SPATIAL MODELING IN TRADISONAL GOLD MINING HG (MERCURY) POLLUTION IN GORONTALO

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Abstract
This study focuses on spatial modeling, ecological risk analysis, and human health risk analysis concerning mercury (Hg) pollution in traditional gold mining areas in Gorontalo. The research aims to safeguard both ecological balance and the health of gold mining workers exposed to mercury in wet and dry deposition, as well as dug well water, particularly in burning areas where amalgam gold mining occurs. The study comprises four main stages: sampling and coordinate determination, THg level examination in water and deposition samples, spatial analysis, and ecological and health risk assessments. Unlike previous studies, this research primarily focuses on mercury intake through inhalation of dry deposition and oral ingestion of dug well water from burning amalgam, excluding other exposure routes such as food and skin contact. A comprehensive literature review was conducted using electronic databases such as ScienceDirect, JOVE, Google Scholar, and SpringerLink. The search employed keywords like "Spatial Model," "Hg Pollution," and "Unlicensed Gold Miners," yielding ten relevant articles published between 2016-2022. Findings from previous research highlight different aspects of mercury pollution, including its presence in various environmental mediums and associated health risks. Studies in locations like Indonesia, Mexico, New York, Ghana, and China have explored mercury contamination in water, soil, air, and food, stressing the importance of ecological and health risk assessments. Additionally, spatial modeling techniques have been crucial in mapping mercury distribution, analyzing spatial variations, identifying pollution causes, evaluating health risks, planning environmental management, and guiding monitoring efforts.

Keywords: *Spatial Modeling, Mercury Pollution, Gold Mining, Ecological Risk Analysis, Human Health Risk Analysis*

1. INTRODUCTION

The Spatial Model investigation aims to assess the distribution and concentration of mercury in the environment, as well as the potential risks posed to human health. Ecological Risk Analysis will focus on the impact of mercury contamination on local ecosystems, including water bodies, soil, and vegetation. Human Health Risk Analysis will assess the potential health effects of mercury exposure on gold mining workers and local communities.

The scope of this research is a Spatial Model study, Ecological Risk Analysis and Human Health Risk Analysis, which are related to safeguarding the ecology and health of gold mining workers related to exposure to mercury (Hg) in wet deposition, dry deposition and dug well water, in burning areas. amalgam gold mining in North Gorontalo Regency.

The object of research in this study is the concentration of mercury metal in wet deposition, dry deposition and dug well water in the gold mining amalgam burning area of North Gorontalo Regency. The first stage of this research involved the collection of samples and the determination of coordinate points. Subsequently, total mercury (THg) levels were examined in samples of dug well water, wet deposition, and dry deposition. The second stage entails conducting spatial analysis to identify spatial trends in mercury distribution within the environment. Following this, the third stage focuses on performing ecological risk analysis to evaluate the potential impact of mercury pollution on the ecology. Lastly, the fourth stage involves calculating the quantity of mercury intake resulting from exposure to dry deposition (via inhalation) and dug well water (via oral ingestion). This is followed by a health risk analysis to assess the magnitude of health risks faced by miners due to mercury exposure in the amalgam burning areas of North Gorontalo Regency.

In theory, exposure to a chemical can occur through several exposure routes, namely oral intake, inhalation and dermal. However, in this study, the health risk analysis of gold mining workers only focused on the intake of dry deposition and dug well water resulting from burning amalgam containing mercury and did not calculate mercury intake from other exposure routes, such as food and skin.

This study investigates spatial modeling, ecological risk analysis, and human health risk analysis related to mercury pollution in traditional gold mining areas in Gorontalo. The research aims to protect both the environment and the health of gold miners exposed to mercury in wet and dry deposition, as well as well water, especially in areas where amalgam gold mining is practiced.

2. RESEARCH METHODS

The method used in this literature review search uses a comprehensive strategy such as searching for both national and international journals. The search strategy used electronic databases such as ScienceDirect, JOVE, googleschoolar and SpringerLink. The keywords used are (Spatial Model, Hg Pollution, Unlicensed Gold Miners) while searches in international journals are (Spatial Model, Geography Information System, Hg). The search results were then filtered based on full text and publication date 2016-2022, 10 articles were found that were deemed appropriate, then screened based on the inclusion criteria that would be used to create a literature review.

3. RESULTS AND DISCUSSION

Table 1. Research Related to Spatial Models, Ecological Risks and Health Risks Due to Exposure to Mercury (Hg)

No	Correlational Studies				Results
	Researcher/Year	Subject	Location	Method	
1	C. Intania, Munawar Ali, B. Faiz, 2019	Potential for Mercury (Hg) Pollution in Rice Fields Due to Gold	North Lebong Village, Lebong Regency,	Laboratory analysis of soil, sediment, water and plant samples	- The research results show that all samples contain mercury and exceed the threshold value. The highest

		Processing Using the Spindle Technique	Bengkulu Province.		total Hg in water is 0.44 ppm, in sediment it is 58.19 ppm, in soil it is 15.44 ppm, and in plants it is 16.85 ppm
2	(Hansen and Gay, 2012)	Mercury content in wet deposition	Tropical regions of Mexico	Ecological analysis	- Precipitation-Weighted Mean (PWM) / average precipitation weight is 8.2 and 7.9 ng L -1 - Wet deposition of Hg in HD01 < US Gulf Coast Mercury Deposition network (MDN) site - Wet deposition of Hg at OA02 < MDN - PWM concentration causes higher deposition in HD01 compared to OA02.
3	(Yu et al., 2013)	Mercury content in wet deposition and dry deposition	Adirondack Park, New York	Modeling and mapping (spatial analysis)	- Average Hg deposition into the Adirondacks is ±17.4 µgm-2 yr-1 with a range of 23.7-46.0 µgm-2 yr-1. - Dry deposition of Hg (370 kg/yr) > (210 kg/yr) throughout the Adirondacks (2.4 million ha). - Spatial pattern of atmospheric Hg deposition in the Eastern Adirondacks total Hg deposition > 30 µgm-2 yr-1, while in the southwest and north Hg deposition starts at 25-30 µgm-2 yr-1
4	(Obiri et al., 2016)	As, Cd, Hg and Pb in Water and Sediment samples	Gold mining areas around the Prestea valley inhabit the region of Ghana	Human health risk analysis	- Average concentrations of As, Cd, Hg and Pb in water samples ranged from 15 µg/L to 325 µg/L (As), 0.17 µg/L to 340 ug/L (Cd), 0.17 µg/L to 122 ug/L (Pb) and 132 µg/L to 866 µg/L (Hg), respectively. - Average sediment concentration < quality standard - Non-cancer human health risk assessment results: 0.04 (Cd), 1.45 (Pb), 4.60 (Hg) and 1.98 (As); HQ > 1 for Pb, Hg and As
5	(Mallongi et al., 2014)	Total mercury in dry deposition, surface soil, and foodstuffs	Small scale artisanal Deme, Buladu and Wubudu village gold mining	THg with AAS (Atomic Absorption Spectrometry) Ecological Risk Analysis Health risk analysis	- HQ of dry deposition, land surface and surface water > 1 (risk) respectively (10, 46 and 1.7) - THQ of chocolate, coconut and corn < 1 (no risk) respectively 0.2, 0.2, 0.1

6	(Nakazawa et al., 2016)	Hg (0) in ambient air	Poboya small-scale gold mining, Palu City, Central Sulawesi	• Hg (0) is measured with a portable handheld mercury analyzer, mercury analyzer • Human health risk analysis	A. Average daytime Hg (0) sample points in the city ranged from 2,096-3,299 ng / m-3. Meanwhile, the average daytime Hg (0) in the Poboya gold processing area is 12,782 ng m-3. B. The results showed that 93% of the overall sample population was at risk (hazard quotient ratio ≥1 sample population).
7	(Amodio et al., 2017)	Mercury in wet deposition and dry deposition in ambient air	Taranto industrial district (Italy)	cold vapor atomic absorption spectrophotometry	C. Simulation models show that rain plays a role in the deposition of mercury from anthropogenic sources in China that is carried to Taranto (Italy)
8	(Zheng et al., 2015)	Mercury (Hg) in street dust samples in various cities	Huainan City, East China.	*Atomic Absorption Spectrometry (Dust) Spatial analysis Health Risk Analysis*	HQ < 1, all respondents (adults) have no significant risk
9	(Zhang et al., 2021)	Heavy metals (Hg, Pb, Zn, Cu, Cr, and Cd)	Urban area in Wuhan, central China	atomic absorption spectrophotometer (AAS, Milestone DMA-80) (Ground) Spatial analysis using the ordinary kriging method	RI > 1, Almost all urban areas of Wuhan face potential major ecological risks caused by traces of heavy metals in the soil.
10	(Weiss-Penzias et al., 2016)	Hg in wet deposition	America and Canada	Spatial temporal analysis	The elemental mercury gas from the dataset is one of the most consistently consistent pollutants in wet deposition, with the last few years (1998–2007) producing a significantly negative trend.

Spatial Modeling in the context of mercury pollution refers to an analytical approach that allows researchers to understand how mercury is distributed in a particular geographic environment. This approach includes the use of spatial data such as maps, satellite imagery and GPS data, along with spatial techniques and mathematical modeling, to identify mercury distribution patterns, factors that influence them, and potential risks to the human environment. The role of using the Spatial Model in mercury pollution can be described in the following components:

1. Mercury Pollution Mapping, Spatial models allow researchers to create maps of mercury distribution in an area. This can include mapping potential sources of pollution such as factories, mines or industrial areas as well as the distribution of mercury in soil, water, air and sediment.

2. Spatial Variability Analysis; The Spatial Model allows analysis of the spatial variability of mercury in a region. This means identifying whether there are certain patterns or trends in the distribution of mercury that can help in understanding the factors that influence its distribution.
3. Factors Driving Pollution; Spatial Models allow researchers to consider factors that influence mercury distribution. This can include the type of human activity (such as mining or the chemical industry), regional geology, weather patterns and others.
4. Analysis of Potential Health Risks; By understanding the spatial distribution of mercury, researchers can conduct health risk analysis. This includes considering how humans and organisms in the environment are exposed to mercury
5. Environmental Management Planning; Information from the Spatial Model can be used to plan management and mitigation actions for mercury pollution. This includes zoning areas susceptible to pollution or identifying major sources of mercury
6. Monitoring and Supervision; Spatial Models can assist in directing monitoring and surveillance programs to monitor and measure changes in mercury distribution over time.

4. CONCLUSION

The utilization of spatial modeling methods offers valuable perspectives on the distribution trends and determinants of mercury contamination in conventional gold mining sites. Through the fusion of spatial analysis with assessments of ecological and human health risks, this research contributes to our comprehension of the dynamics of mercury pollution. The results emphasize the importance of customized strategies for management and mitigation to effectively address mercury pollution. By integrating spatial modeling into environmental research and management practices, stakeholders can enhance the protection of ecological balance and human health in gold mining areas such as Gorontalo. This approach facilitates well-informed decision-making and proactive actions to alleviate the negative effects of mercury pollution on both the environment and human well-being.

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