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Vertical variations of heavy metals in tailings site of the Sangdong W mine, Korea

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Abstract: The objective of this study is to investigate the vertical variation of heavy metals in tailings from the Sangdong W mine. Tailings samples were taken at 6 drilling sites with 50cm intervals up to 21 meters in depth and dried at room temperature. The pH value, loss-on-ignition and water contents were measured. In addition, chemical compositions of the samples were determined by AAS after 0.1N HCl leaching and ICP-AES after aqua regia leaching. The pH values were in the range of 7.4 to 9.5 due to chemical reactions of carbonate minerals. The ranges of heavy metals (mg/kg) extracted by 0.1N HCl were from 0.17 to 0.93 for Cd, 0.04 to 4.39 for Cu, 0.03 to 10.9 for Pb and 0.06 to 14.1 for Zn and those extracted by aqua regia were 3.10~10.5, 23.61~251, 63.7~337 and 42.6~134 for Cd, Cu, Pb and Zn, respectively. Generally, the metal concentrations in tailings extracted by 0.1N HCl decreased with depth, whilst those extracted by aqua regia have a tendency to increase with depth in some case. Those trends might be due to the change of oxidation-reduction condition of the tailings.

1. Introduction

There are about 900 metalliferous mines in Korea and over 80% of the mines were closed, mainly due to economic reasons. Upon closure of the mines, mine waste materials, including tailings were left without full environmental treatment. Thus, soils, plants, waters and sediments in the vicinity of the mines have been contaminated by potentially toxic elements from tailings by clastic movement through wind and water. The study area, the Sangdong W mine, is one of the largest metal mines in Korea. During the operation period from 1950s to 1990s, the mine produced up to 1 x 10^5 tons of W and 2 x 10^4 tons of Bi and Mo. As a result of mining and milling operation, together with grinding, concentrating ores and disposal of tailings, provide obvious sources of contamination in the surface environment. For the mine, the amount of tailings is up to 12 x 10^6 tons with 4 x 10^6 tons in old tailings site and 8 x 10^6 tons in new tailings site.

The objective of this study is to investigate the vertical variations of heavy metals in the old tailings site. In the present study, mineralogical and chemical properties of the tailings are also

2. Materials and methods

At the old tailings site with 4 x 10^6 tons of tailings, 6 drilling sites were selected and tailings samples for core types were taken up to 21meters in depth with 50 cm intervals. The core samples were dried at room temperature. The pH value were measured by 2.5 : 1 of deionised water to dried sample with pH meter after proper calibration. The water contents and loss-on-ignition were measured at 105°C and 450°C, respectively. In addition, chemical compositions of the samples for Cd, Cu, Pb and Zn were determined by AAS after 0.1N HCl leaching procedure and those for 18 elements including major, minor and trace elements by ICP-AES after aqua regia leaching procedure. Data were assessed for accuracy using SRM2710 and SRM2711 (Montana soils from NIST, USA) and precision (5 duplicate samples at each batch of 100 samples) using quality control system integral to analytical procedure.

3. Results and discussions

Physical and chemical properties of tailings sample

According to mineralogical study, the tailings samples are mainly composed of quartz, chlorite, anorthite, codierite, enstatite, kaolinite, calcite and albite etc. The chemical compositions of the tailings are 59.0% of SiO_2, 10.9% of Al_2O_3, 11.3% of Fe_2O_3, 14.0% of CaO, 1.7% of MgO and its specific gravity is 2.60 g/cm^3. As a result of particle size analysis, the median diameter (d_{50}) is in the range of 10 to 50 μm.

The pH value of the samples ranges from 7.4 to 9.5 and most of the samples are 9.0. This may be due to the weathering of calcite contained at the tailings. Most of the samples contain relatively low contents of loss-on-ignition of 0 to 4% caused by unsuitable conditions of biological activities in the tailings site. Relatively high values of water content are measured in the samples with an average of 20%.

Average concentrations in tailings

The concentrations of major elements in the tailings were varied widely. The average concentrations of each element in the tailings are shown in Fig. 1. As shown in the figure, Mg, Ca, Al and Fe contents are over 1% and Na K, Ti, S and Mn contents are in the range of 0.1 to 1%. Compared with the other tailings, the concentrations of W and Mo are relatively enriched by mineralization of the elements. In addition, some heavy metals, including Cu, As Zn and Pb, are also enriched.

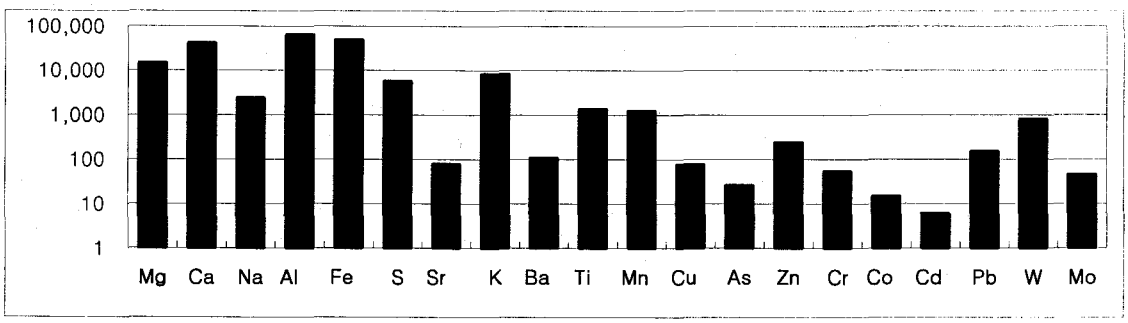

Fig. 1. Average concentrations of elements in the tailings from the Sangdong W mine (unit in mg/kg).

Vertical variations of some major elements

Vertical variations of some major elements are shown in Fig. 2. As seen in the figure, the concentrations of most of major elements including Ca, Fe, Al and K in tailings increased with depth. It may be due to variations of redox potential of the site. Adriano (1986) also reported that most of major elements, especially for Mn and Fe, are more soluble under reducing condition. In the study area, major elements can be migrated to downward with water movement and they were existed in relatively soluble or mobile fractions by the reducing conditions (low contents of oxygen).

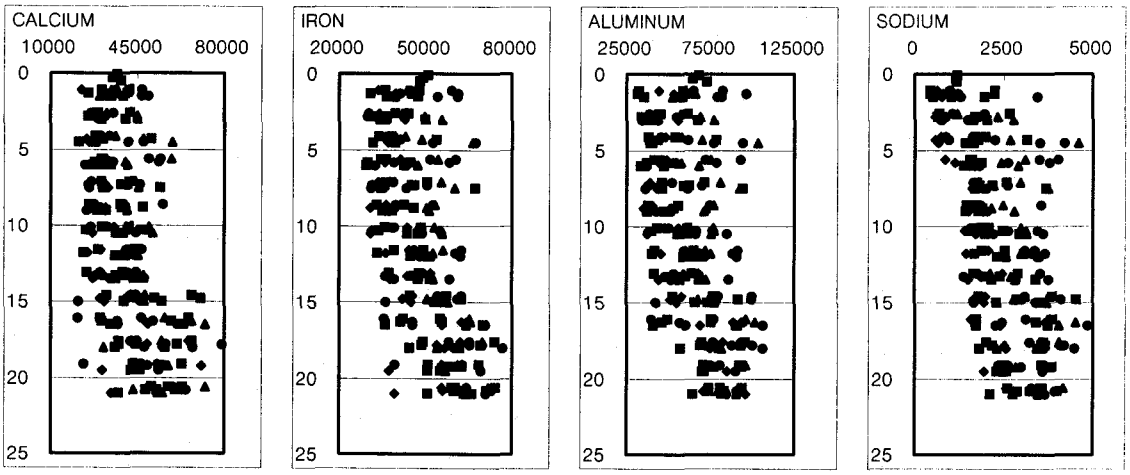

Fig. 2. Vertical variations of Ca, Fe, Al and Na in the tailings from the Sangdong W mine (unit in mg/kg).

Vertical variations of some trace elements

The concentrations of heavy metals were measured as extracted by both 0.1N HCl and aqua regia. Some vertical variations of metal concentrations in the tailings are shown in Fig. 3. It is shown that Cd and Cu contents extracted by 0.1N HCl generally decreased with depth. It can be explained that relatively soluble fractions of the metals decreased with depth due to reducing conditions of the site. Metals extracted by an aqua regia, however, increased with depth. Finally, the vertical variations of a ratio for metal contents extracted by aqua regia to 0.1N HCl are well adapted that tailings in deep area is more stable or strong bounding than that in the surface area, which can be explained by oxidation and reducing conditions. It is well known that most of metals are soluble or mobile under oxidation conditions and they can be adsorbed under reducing conditions. Adriano (1986) also reported that under reducing conditions, sulphides of elements such as Cd, Zn, Ni, Co, Cu, Pb and Sn can form and the sulphides of these elements are quite insoluble, so that their mobility is limited. This study is also confirmed the variation of chemical forms under oxidizing and reducing conditions.

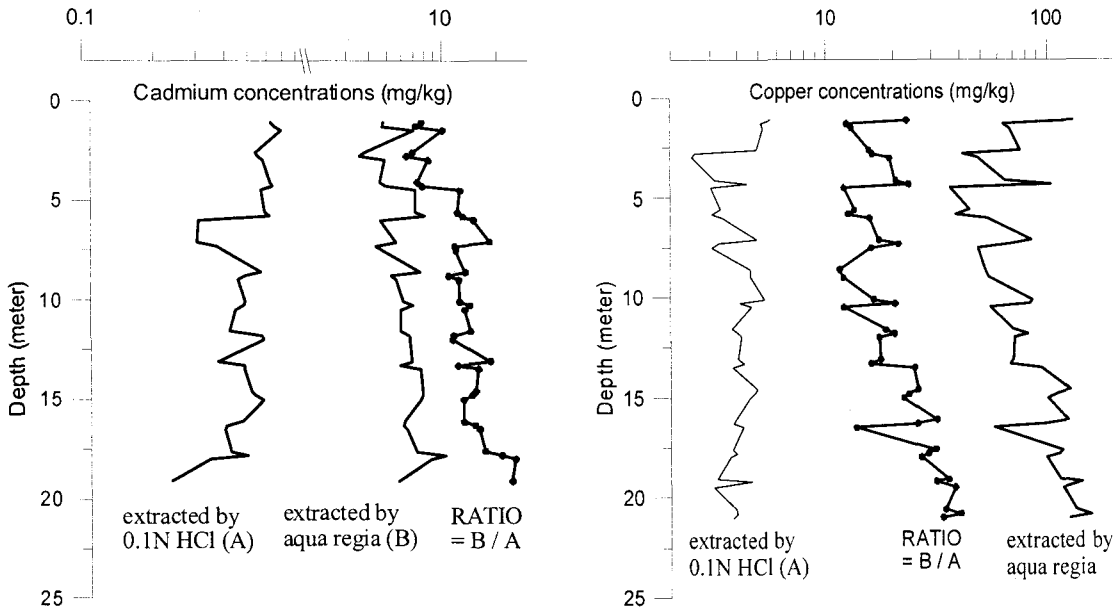

Fig. 3. Vertical variations of metals in tailings extracted by 0.1N HCl, aqua regian and their ratio (unit in mg/kg).

4. Conclusions

This study has focused on investigation for vertical variations of elements in tailings from the Sangdong W mine At 6 drilling sites from the tailings, 241 core samples were taken with 50 cm intervals up to 21 meters. The results can be concluded as follows.

1) According to mineralogical study, the tailings sample is mainly composed of quartz, chlorite, anorthite, codierite, enstatite, kaolinite, calcite and albite etc. and its specific gravity is 2.60 g/cm^3. As a result of particle size analysis, the median diameter (d50) is in the range of 10 to 50 μm.
2) The pH value of the samples ranges from 7.37 to 9.47 and most of the samples are 9.0. Most of the samples contain relatively low contents of loss-on-ignition and relatively high values of water content.
3) Most of major element concentrations including Ca, Fe, Al and K in tailings increased with depth due to variations of redox potential of the sites
4) The vertical variations of a ratio for metal contents extracted by aqua regia to 0.1N HCl are well adapted that tailings in deep area is more stable or immobile than that in the surface area, which can be explained by oxidation and reducing conditions.

Acknowledgement

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References

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