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学 位 論 文 要 旨
Dissertation Summary

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論 文 名 :

Environmental effects of mercury pollution by artisanal and small-scale gold mining in Bombana area, Southeast Sulawesi Province, Indonesia

Artisanal and small-scale gold mining (ASGM) is defined as mining activities producing gold by individuals or small groups with simple processes. ASGM plays an economic role in developing countries with poverty into a background. Indonesia has a large population of ASGM sectors so as the third largest mercury emitter in the world after China and India. Significant health risk associated with ASGM includes exposure of mercury due to the hazardous working condition. Assessment of environmental effects is needed to evaluate and systematically identify the physical, chemical, biological, cultural and socioeconomic effects of the total environment. The study aims to evaluate the socio-economic and environment effects by ASGM in Bombana area, Southeast Sulawesi Province, Indonesia.

To achieve the purpose, the study was undertaken at three research steps; (1) to assess the socio-economic feature of miners and their family in the ASGM sites of Bombana area, (2) to assess the mercury exposure of human and nature in Bombana area, and (3) to identify the mercury

pollution pathway in Bombana area. Sampling was performed in three areas such as ASGM area, mining company area, and control area by stratified and purposive sampling methods. All 237 samples including human scalp hair, cattle hair, soil, and grass were analyzed by PIXE. A cattle horn is analyzed by a micro-PIXE. Paleontological Statistic (PAST) Ver. 3.17 and IBM SPSS Statistic 21 Ver. 21.0 were used for data analyses.

The results of socioeconomic assessments indicate that the income of miners is lower (ranging from 200,000 IDR to 5,000,000 IDR) than that of the control group (ranging from 2,000,000 IDR to 6,000,000 IDR). The economic effects of miners by the ASGM are not enough for their livelihood and result in a lack of access to the basic sanitation and housing facility. Unsafe working practices of miners cause several occupational hazards such as the musculoskeletal disorder, neurological symptoms, respiratory disorder, and degenerative disease.

The analytical results showed that the mean values of mercury concentration in human scalp hair from the ASGM area and company area are higher (13.0 and 14.0 $\mu\text{g/g}$, respectively) than that from control group (5.70 $\mu\text{g/g}$) and exceeds the Human Biomonitoring threshold limit (5 $\mu\text{g/g}$ hair). The exposure to mercury during the ASGM activities brings about health issues to the miners and their family; mercury is also at hazardous levels for people who live in the ASGM and mining company areas.

The gold mining activities by the ASGM in Bombana causes a considerable environmental impact on nature, most importantly related to mercury contamination. Compared to the control area, mercury concentration of cattle in the ASGM area registered an extensive increase in cattle hair (7.80 $\mu\text{g/g}$) (control area mean: 2.50 $\mu\text{g/g}$). The main factors affecting mercury accumulation in cattle are environmental conditions, age, maturity, sex, and hormonal status. Grass mercury concentrations in the ASGM area (mean value: 9.90 $\mu\text{g/g}$) are higher than those of the control area (mean values: 2.70 $\mu\text{g/g}$). Furthermore, soil mercury concentrations in the ASGM area (mean values: 390 $\mu\text{g/g}$) are higher than those of the control area (7.40 $\mu\text{g/g}$). The mercury levels in the three types of soil samples exceed the international regulation limit. Mercury level in human and nature imply that mercury emissions have expanded in large areas of Bombana.

The environmental assessment identifies several mercury sources: gold mining trommels facilities and amalgam burning houses in the ASGM area, and the gold mining companies. The possibility of atmospheric contamination of mercury is determined by the quantitative concentrations of heavy metals including Hg in the cattle horn samples. The quantitative 2D

elemental images by the micro-PIXE analysis show that the maximum values for Hg in the cattle horn were 275 $\mu\text{g/g}$. Atmospheric contamination is the most important route on Hg emission transport, driving the primary exposure to human and nature.

The mercury levels in human and nature designates that the mercury pollution is a severe problem in Bombana area. The high positive correlation between the concentration of mercury in cattle hair and human scalp hair reveals that cattle hair is one of useful bioindicator to evaluate atmospheric mercury contamination. The continuous growth of the ASGM sector imposes the critical environmental impact on miners and inhabitants living around ASGM areas. Mercury pollution reduction programs are most essential to alleviate environmental hazard.