminated soils reported by Bowen (1979). Especially, As, Cd, Pb and Zn are elevated in paddy fields and the forest soils due to dispersion of metals from the tailings by rain and wind action. Levels of heavy metals in soils can influence the metal uptake by plants grown on contaminated soils. High concentrations of heavy metals were found in soils sampled before rainy season rather than after rainy season.

Also, high concentrations of heavy metals were found in sediments from the Hwacheon mine area (Table 1). Especially, Cd, Pb and Zn concentrations are significantly higher than the guideline value reported by US-EPA and the tolerable level by the Ontario Ministry of Environment (Persaud et al., 1989). These levels are greatly influenced by clastic movement from the tailings by rain and wind action. However, relatively low concentrations of metals were found in waters collected from the same points. These are no large seasonal variations of heavy metals concentrations in sediments.

Table 1. Ranges and mean concentrations of As and heavy metals in tailings, soils and sediments extracted by aqua regia from the Hwacheon mine area (unit in mg/kg).

Sample type	Sampling period	As	Cd	Cu	Pb	Zn
Tailing	Oct., 2002 (After rainy seaon)	72.4	12.4	34	578	1304
	May., 2003 (Before rainy season)	37.5	12.7	15	537	1257
Soils	Oct., 2002	8.8-32.7	1.6-4.8	9-32	51-296	53-448
	(After rainy seaon)	16.6	2.6	16.8	160	166
	May., 2003	5.2-90.2	2.4-12.2	18.8-90.4	37-984	59-1080
	(Before rainy season)	25.1	5.2	41.9	323	357
Sediments	Oct., 2002 (After rainy seaon)	74	15	134	770	2128
	May., 2003 (Before rainy season)	21	18	156	380	1786

Microbial effects on Cd speciation in sediments

In the environment, mobile metal concentrations are more important than total metal contents. Mobile fraction of toxic heavy metals poses a greater risk for ecological functioning, agricultural production and water quality (Temminghoff *et al.*, 1995). Moreover, because of changes in environmental conditions, originally immobile heavy metals can be mobilized. Thus, to investigate the microbial effects on heavy metal (Cd) speciation is very important. A variety of resistance mechanisms enable to adapt microorganisms to Cd by growing microorganisms include ex-

tracellular precipitation, and efficient pumping out when Cd enters to the cell. Cadmium adsorption capacity of isolated bacteria was characterized according to growth stages of bacteria, pH and competing heavy metals. A microbial population generally shows a characteristic growth pattern when they were inoculated into a fresh culture medium. For the isolated bacteria in this sediments, the observed lag phase of isolated bacteria was 10 hours and exponential phase was about 10 hours. 20 hours after incubation, there was no net increase or decrease. The Cd bioremoval efficiency in Cd solution (5 ppm) by bacteria was more than 90%. The pH is one of environmental factors influencing not only site dissociation but also the solution chemistry of the heavy metals. The Cd biosorption by isolated bacteria increased with increasing pH. Optimal pH for maximum Cd bioremoval was 9. Bioremoval efficiency in single metal solution was higher than that in mixed metal solution of Pb and Zn.

4. Conclusions

In this study of an area around Hwacheon Au-Ag-Pb-Zn mine, tailing, soils and sediments have been contaminated by past mining activities. Elevated levels of heavy metals including Cd, Pb and Zn were found in soils and sediments. These significant concentrations can be greatly influenced by surface erosion, wind and rain action. As a result of seasonal variations, soils sampled before rainy season contained higher metal concentrations than those sampled after rainy season. Also, microorganisms in sediments have a effect on Cd speciation. Bacteria can leach Cd from sediments, adsorb Cd on their cell wall. The Cd bioremoval efficiency in Cd solution using isolated bacteria that were adapted to Cd was more than 90%. Optimal pH for maximum Cd bioremoval was 9. Bioremoval efficiency in single metal solution was higher than that in mixed metal solution of Pb and Zn.

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