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学位論文要旨
Dissertation Summary

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論文名: Study of Medical Geoscience of Heavy Metal Pollution in Bone River Area, Eastern
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Heavy metals are known to be toxic to biotic factors such as human, animal, plant, and fungi, as well as to the abiotic system such as water, air, sediment, and soil. They are emitted into the atmosphere, hydrosphere, and the biosphere from both natural and anthropogenic source. Nowadays, the results of Hg pollution to the environment came from the anthropogenic activity such as the process of gold extraction at artisanal small-scale gold mine (ASGM). However, the other heavy metals have not been studied even though they also have unique characteristics of hydrothermal gold mineralization. This study also defines and uses the new term “medical geoscience” which is an emerging interdisciplinary scientific investigating on the relationship between geoscience factors and their effects on human and animal health. The main objective of this research is to study the medical geoscience of heavy metal pollution by ASGM activities in Bone River area, Eastern Gorontalo Province, Indonesia.

The samplings of rocks, waters, sediments, *Pteris vittata*, soils, and human scalp hair of the residents were performed from the ASGM sites in the upper stream to Gorontalo City in the downstream along Bone River. Rock samples were analyzed by a scanning electron microscope equipped with an energy dispersive X-ray spectrometer (SEM-EDS) to investigate the mineral and

the distribution of potentially heavy metal. The samples of water, sediment, plant, and soil, were analyzed by Particle Induced X-ray Emission (PIXE), while human scalp hair was analysis by Inductively Coupled Plasma Mass Spectroscopy (ICP-MS). The water samples were taken from the mine wastewater, hot spring, river, and underground water which was used for daily consumption. In order to make sure for the source of heavy metals that contaminated to water, the plant and soil samples were also collected.

The rocks mainly consist of pyrite (Py) and quartz (Qz). Pyrite is the main host of Fe, and the quartz is the main host of Si however the heavy metals As and Hg have the same pattern with the pyrite. It indicates that those metals can incorporate with pyrite as well.

The analytical results show that As, Hg, and Pb contaminate the water of mining waste ponds, hot spring, river water, and underground water. The concentrations of As, Hg, and Pb in water samples ranged from 4.00 to 383000 µg/L, 0.30 to 2080 µg/L, and 0.10 to 1670 µg/L, respectively. This concentration could be harmful to human health according to both WHO and Indonesian guidelines for water. Besides that, the concentrations of As, Hg, and Pb of the sediment samples in the Bone River ranged from 16 to 120000 µg/g, 0 to 790 µg/g, and 24 to 10700 µg/g, respectively.

The distribution of *Pteris vittata* in this study showed huge stocks in mining sites, hot springs, and around the Bone River which indicated that the As had polluted the area. The As concentration of *Pteris vittata* shows ranged from 2.10 to 17700 µg/g. This result reveals that the *Pteris vittata* is a hyperaccumulator of As which accumulate more than 1000 µg/g. Also, the *Pteris vittata* also shows the possibility to absorb other heavy metals, as well as Hg and Pb with the concentration, ranged from 0 to 5 µg/g, and 0 to 39 µg/g, respectively. The results of *Pteris vittata* also indicated that the soil in this area also was contaminated with those heavy metals. The concentration of As, Hg, and Pb in the soil are the ranges from 0 to 400 µg/g, 0 to 36 µg/g, and 8 to 160 µg/g, respectively. It could reveal that this area has been naturally polluted by those heavy metals due to the weathered process of rocks to form the soils.

Level of Hg in human scalp hair ranged from 0 to 1570 µg/g. This result shows that the maximum level exceeds the limit of the German Human Bio-Monitoring commission authorized toxicology threshold limit. Not only Hg but also As and Pb concentration in hair sample also indicate that the participants were exposed to As and Pb with the range from 0 to 13.5 µg/g and 1 to 32 µg/g, respectively.

These results show that the environments in the Bone River area have been polluted by As, Hg, and Pb due to the ASGM activities, weathered rocks from mine site and surrounding the river, and

hot spring. The source of Hg contamination is derived from the ASGM activity, which uses it for the gold extraction that discharges wastewaters into the Bone River. The distribution and concentration of heavy metals of *Pteris vittata* indicate that the weathered rocks which transform to soil surrounding Bone River area originally contain As and Pb as a natural source. This fact could correlate with the release of these heavy metals from the weathered rocks hydrothermally altered on the gold mineralization process and hot spring water.

This study reveals the significance of medical geoscience, as emerging a new interdisciplinary scientific field, to predicts effects on human and animal health-related to geoscience factors. The results in this study revealed that the source of heavy metal pollutants in Bone River area was derived from the natural processes such as hot springs and weathered rocks, and as well as an anthropogenic activity such as ASGM. It is also acknowledged that the heavy metals pollution by geoscience factors affect the human and animal as human scalp hair is used as an indicator of heavy metals exposure in this study.