INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 24, No. 1, p. 16-22, 2024
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Evaluation the mercury after a decade of gold mining termination in Sijunjung Regency, West Sumatra, Indonesia

Khin Nilar Tin*[1], Syafrimen Yasin[2], Mahdi[3]

[1]*Department of Integrated Natural Resources Management, Andalas University, Padang, Indonesia*

[2]*Department of Soil Sciences of Faculty of Agricultural, Baiturrahmah University, Padang, Indonesia*

[3]*Department of Socio-Economic of Faculty of Agricultural, Andalas University, Padang, Indonesia*

Article published on January 05, 2024

Key words: Gold mining, Mercury accumulation, Water contamination, Environmental pollution

Abstract

Before mining exploration, the study was agricultural area especially for paddy plantation. The area was totally transformed into gold exploration site, however, the production had completely finished for ten years. As usual, gold mining especially small business types of such exploration mainly relies on mercury (Hg) for gold recovery process. Although mining activities were ended in study area for a long time, transboundary as well as extremely persistence properties make the Hg still contains in soil and water. Another factor may exist a great number of mining operations along the Ombilin River; study area is located which drive the Hg infiltrate the surrounding area. Toxication effects of Hg introduce a wide range of the short-termed health problems to lethal diseases for the public and environmental pollution. For this reason, the study was commenced with the purpose of Hg evaluation both in soil and in water. Purposive sampling method was applied when collecting soil and water samples. According to the laboratory test results, Hg in soil was agreed with the minimum acceptable limit then water was still polluted with Hg which was higher than the standard guidelines. In spite of causing adverse effects of Hg, residents are consuming Hg rich water not only for their agricultural activities but also for their households.

***Corresponding Author:** Khin Nilar Tin ✉ khinnilar.shakila@gmail.com

Introduction

Indonesia has a vibrant physical gold market with an internationally recognised gold refinery a large gold jewellery sector and wide availability of retail investment gold bar products (Indonesian Gold Market, 2015). Depend on the types of mining exploration, emission of metals can be different for example, Hg is used in ASGM. Hg metal is used to extract gold from ore as a stable amalgam in which elemental Hg is frequently added to capture the gold in case of the metal form very fine-grained (Esdaile and Chalker, 2018). Hg discharging into the water bodies is the key issue at the gold production areas. Once Hg flows to water which is transformed into the most toxication substance CH_3Hg by the action of aquatic biota. One of the most negative impacts of the Hg which destructs the harmony the ecological balance of the environmental baselines. Tiny living creatures regardless in soil and water they can convert the Hg into the most poisonous form, CH_3Hg. Accordance with United States Environmental Protection Agency (EPA, 2021) microscopic organisms can combine Hg with carbon, thus converting it from an inorganic to organic form.

Before commencing mining exploration, the study area was the paddy field. Paddy is favour to the clayey rich soil type then Liao et al (Liao *et al.*, 2009) stated that clay has the highest capacity of adsorption for Hg compared to loam and sand, implying a smaller grain size is beneficial for the enrichment of Hg. This metal is mainly accumulated in plant roots, from which it is transferred at different rates to the parts above the surface (Boening, 2000; Gochfeld, 2003). The methylation of Hg can occur abiotically or biotically. Biotically, the primary methylators of Hg are sulfate-reducing and iron-reducing bacteria (Fleming *et al.*, 2006). CH_3Hg can be biomagnified through food webs to high concentrations in top predatory species (e.g., piscivorous fish, large birds, and mammals (Emmerton *et al.*, 2018). Accumulation of metals in soil could affect the ecosystem safety and pose a threat to animals, plants, and human (Sulaiman and Hamzah, 2018). A long-term resistance and existence nature of Hg can be stable in the tissue of fish and other living things in water. Addition to this, other medical aliments such as reduced liver function and metabolism, altered behavior, impaired reproduction, deformity, damage to the gills and olfaction organs, and mortality (O'Bryhim *et al.*, 2017). Birds are considered excellent bio-indicators of environmental Hg contamination (Evers *et al.*, 2003).

Additionally, CH_3Hg has a high affinity for keratin and thus a large proportion of ingested mercury travels to growing feathers (Fournier *et al.*, 2002). Perhaps heavy metals can enter human bodies via the food chain, leading to incremental of chronic diseases such as cancer (Muller and Anke, 1994; Ramadan and Al-Ashkar, 2007) and affecting the central nervous system, particularly in children (Zhao *et al.*, 2009). The other internal organs namely nervous system, respiratory function, kidney damage and or renal dysfunction as well as heart failure which are more likely to suffer as the long-standing diseases. It is a toxic metal that can cause a variety of adverse health effects depending on the form of Hg (element, inorganic or organic) and pathway, quantity and duration of exposure (Hatika *et al.*, 2020). Besides, gold mine in the Sijunjung regency is located along the Ombilin river, Batang and Batang Sukam Palangki or in some other streams (Zulfa *et al.*, 2016). According to the facts mentioned above, the aim of the study was evaluation or investigation the concentration of Hg after a decade of mine termination in order to raise the government and public awareness concerned with the adversity effects of Hg.

Material and methods

Study area and data collection

Limo Koto VII where the study site is located, total area is 143.90 km², is surrounded by Sumpur District in the north, Cupitan in the south, Sijunjung in the east and Sawahlunto City in the west, respectively. The Coordinate of the regency is 1000 48′ 1″ - 1000 0′ 58″ E and 00 33′ 13″- 00 47′ 22″ S and then 120-635 masal above the sea level (BPS Sijunjung Regency). The method of this research was purposive sampling for natural resources, in which soil was sampled randomly at each of the five types (paddy field, oil palm, citrus plantation, bushes and forest) of land use. Water samples were taken from well, pond and river for drinking/cleaning purposes, fish raising pond and the paddy field's irrigated water.

Data analysis and processing

Collected samples will be transferred to the Laboratory of the Faculty of Engineering, Department of Environmental Engineering, Andalas University. The chemical parameters had to be tested pH, OM and Hg content both soil and water. In this research, soil quality will be compared with Indonesia's Soil Quality Standard (Twardy, 1995) along with the FAO (2021). Moreover, National Indonesia Standard Guideline (2001), FAO (1985) and WHO (2008 and 2011) would be prioritized as the guideline for water quality. Then the correlation between pH and Hg in soil/water were conducted by using Surfer (Golden Software, latest version 23.4).

Results and discussion

Collected samples (both soil and water) were immediately delivered to the respective laboratory with the aim of analyzing the Hg concentration and others parameters (SOM/OM, BOD, and COD). The test results were mentioned in Table 1 and Table 2. Depends on the Hg and pH values, correlations were made soil and water so as to determine pH level influenced or controlled on the Hg concentration, shown in Fig. 1 and Fig. 2.

The average Hg in soil samples at the surrounding area of study site were ranging from 0.09 ppm to 0.15 ppm. The values are remarkably lower than the guideline (Twardy, 1995). After that the allowable pH value for various plants are between 6.0 - 7.5 by FAO (2021), the minimum pH of the samples was 4.51 and the maximum was 5.93 according to the laboratory result. Most of the agricultural lands were moderately lower than the acceptable pH value but a few were found strongly acidic soil type if the pH values are <5.5 which can be seen especially in the forest area where 4.62 was given account of pH value.

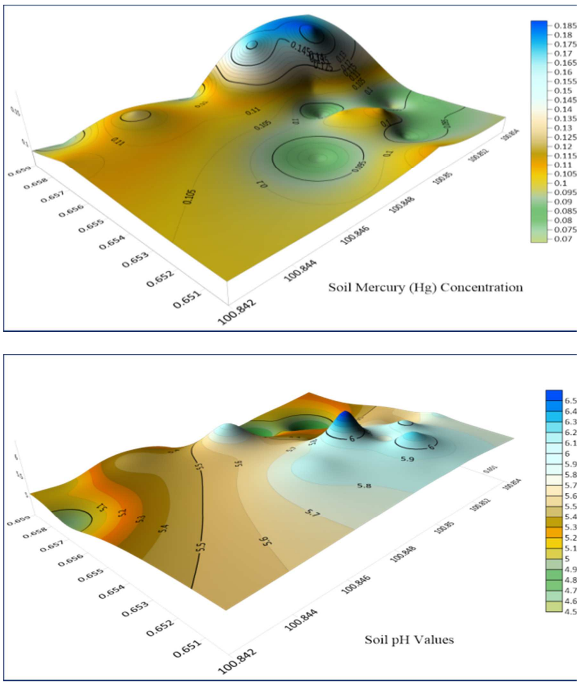

Fig. 1. Correlation between Mercury (Hg) and pH of the soil samples

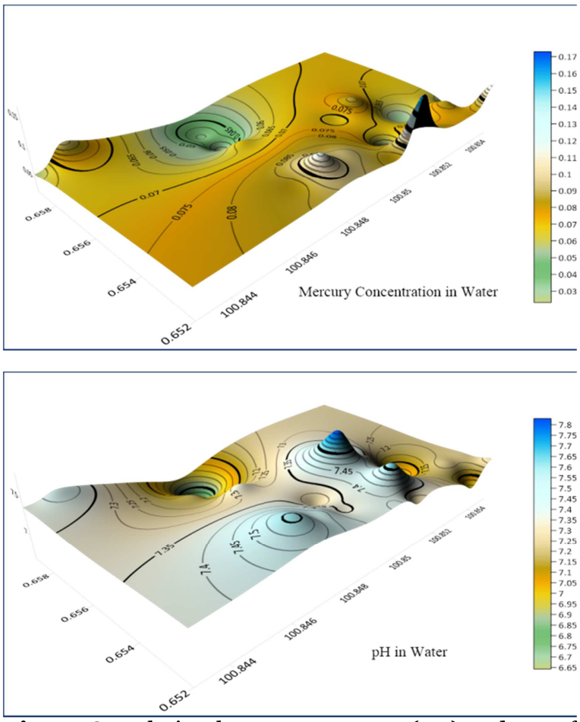

Fig. 2. Correlation between Mercury (Hg) and pH of the Water Samples

Average percentage of C-organic in all agricultural land was agreed with the guideline between 0.7% and 4%, however, one of the areas, forest was rising nearly 1% than the other cropping lands. Most of the agricultural lands were moderately lower than the acceptable pH value. Average percentage of C-organic in all agricultural land was agreed with the guideline between 0.7% and 4%.

Percentage of SOM concentration was agreed with the limit between 1.41% and 3.5% thus, composition of SOM in the forest was under the maximum limit. The component of SOM in forest was 3.5%, was exactly 1.17% increase than the other land use. SOM in forest was not much higher than the others, if pH level would be continuously lower than the current pH value (>4.62), involvement of SOM would be risen.

Minimum limitation of pH by WHO (2008) is ranging from 7 to 8.5 then maximum allowable guideline is 6.5 to 9.2 as same as the Indonesian drinking water standard (2001), mentioned in Table 2. Depend on the permissible pH values surrounding area of the study area was agreed with the described ones. The average concentrations of Hg ranged between 0.41 mg/L and 0.117 mg/L such measured values were higher than the standard. Among them, the highest Hg element concentration could be seen in irrigation water and drinking water from well which was 0.117 mg/L and 0.098 mg/L receptively.

Table 1. Soil quality of the study area

Types of plants	Average value of Hg (ppm)[1]	Average value of pH[2]	Average value of C-Organic (%)	Average value of OM (%)	Remark for average Hg concentration
Oil Palm (Sawit)	0.10	5.65	0.92	1.58	Eligible
Citrus (Jeruk)	0.10	5.53	1.35	2.33	Eligible
Paddy Field (Sawah)	0.10	5.93	0.82	1.41	Eligible
Bush (Semak)	0.09	5.6	0.86	1.48	Eligible
Forest (Hutan)	0.15	4.62	2	3.5	Eligible

[1]0.5ppm, Indonesia soil quality standard (1995); [2]6-7.5, FAO (2021)

Table 2. Water quality of the study area

Type of samples		Average pH[1]	Average value of Hg[2] (mg/L)	Average BOD (mg/L)	Average COD (mg/L)	Remark for average Hg concentration
Pond		7.3	0.063	6	24	Not eligible
River		7.24	0.07	7	29	Not eligible
Fish farming (Pond)		7.08	0.041	5	26	Not eligible
Well water	Household water	7.5	0.063	7	31	Not eligible
	Drinking water	7.4	0.098	7	33	Not eligible
Irrigation water		7.4	0.117	26	63	Not eligible

[1]7-8.5, WHO (2011); [2]0.001ppm, Indonesia water quality standard (2001)

The average Hg from fish farming pond, was 0.041 mg/L that overshot 0.038 mg/L than the standard limit. Laboratory analysis result was between 5 mg/L and 11 mg/L, comparing to the national's BOD standard guideline in drinking water; each of the samples test results were the fairly exceed the limit. Water quality for the fish raising pond was 5 mg/L which value was below the Indonesian's BOD standard.

COD was ranging from 24 mg/L to 63 mg/L but those were extremely higher than the standard. There were 63 mg/L COD concentration in plantation water which was totally agreeable both of the FAO (1985) and National standards (100mg/L). For sustainable aquafarming, the component of COD was not more than 50 mg/L by national standard; the water sample from the fish raising area was 26 mg/L that was remarkably below the limitation.

When correlate with Hg and pH values not only in soil and but also in water, Hg concentration hit the lowest value ranging from 0.09 to 0.1 ppm can be found in four land use types except forest where pH value was the lowest as >5 (4.62, strongly acidic), mentioned in Fig. 2. In addition to this, pH is indirectly proportional to Hg concentration; the stronger concentration of Hg, the lower value of pH can be seen. Maximum adsorption ranged from 86 to 98% of added Hg and occurred at pH 3 to 5 (Yujun *et al.*, 1996).

When soil pH is <6.5, Hg level uptake by the plant increases, whereas it decreases when the pH is >7.5, meaning that increased soil pH reduces mercury uptake in soil (Haixin *et al.*, 2018).

Hg accumulation may be much lower than the amount of discharging such metal every day by different mine sites. Otherwise, some area for example; the area between 0.654-0.652S to 100.852E irrigated water sample located in which Hg was highest in the same area pH value was slightly lower than others. It can reflect that even slightly changes of pH has greatly influence on the Hg accumulation.

Conclusion

In spite of the mining operation was completely terminated in the study area, Hg was still contained in soil and water. However, accumulation of Hg in water was higher than the standards (WHO and National guideline) along with soil Hg was acceptable to utilize with general purposes. That was due to the small-scale gold mining activities along the bank of Ombilin River then Hg can persist long-term as well as its travels several miles regardless the boundary is. Owing to those properties Hg can be detected after a decade of mining closure in the study area. Furthermore, the public is still consuming Hg contaminated water in their livelihood activities (irrigation and aquaculture) and domestic water as well.

Recommendation

One of the most important things is rehabilitate the deteriorated land and replantation must be priority because plants are able to eliminate or at least mitigate the Hg concentration by absorption the metals such as phytoremediation as well as other toxic substances. The local government and authorities should be legislation about (illegal or legal) small-scale mining effectively, the systematic waste disposal methods especially handling the heavy metals during the exploration and well-organized rehabilitation plans after termination the mining processes. Charge a basic rate of taxation depend on the size of projects and or penalties tax on who disregard the laws and regulations. Those funds should be spent on the CSR program in the affected regions. Having the systemic educational campaigns or knowledge sharing sections for raising people awareness.

Acknowledgements

Praise and gratitude the authors say to ALLAH (SWT) who has bestowed His grace and guidance, so that with His permission the author can complete this research. On this occasion, the author would like to express the sincere gratitude to Prof. Dr._ Rer. Nat. Ir. Syafrimen Yasin, MS. M.Sc (Chairman) and Dr. Mahdi, SP, M. Si (Member) as a supervisor who always provide guidance, advice, suggestion and limitless patience from the first stage of the research journey and until now. In addition to this, the author would like to say deep thankfulness to Dr. Jabang Nurdin, M. Si who is the head of Environmental Science. Heartily thank to Dr. Ardinis Arbain and Prof. Dr. Afrizal, MA supported with the valuable suggestions and feedbacks to improve the research.

Declaration of interests

The authors declare that there is no conflict of interest regarding the publication of this article.

References

A.G. Twardy, 1995. Soil quality standards for Indonesia. Prepared by for the Environmental Management Development in Indonesia Project (EMDI). Publisher: School of Resource and Environmental Studies, Dalhousie University. Co-published by the Indonesian Ministry of State for Environment. Environmental Reports, ISSN 1181-6457.

Boening DW. 2000. Ecological effects, transport, and fate of mercury: a general review. Chemosphere **40**(12), 1335–1351.
DOI: 10.1016/S0045-6535(99)00283-0.

Emmerton CA, *et al.* 2018. Total Mercury and Methylmercury in Lake Water of Canada's Oil Sands Region. Environ. Sci. Technol. **52**(19), 1094610955.
http://pubs.acs.org/action/showCitFormats?doi=10.1021/acs.est.8b01680.

Evers DC, Taylor KM, Major A, Taylor RJ, Poppenga RH, Scheuhammer AM. 2003. Common loon eggs as indicators of methylmercury availability in North America. Ecotoxicology **12**, 69–81. https://doi.org/10.1023/a:1022593030009

Sulaiman FR, Hamzah HA. 2018. Heavy metals accumulation in suburban roadside plants of a tropical area (Jengka, Malaysia). https://doi.org/10.1186/s13717-018-0139-3.

Fleming EJ, Mack EE, Green PG, Nelson DC. 2006. Mercury methylation from unexpected sources: molybdate-inhibited freshwater sediments and an iron-reducing bacterium". https://doi.org/10.1128%2FAEM.72.1.457-464.2006

Food and Agriculture Organization of the United Nations (FAO). 1985. International Institute for Land Reclamation and Improvement.

Food and Agriculture Organization of the United Nations (FAO). 2021. Standard operating procedure for soil pH determination.

Fournier F, Karasov WH, Kenow KP, Meyer MW, Hines RK. 2002. The oral bioavailability and toxicokinetics of methylmercury in common loon (Gavia immer) chicks. Comp. Biochem. Physiol. A **133**, 703–714. https://doi.org/10.1016/s1095-6433(02)00140-x

Gochfeld M. 2003. Cases of mercury exposure, bioavailability, and absorption. Ecotoxicol Environ Saf **56**(1), 174–179. doi:10.1016/S0147-6513(03)00060-5.

Government Regulation, 2001. The water quality classification in Indonesia. **82**/2001.

Haixin Yu, Jing Li, Yaning Luan. 2018. Meta-analysis of Soil Mercury Accumulation by Vegetables. https://www.nature.com/articles/s41598-018-19519-3

Indonesia's Gold Market, Economic Data, 2015. Source: FocusEconomics. https://www.sbma.org.sg.

Liao L, Selim HM, Delaune RD. 2009. Mercury adsorption-desorption and transport in soils. J. Environ. Qual. **38**, 1608–1616. https://doi.org/10.2134/jeq2008.0343

Esdaile LJ, Chalker JM. 2018. The Mercury Problem in Artisanal and Small-Scale Gold Mining. Chemistry A European Journal **24**(27). doi.org/10.1002/chem.201704840.

Winfrey MR, Rudd JWM. 1990. Environmental Factors Affecting the Formation of Methylmercury in Low pH Lakes. Environmental Toxicology and Chemistry **9**(7), 853 – 869. 10.1002/etc.5620090705

Muller M, Anke M. 1994. Distribution of Cadmium in the Food Chain (soil-plant-human) of A Cadmium Exposed Area and The Health Risks of the General Population. Science of the Total Environment **156**(2), 151–158. doi.org/10.1016/0048-9697(94)90352-2.

O'Bryhim JR, Adams DH, Spaet JLY, Mills G, Lance SL. 2017. Relationships of mercury concentrations across tissue types, muscle regions and fins for two shark species. Environ Pollution **223**,323–333. DOI: 10.1016/j.envpol.2017.01.029.

Ramadan MAE, Al-Ashkar EA. 2007. The Effect of Different Fertilizers on the Heavy Metals in Soil and Tomato Plant. Aust J Basic Appl Sci **1**(3), 300–306.

Hatika RG, *et al.* 2020. Illegal Gold Mining in Kuantan River: Mercury Contamination Analysis. IOP Conf. Ser.: Earth Environ. Sci 469 012005.

United States Environmental Protection Agency (EPA). 2021. Basic Information about Mercury.

World Health Organization (WHO), 2008. Guidelines for Drinking Water Quality- 3rd edition, **Vol. 1**. Incorporation the 1st and 2nd Addenda.

World Health Organization (WHO). 2011. Guidelines for Drinking Water Quality- 4th ed. ISBN: 978 92 4 154815 1.

Yujun Yin, Allen HE, Li Y, Huang CP, Sanders PF. 1996. Adsorption of Mercury (II) by Soil: Effects of pH, Chloride, and Organic Matter. Journal of Environmental Quality **25(**4), Citation: 188. www.doi.org/10.2134/jeq1996.00472425002500040027x.

Zhao K, Zhang W, Zhou L, Liu X, Xu J, Huang P. 2009. Modeling Transfer of Heavy Metals in Soil-Rice System and Their Risk Assessment in Paddy Fields. Environ Earth Sci **59**(3), 519–527.

Zulfa, Husnita L, Kaksim. 2016. The Empowerment of Gold Miners Woman in Minangkabau to Support Household Economy. Mimbar: Jurnal Sosial dan Pembangunan **32(**1), 187-193.