学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Potential impacts of mining in Fiji on the surrounding environment: Toward sustainable mining management

(フィジー国鉱山周辺環境への影響ポテンシャル: 持続可能な鉱山管理に向けて)

This study focuses on the chemical and mineral characterization of several mines in Fiji to evaluate the environmental impacts of hazardous elements released from rock samples obtained at these mines. The results provide important details about the chemical properties of mineral deposits, their interactions, mobilization of hazardous elements and their impacts to the surrounding ecosystem and environment. The characterization was conducted by applying a variety of tests including X-ray powder diffraction (XRD), X-ray fluorescence spectroscopy (XRF), optical microscope observation, sequential extraction (SE), etc. for rock samples as well as chemical analysis of the leachates by leaching tests. In addition, acid forming tests i.e., acid base accounting and (ABS) and pH with hydrogen peroxide acidification (pH H_2O_2) were also applied with PCA statistical analysis and thermodynamic modeling using Visual MINTEQ.

In Chapter 1, an overview of mining in Fiji is presented, it also reflects on mining's global contributions as well as its environmental consequences. The chapter concludes by outlining the objectives and goals of this research, offering a concise summary of the structure of this thesis.

Chapter 2 covers the chemical and mineral characterization of rock samples collected from five representative mine sites in Fiji, i.e., Nukudamu abandoned mine, Mt. Kasi mine, Tuvatu development mine, Vatukoula operating mine and Wainivesi dormant mine to evaluate the chemical and mineral properties of these mines. The results showed that sulfide minerals typically found in the rock samples, such as pyrite, chalcopyrite, and sphalerite were responsible for the release of hazardous elements such as copper (Cu), lead (Pb), and zinc (Zn) via oxidation. Leachates of rock samples from Mt Kasi, Nukudamu, and Wainivesi exceeded the World Health Organization (WHO) regulatory limit for Cu (2 mg/L), Pb (0.01 mg/L), and Zn (3 mg/L) in drinking water. In contrast, no hazardous elements were leached from the Tuvatu and Vatukoula rock samples, which could be attributed to the dissolution of calcite and dolomite that buffered the pH and limited heavy metal mobility. The ABA and pH (H_2O_2) test indicated that most of the rock samples containing sulfide minerals were likely to generate acidity. Furthermore, the results highlighted that once carbonate minerals are depleted in the rock samples, AMD generation is inevitable.

Chapter 3 focuses on the Nukudamu abandoned mine since it was assessed to be highly vulnerable. Ten representative rock samples were selectively collected by considering the geological features such as rock type and alternation/silicification, also surface water samples were collected at seven strategic locations from the mine open cut and surrounding drainage to assess the quality. The hazardous elements, arsenic (As), Cu, Pb, Zn, were observed in the leachates of altered rock samples, which showed

strong acidic pH (1.9–3.1) but none from unaltered samples, which were weakly acid pH (4.7–4.9). Surface water samples collected from open-cut revealed low pH levels and elevated concentrations of the hazardous elements, which discharge into Nataratara Creek. As the surface water flows down-creek, the pH increased and the concentrations of the hazardous elements decreased due to natural attenuation. However, the hazardous elements in weathered and altered rocks have a greater potential to mobilize by the results of the SE test. Furthermore, the same rock types were largely responsible for AMD formation due to the oxidations of sulfide minerals which they contain in abundance. Nevertheless, based on this detailed study, the natural attenuation by Nataratara creek is sufficient to suggest that a prudent monitoring system is the best approach rather than countermeasures, which is to be seriously considered if the site is to be redeveloped in future.

Chapter 4 focuses on the rock and water samples collected from Vatukoula gold mine Ltd (VGML), an underground and currently operational mine. It has operated for more than 80 years, the longest active gold mine in Fiji. Five host rocks and five altered, mineralized rocks were collected from the working face underground with four tailing samples collected from the tailings storage facility. In addition, surface water samples were collected at eight strategic locations from the surface drainage around the mine site. The results of leaching tests using rock and tailings samples indicated that there was limited leaching of hazardous elements with only Fe (0.46 mg/L) and Zn (6.1 mg/L) detected for two altered samples. This is attributed to the circumneutral pH of the leachates due to the dissolution of dolomite which were found abundance in host rocks and tailings. Trace amounts of As were leached from all samples, ranging from 0.001 to 0.026 mg/L. The quality of water samples met the safe limits set by the government for hazardous elements. Altered rock samples had the potential to generate AMD by the pH (H_2O_2) tests. However, the dominant presence of carbonate mineral like dolomite may neutralize AMD generation. Thus, Vatukoula gold mine shows low mobility of hazardous elements although a monitoring system is best recommended.

Chapter 5 summarizes all general conclusions focusing on the fundamental knowledge of the chemical and mineral characteristics of the studied Fiji mine sites. It provides basic and essential details about the mineral nature and the chemical properties of the orebodies of these mine sites that are useful for future studies. A key contribution from this study is the confirmation of high sulfide mineral oxidations and carbonate minerals dissolution effects occurring in the studied sites even though common mechanisms in such mining condition. The impacts of such mineral and chemical occurrences and its connection to the environmental vulnerability of these mine sites are additional information never available in Fiji before. Also, the methodologies used in this study has the potential to be applied or replicated elsewhere which shares similar mineral deposits as those studied in this research from Fiji. Furthermore, the knowledge generated through this study is useful to strengthen systems and processes in Fiji's mining sector and will certainly bring confident to staff and add capacities to better evaluate mining applications that ensure responsible decisions pertaining to safer and sustainable mining development and in countries alike.