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学 位 論 文 要 旨
Dissertation Summary

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論 文 名：
(Dissertation Title) Geomedical Science Approach to Early Risk Assessment of Heavy Metal Contamination in Artisanal and Small-Scale Gold Mining Areas in Gorontalo Province, Indonesia

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Humans and the environment develop a natural relationship that influences both parties. Geomedical science, a comparatively new interdisciplinary science that deals with the complex relationship between environment and human health as a function of the interaction of the geosphere and sociosphere, the natural and man-made. The principles of geomedical science fall into three broad areas: clinical evaluation, risk assessment, and hazard control and monitoring.

Artisanal and small-scale gold mining (ASGM) refers to mining by individuals, groups, families, or cooperatives with minimal or no mechanization, often in the informal (illegal) sector of the market. The United Nations and Environment Programme (UNEP) reported that in 2006, ASGM was the world's largest mercury consumer, using around 1,400 tonnes per year, and was responsible for 37% of global mercury emissions.

The pollution problems associated with ASGM are not limited to mercury contamination, and sources of other contaminants that arise from natural processes and affect human health, such as mercury (cinnabar), arsenic from hot-spring areas, cadmium and copper. The evaluation of these contaminants is extremely important for risk assessment, particularly when assessing lower exposure levels because the biomarkers of early exposure are much more sensitive than the classical parameters such as clinical symptoms, functional tests, or morbidity. Heavy metals can affect multiple organs and hence there exists the potential of toxicity by more than one metal occurring at the same time in a given target organ. For example, neurotoxic disorders can be caused by mercury, arsenic, and lead. On the other hand, respiratory disorders can be caused by mercury and arsenic contamination. The sign of the Kayser-Fleischer

ring is a specific sign for copper toxicity. For this reason, the purpose of this study is to identify and analyze the risk of the heavy metals discovered in the ASGM area related to human health in Gorontalo Province, Indonesia.

Data were collected from six areas in Gorontalo Province, four representative mining sites (ASGM area), and two control sites. The environmental/geogenic sample tested was soil and dust samples. The biological sample was human hair samples. The health data were collected by conducting a general health check-up, a spirometry test, and assessment of neurological and other vital functions. The total of 192 respondents included 67 miners, 53 non-miners, and 72 control subjects from a non-ASGM area

Different sets of data were used in the analyses because geogenic samples were analyzed with particle-induced X-ray emission at the Cyclotron Research Center, Iwate Medical University, Japan, and hair samples were analyzed with inductively coupled plasma-mass spectrometry at the Research Institute for Humanity and Nature, Kyoto, Japan. The correlations between the human variables and the heavy metal concentrations in the hair samples were then analyzed.

The health assessments, made with a health-based questionnaire, were divided into the following categories: general health status, neurological assessment, and lung function (tested with spirometry). Informed consent was received from all respondents before the health examination, and the study was approved by the Ethics Committee of Hasanuddin University, Makassar, Indonesia.

The heavy metals concentration of the soil and dust samples were evaluated using two formulas called Hazard Quotient (HQ) and Geoaccumulation index (Igeo) which compares this research result concentration with the normal range concentration. In addition, the heavy metals concentration of hair samples was evaluated using the HQ index. The HQ calculation results for soil samples obtained in the East Tulabolo area (copper concentration 73 times the normal range, and arsenic 37 times the normal range) and Hulawa area (copper 26 times the normal range, and arsenic 23 times the normal range) showed them to be copper- and arsenic-rich areas, whereas Dunggilata was a mercury-rich area (six times the normal range), and Bumela and the control area were copper-rich areas (six and three times the normal range, respectively). Analysis using Igeo's interpretation shows that the highest values for copper and arsenic concentrations are at moderate class, while the highest values for mercury and lead are in the uncontaminated to moderate class.

The dust samples were collected from 2 mining areas (East Tulabolo and Dunggilata) and also from 2 control areas. The HQ calculation results for dust samples showed a higher multiple than soil. The East Tulabolo area (copper concentration 153 times the normal range, and arsenic 13 times the normal range), whereas Dunggilata was a mercury-rich area (eleven times the normal range), and the control areas were copper, mercury and arsenic-rich areas (around one and two times the normal range). Analysis using Igeo's interpretation shows that the highest values for copper concentrations are at moderate to heavy class, arsenic concentration is at moderate class, while the mercury and lead are in the uncontaminated to moderate class. Furthermore, Igeo correlation analysis between soil and dust samples using Spearman's test with a significance value for mercury, arsenic, copper, and lead are 0.253, 0.019, 0.139, and 0.023, respectively.

The heavy metals concentration in scalp hair has shown the same elemental richness as soil samples according to the area. The result obtained in the East Tulabolo area was a copper (7 times the normal range) and arsenic (358 times the normal range)-rich sample, whereas the Dunggilata was to be the mercury-rich sample (2 times the normal range).

Health assessment showed that the prevalence of neurological and respiratory disorders is higher in Dunggilata and East Tulabolo areas (as mercury and arsenic-rich area). Kayser-Fleischer sign was also found abundantly in that two mining area, as a result of their copper-rich characteristic.

The discovery of high copper, arsenic, and lead concentrations in the ASGM regions in Gorontalo Province prompted the analysis of their relationship to human health. The effects of toxic metal contamination on human health have been widely studied. However, previous research focuses more on the final effects that appear on humans such as neurological symptoms. A Kayser Fleischer ring on eye examination was also observed even in children. Human contact with these heavy metals can be predicted by the food chain. On the other hand, a correlation between lung function and heavy metals concentration in scalp hair shows a negative correlation. This suggests that the accumulation of heavy metals in the hair as a bio-indicators is only one process and not be a major determinant in the diagnosis of contamination with heavy metals. This phenomenon is related to the complexity of the human body system and the different characteristic of each individual.

Statistical analysis was carried out to support the statements of phenomena arising from the negative correlation. A logistic regression analysis proved that the odds ratio of an association was not consistent with the high concentration of HM in hair samples (used HQ). The result would be that the higher the odds ratio (OR), the low the Hazard Questions (HQ).

In a word, research on humans is indeed complicated and challenging. In the final analysis, I conclude that 1) the harmful effects exert not only on an individual but also on the wider community; 2) the results of heavy metal concentrations in the environment show connectedness parallel with specific signs as an effect of heavy metal contamination in the human being; 3) a negative correlation between lung function assessment and the heavy metals concentration in scalp hair shows that the possibility of disease related to heavy metals contamination is determined not only by the accumulation process as a bioindicator; and 4) it is imperative to assess exposure and detect early effects predictive of toxicity, that is, an early stage of an adverse effect, especially in vulnerable populations.

The role of Geomedical science is significant in risk assessment and early predictions so that preventive steps can be taken in advance. Therefore, this research shows the importance of the environmental role related to human health.