Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2023 Jan 01; 11(E):29-33.
https://doi.org/10.3889/oamjms.2023.9513
eISSN: 1857-9655
Category: *E - Public Health*
Section: *Public Health Disease Control*

Научна фондација СПИРОСКИ
Scientific Foundation SPIROSKI
Since 2002

OPEN ACCESS

Identification of Mercury Emissions in Soot with the Quadrant Method on Combustion of Gold in Aceh Jaya District

Lensoni Lensoni[1,2], M. Adlim[3], H. Kamil[4], T. Karma[5], Suhendrayatna Suhendrayatna[6]*

[1]GraduateSchool of Mathematics and Applied Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia; [2]Department of Public Health, Faculty of Public Health, Universitas Abulyatama, Aceh Besar, Indonesia; [3]Department of Chemistry, FKIP, Universitas Syiah Kuala, Banda Aceh, Indonesia; [4]Department of Management Nursing, Faculty of Nursing, Universitas Syiah Kuala, Banda Aceh, Indonesia; [5]Department of Occupational Safety and Health, Faculty of Public Health, Universitas Abulyatama, Aceh Besar, Indonesia; [6]Department of Chemical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia

Edited by: Sasho Stoleski
Citation: Lensoni L, Adlim M, Kamil H, Karma T, Suhendrayatna S. Identification of Mercury Emissions in Soot with the Quadrant Method on Combustion of Gold in Aceh Jaya District. Open Access Maced J Med Sci. 2023 Jan 01; 10(E):29-33. https://doi.org/10.3889/oamjms.2023.9513
Keywords: Mercury; Amalgamation; Soot; Emission
***Correspondence:** Suhendrayatna Suhendrayatna, Department of Chemical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia. E-mail: suhendrayatna@unsyiah.ac.id
Received: 03-Feb-2022
Revised: 20-Apr-2022
Accepted: 28-Apr-2022
Copyright: © 2023 Lensoni Lensoni, M. Adlim, H. Kamil, T. Karma, Suhendrayatna Suhendrayatna
Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist
Open Access: This is an open-access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0)

Abstract

BACKGROUND: Gold mining, especially by the community, causes many problems. One of the problems is the increase in mercury pollution. The amalgamation technique involving mercury in the gold processing process is still widely used by miners and has the potential to threaten the health of workers and the surrounding community.

AIM: This study aimed to identify mercury levels in soot at the location of a traditional gold processing plant in Paya Seumantok Village, Krueng Sabee District, Aceh Jaya District.

METHODS: This research was conducted at the Environmental Quality Analysis laboratory, Chemical Engineering Department, Syiah Kuala University, Banda Aceh, in May–August 2021. The sample in this study was soot caught on cloth attached to the gold kiln location by amalgamation using the quadrant method. The soot sample was obtained from the people's gold processing unit in Gampong Paya Seumantok, Krueng Seabee District; then, the fabric sample containing soot was destroyed using HNO3 in the microwave. Measurement of mercury levels, using AAS Perkin-Elmer Analyst 600, equipped with Graphite Furnace (AAS) Technique.

RESULTS: The results of the identification show that the mercury level in the first stage of measurement found the highest mercury concentration at a distance of 10 cm with a concentration of 41.90 (±21.64) g-Hg/g, a distance of 5 cm was obtained at 28.71 (±11. 0.98) g-Hg/g, and at a distance of 15 cm obtained 28.20 (±2.85) g-Hg/g. Furthermore, in the measurement of samples in stages 2 and 3, the mercury concentration in soot is influenced by distance, where the closer the distance, the higher the mercury concentration. Stage 2 measurement at a distance of 5 cm, the mercury concentration obtained is 26.84 (±21.05) g-Hg/g, a distance of 10 and 15 cm each has a concentration of 9.25 (±1.26) g-Hg/g and 9.91 (±3.59) g-Hg/g, and in the third stage of the test, the highest concentration located at a distance of 5 cm with a concentration of 20.27 (±3.57) g-Hg/g.

CONCLUSION: The average value of mercury concentration in soot obtained far exceeds the threshold set by the World Health Organization, which is 1 g-Hg/gram. Mercury levels that have exceeded the threshold need to be filtered in an enclosed space before the smoke from burning gold spreads into the free air.

Introduction

Gold is a natural resource that has a very high economic value. According to estimates, about 15% of gold (~400 tonnes) is mined manually by 10–15 million miners in 70 countries working in artisanal and small-scale gold mining (ASGM) [1]. For more than two decades, ASGM has been operated in Indonesia, spread widely across 31 provinces [2]. This mining activity causes heavy metal pollution, especially mercury, and is bad for living things in the vicinity. Mercury is used worldwide in small-scale and artisanal gold mining (ASGM) and can threaten miners and the mining community [3]. Heavy metal pollution in the gold mining environment is a significant problem many countries face [4]. Mercury (Hg) is a metal with high solubility in water and quickly changes to the gas phase. Mercury released into the environment will directly enter water bodies soil and remains in the atmosphere for a long time [5].

Mercury emissions from artisanal gold mines are a serious environmental problem in developing countries. Workers who live in gold mining areas are very susceptible to exposure to inorganic mercury poisoning [6]. Mercury released into the environment has the potential to spread to all environmental media, such as air, water, and soil. Studies have found that Hg contamination occurs in water, air, sediment, soil, biotas such as mammals and birds, fish, rice, vegetables and trees, and nearby miners, processors, or residents [7], [8]. Exposure to mercury in the long term can cause health problems in humans and become very toxic. Chronic mercury poisoning is common in

humans living near mines [9], [10]. Poisoning cases in Indonesia occurred in several places, such as the case of Buyat Bay; from an examination conducted on four people living around Buyat Bay, it was found that the mercury content in the blood exceeded the threshold [11].

In Aceh Province, community-scale gold management is located in Aceh Jaya Regency and generally uses mercury (Hg) in processing gold ore. In the processing process, the gold ore from mining in the mountain area in Krueng Sabee District is ground with a coil tool that has been added with mercury until it becomes sand powder and then mixed with mercury and squeezed using a cloth so that some of the mercury and water come out of the pores of the cloth. The collected gold carries the ignition or burning out. When viewed from an environmental perspective, sources of pollution can occur from each stage of gold processing.

At the milling stage, elemental mercury can be released from the coils so that they fall and can, pollute the surrounding soil, and can also pollute rivers. At the washing and extortion stage, liquid waste containing mercury from the results of these activities can be scattered around the gold processing area so that it can pollute the soil. Furthermore, mercury vapor produced from this activity can pollute the air at the combustion stage and then settles on the ground surface. Based on the description above, this research is focused on identifying mercury levels in soot in the community of gold miners in Paya Seumantok Village. This study aimed to determine the concentration of mercury in soot resulting from the amalgamation of gold burning in people's gold combustion.

Methods

This research was carried out in the Environmental Quality Analyst Laboratory of the Chemical Engineering Department, Faculty of Engineering, Syiah Kuala University, Banda Aceh, in May–August 2021. The sample in this study is soot captured on a cloth attached to the location of the gold kiln by amalgamation using the quadrant method. The soot sample was obtained from the artisanal gold processing unit in Gampong Paya Seumantok, Krueng Sebee District, Aceh Jaya Regency. The following is Figure 1, showing a map of the research location.

A sampling of soot from the burning of gold is carried out in the following way:

1. Fabric that has been made of a quadrant system is installed above the amalgam kiln

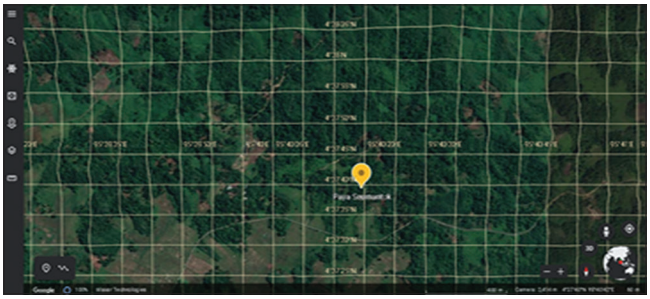

Figure 1: Research location

2. Fabric installation is carried out with distances ranging from 0 cm, 5 cm, 10 cm, and 15 cm at each quadrant point (the number of samples for one quadrant is four points, so the total sample is 14 samples (Figure 2))
3. Prepare wood as a pole for placing fabrics that have been made in quadrants with a height of 100 cm from the place of burning
4. The cloth is left for 30 days, waiting for the soot to stick from the amalgam combustion
5. After 30 days, take as much as ± 1 mg with a total of 14 samples. Samples taken must be following the distance that has been determined in the quadrant
6. The sample was put into a sample bottle (pyrex) for weighing, followed by preparation at the Environmental Chemistry Laboratory of Syiah Kuala University to check its mercury levels.

The fabric samples were destroyed in the laboratory using HNO 3 in the *microwave according* to SNI 2354. 5: 2011. Subsequently, mercury levels were measured. The sample was tested and used the *Perkin-Elmer tool. Analyst* 600 equipped with *Graphite Furnace* (AAS) Technique. Furthermore, the fabric samples containing soot were destroyed using HNO3 in the microwave. Measurement of mercury levels, using AAS Perkin-Elmer Analyst 600, equipped with Graphite Furnace (AAS) Technique.

Results

Research site demographics

This research was conducted at one of the traditional gold processing sites in Gampong Paya Seumantok, Krueng Sabee District, Aceh Jaya Regency, running for more than 5 years. Gampong Paya Seumantok, Krueng Sebee District, Aceh Jaya Regency has 928 people. The village has as many as 4 (four) log locations (gold mines). This community gold mine is running actively where almost every day, the gold processing process is carried out using the amalgamation method using mercury; as mentioned in the previous chapter, mercury harms the environment

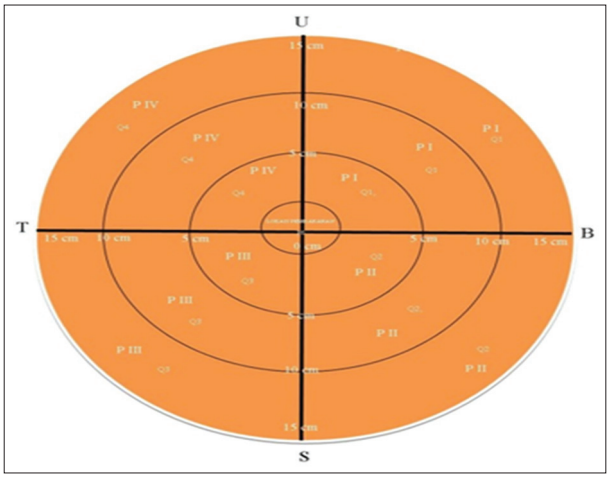

Figure 2: Quadrants on the Hg catcher fabric people's gold burning ground

and human health. The research was conducted by measuring mercury levels in soot at the local people's gold burning location. In this study, researchers identified mercury levels in soot at traditional gold processing locations using the amalgamation method; the sampling location in this study was one of the gold processing sites in Paya Seumantok Village, Krueng Seabee District, Aceh Jaya Regency. This research was conducted to obtain an overview of the mercury analysis results of air quality in the gold processing location environment.

Mercury level measurement results in soot

Measurement of mercury levels in soot was carried out using the AAS instrument. The analysis of mercury levels was carried out in the laboratory of the chemical engineering department of Syiah Kuala University. Before measuring the fabric test sample, measurements were made to make a calibration curve. The following figure shows the calibration curve of the mercury standard measurement results.

Based on Figure 3, it can be seen that the value of r is 0.9905; this shows that the curve formed is quite linear, indicating that the tool can work well. The

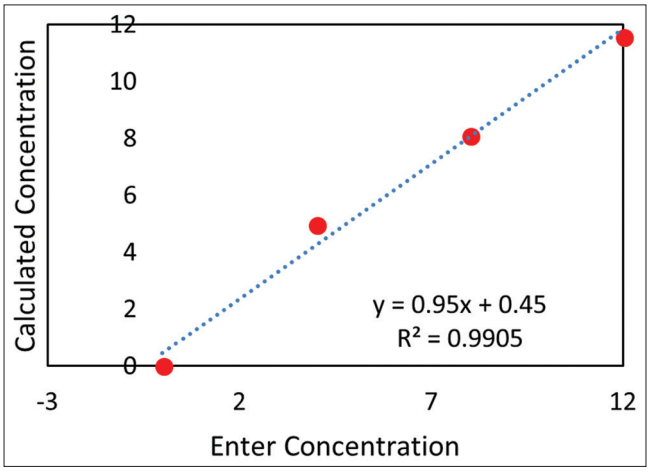

Figure 3: Mercury calibration curve

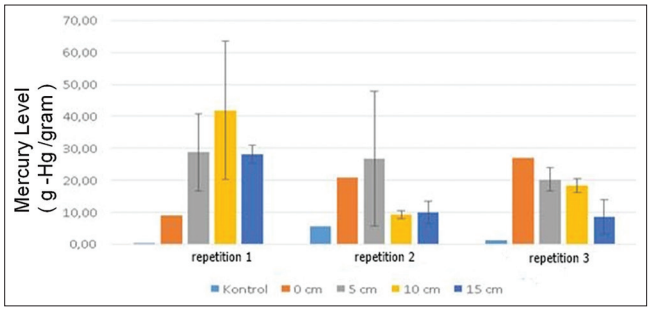

Figure 4: Identification results mercury levels in soot at the location of the people's gold mine

mercury in the soot is taken/captured using a cloth that has been divided according to the square, the mercury trapped in the cloth is then destroyed using HNO 3 in the *microwave*. The results of the destruction were then measured using the AAS instrument. Sampling was carried out for three repetitions; each repetition contained 14 samples. The identification results are shown in Table 1;

Table 1: Results of identification of mercury levels in soot

Distance	Repeat (Month) (μg-Hg/gram)		
	1	2	3
Control	0.322	5.513	1.252
0 cm	9.06	20.942	27
5 cm	28.71 (± 11.98)	26.84 (± 21.05)	20.27 (± 3.57)
10 cm	41.90 (± 21.64)	9.25 (± 1.26)	18.27 (± 2.13)
15 cm	28.20 (± 2.85)	9.91 (± 3.59)	8.57 (± 5.26)

Based on the identification results in Table 1, it can be seen that the mercury level in the first stage of measurement of mercury levels has the highest mercury concentration at a distance of 10 cm with a mercury concentration of 41.90 (±21.64) g-Hg/g, at a distance of 5 cm. The mercury concentration obtained was 28.71 (±11.98) g-Hg/g, and at a distance of 15 cm, the mercury concentration obtained was 28.20 (±2.85) g-Hg/g. Furthermore, in the measurement of samples in stages 2 and 3, the concentration of mercury in soot is affected by distance, where the closer the distance, the higher the mercury concentration (Figure 4).

Stage 2 measurement at a distance of 5 cm, the mercury concentration obtained is 26.84 (±21.05) g-Hg/g, 10 and 15 cm apart had concentrations of 9.25 (±1.26) g-Hg/g and 9.91 (±3.59) g-Hg/g, respectively. In the third stage of the test, the highest concentration was at a distance of 5 cm with a concentration of 20.27 (±3.57) g-Hg/g.

Discussion

Mercury concentration in soot obtained far exceeds World Health Organization (WHO's) threshold, one g-Hg/g. At a distance of 10 cm with a mercury concentration of 41.90 (±21.64) g-Hg/g, at a distance of 5 cm, the mercury concentration obtained was 28.71 (±11.98) g-Hg/gram, and at a distance of 15 cm, the

mercury concentration obtained was 28.20 (±2.85) g-Hg/g. Furthermore, in the measurement of samples in stages 2 and 3, the concentration of mercury in soot is affected by distance.

Stage 2 measurements at a distance of 5 cm obtained a mercury concentration of 26.84 (±21.05) g-Hg/g, a distance of 10 and 15 cm, each had a concentration of 9.25. (±1.26) g-Hg/g and 9.91 (±3.59) g-Hg/g. Stage 3 testing, the highest concentration was at a distance of 5 cm with a concentration of 20.27 (±3.57) g-Hg/g.

Based on the identification results that have been carried out, the average value of mercury levels obtained far exceeds the threshold set by the WHO, one g-Hg/g [12], [13]. Other studies in Indonesia also found hair Hg contamination. In North Gorontalo Regency, Gorontalo Province, the hair Hg levels of ASGM miners ranged from 7.1 to 17.9 ppm [14]. The mean hair Hg levels of miners and non-miners in Sekotong ASGM were 2.77 ± 1.68 ppm and 2.37 ± 1.82 ppm, respectively, and the highest level of Hg in the hair of miners was 12.93 ppm [15].

Another study reported that mercury content in hair sampled in an ASGM community in Cisitu, Banten province, reached 25 ppm [10]. Furthermore, the National Institute for Occupational Safety and Health, WHO, and the US Government Conference of Industrial Hygienists have occupational exposure criteria for workers with potential inhalation exposure to mercury. The NIOSH recommended exposure limit for mercury is 50 g-Hg/g [16].

According to these data, mercury concentrations in soot around traditional gold processing plants do not exceed occupational health standards. This finding is in line with the results of other studies, where mercury was also found in 130, 170, and 200 g-Hg/g, respectively, in the milling area [17]. Other research reported that artisanal gold milling operations contributed to the average emission of mercury into the air reaching 81.8 g-Hg/gram in the range of 37.6–139.3 g-Hg/g [12].

The concentration of mercury emission in ambient air depends on the height of the sampling point from the ground level. The mercury content was more significant at the height of 30–50 cm than 100–150 cm. These results indicate that gold mill workers who work in locations are significantly at risk of being contaminated by mercury released by the factory. This fact shows that workers in factories can have adverse effects caused by exposure to high mercury concentrations.

The Canadian center for Occupational Health and Safety stipulates that the working limit for mercury vapor in Canada – a ceiling level that should not be exceeded in the work environment, is 0.1 g-Hg/g. In urban and rural areas, normal mercury levels in soot are around 10–20 g-Hg/g and 2–4 g-Hg/g, respectively [18].

Mercury can enter the human body in three ways: through digestion, consuming fish, shellfish, squid, and other marine fish that contain MeHg; the second way is through breathing, namely, by inhaling Hg obtained from various sources such as mercury vapor from combustion. The third way is through skin absorption. Reducing the consumption of fish exposed to MeHg is very important because it will impact health [19]. In several studies, mercury found in nature exists naturally and exists as a contaminant due to human activities. The release of mercury into the environment can cause a progressive increase in the amount of mercury in nature, which can enter the distribution cycle of air, soil, and water distribution cycle, where mercury can remain-environment over the years [20].

A limitation of this study is the lack of examination of the participants' symptoms of Hg intoxication associated with Hg contamination in this area, as suggested by the previous studies [21]. It is necessary to reduce or stop the use of mercury in gold mining based on the results of community evaluations [22]. However, government support for these measures is critical, as has been proposed in Nigeria, especially in providing new job alternatives that can replace gold mining activities [23]. Since these villages are located near state forests, the government can introduce a social forestry management system as an alternative source of income based on economic and ecological viability [24], [25].

Conclusion

The average value of mercury concentration in soot obtained far exceeds the threshold set by the WHO, which is 1 g-Hg/g. Mercury levels that have exceeded the threshold need to be filtered in an enclosed space before the smoke from burning gold spreads into the free air.

References

1. United Nations Environment Programme (UNEP). A Practical Guide-Reducing Mercury Use in Artisanal and Small-Scale Gold Mining. Geneva, Switzerland: United Nations Environment Programme; 2011.
2. Rahmayani A. Mine city dynamics gold. Patanjala. 2015;7(2):345-60. https://doi.org/10.30959/patanjala.v7i2.105
3. Rajaee M, Long RN, Renne EP, Basu N. Mercury exposure assessment and spatial distribution in a ghanaian small-scale gold mining community. Int J Environ Res Public Health. 2015;12(9):10755-82. https://doi.org/10.3390/ijerph120910755 PMid:26340636
4. Hidayati N, Juhaeti T, Syarif F. Mercury and cyanide contaminations in gold mine environment and possible solution

of cleaning up by using phytoextraction. Hayati J Biosci. 2009;16(3):88-94. https://doi.org/10.4308/hjb.16.3.88

5. Fashola MO, Ngole-Jeme VM, Babalola OO. Heavy metal pollution from gold mines: Environmental effects and bacterial strategies for resistance. Int J Environ Res Public Health. 2016;13(11):1047. https://doi.org/10.3390/ijerph13111047
   PMid:27792205
6. Kristianingsih Y. The dangers of mercury to society small-scale gold mining (pesk) in Lebaksitu. J Ilmiah Kesehatan. 2018;10(1):32-8.
7. Mostafazadeh B, Kiani A, Mohamadi E, Shaki F, Shirazi FH. Mercury exposure of gold mining workers in the northwest of Iran. Pak J Pharm Sci. 2013;26(6):1267-70.
   PMid:24191337
8. Gafur NA, Sakakibara M, Sano S, Sera K. A case study of heavy metal pollution in water of bone river by artisanal small-scale gold mine activities in eastern part of Gorontalo, Indonesia. Water. 2018;10(11):1507. https://doi.org/10.3390/w10111507
9. Krisnayanti BD. ASGM status in West Nusa Tenggara Province, Indonesia. J Degrade Min Land Manage. 2018;5(2):1077-84. https://doi.org/10.15243/jdmlm.2018.052.1077
10. Bose-O'Reilly S, Schierl R, Nowak D, Siebert U, William JF, Owi FT, *et al*. A preliminary study on health effects in villagers exposed to mercury in a small-scale artisanal gold mining area in Indonesia. Environ Res. 2016;149:274-81. https://doi.org/10.1016/j.envres.2016.04.007
    PMid:27174690
11. Asmarani AR, Abbas HH, Sulaeman U. Exposure risk analysis mercury (Hg) ambient air on pekerta gold in kelurahan rappokalling Makassar city. Window Public Health J. 2021;2(3):1263-75.
12. Suhendrayatna, Simeulu P, Hafdallah, Lizam T. Mercury emissions from artisanal gold milling operation and its impact on the health of workers: Case study in panton luas, aceh selatan district in Indonesia. In: Ferasyi TR, editors. Behavioral and Earthquake Science-From Geology to Animal Perception. Indonesia: Syiah Kuala University Press; 2018. p. 114-20.
13. Suhendrayatna, Sofia, Ibrahim T, Elvitriana. Mercury Emissions to Ambient Air from Activities of Small Scale Gold Mining plants in Krueng Sabee, Aceh Province, Indonesia. In: 8th Annual International Workshop and Expo on Sumatra Tsunami Disaster and Recovery; 2013. p. 7-9.
14. Arifin YI, Sakakibara M, Sera K. Impacts of artisanal and small-scale gold mining (ASGM) on environment and human health of Gorontalo Utara Regency, Gorontalo Province, Indonesia. Geosciences. 2015;5(2):160-76. https://doi.org/10.3390/geosciences5020160
15. Ekawanti A, Krisnayanti BD. Effect of mercury exposure on renal function and hematological parameters among artisanal and small-scale gold miners at sekotong, West Lombok, Indonesia. J Health Pollut. 2015;5(9):25-32. https://doi.org/10.5696/2156-9614-5-9.25
    PMid:30524774
16. Gibb HJ, Kozlov K, Buckley JP, Centeno J, Jurgenson V, Kolker A, *et al*. Biomarkers of mercury exposure at a mercury recycling facility in Ukraine. J Occup Environ Hyg. 2008;5(8):483-9. https://doi.org/10.1080/15459620802174432
    PMid:18569515
17. García O, Veiga MM, Cordy P, Suescún OE, Molina JM, Roeser M. Artisanal gold mining in Antioquia, Colombia: A successful case of mercury reduction. J Clean Prod. 2015;90:244-52. https://doi.org/10.1016/j.jclepro.2014.11.032
18. Veiga MM. Antioquia, Colombia: The World's Most Polluted Place by Mercury: Impressions from Two Field Trips. Canada: University of British Columbia, Prepared for UNIDO (United Nations Industrial Development Organization; 2010.
19. Susanti HD. Transport of Methylmercury and Inorganic Mercury to the Fetus and Breast-Fed Infant. J Keperawatan. 2013;4(2):109-15. https://doi.org/10.22219/jk.v4i2.2360
20. Ronchetti R, Zuurbier M, Jesenak M, Koppe JG, Ahmed UF, Ceccatelli S, *et al.* Children's health and mercury exposure. Acta Paediatr Suppl. 2006;95(453):36-44. https://doi:10.1080/08035250600886157
    PMid:17000568
21. Rice KM, Walker EM Jr., Wu M, Gillette C, Blough ER. Environmental mercury and its toxic effects. J Prev Med Public Health. 2014;47(2):74-83. https://doi:10.3961/jpmph.2014.47.2.74
    PMid:24744824
22. Spiegel SJ, Agrawal S, Mikha D, Vitamerry K, Le Billon P, Veiga M, *et al*. Phasing out mercury? Ecological economics and Indonesia's small-scale gold mining sector. Ecol Econ. 2018;144:1-11. https://doi.org/10.1016/j.ecolecon.2017.07.025
23. Salati LK, Mireku-Gyimah D, Eshun PA. Evaluation of stakeholders' roles in the management of artisanal and small-scale gold mining in Anka, Zamfara State, Nigeria. Evaluation. 2014;4(19).
24. Iswandi RM, Baco L, Yunus L, Alwi LO. Kelayakan finansial pengembangan usaha tani dalam suatu wilayah lingkar tambang emas di Kabupaten Bombana, Provinsi Sulawesi Tenggara. J Agro Ekonomi. 2017;35(1). https://doi.org/10.21082/jae.v35n1.2017.67-75
25. Ramírez MG, Ruiz CM, Gomringer RC, Pillaca M, Thomas E, Stewart PM, *et al*. Mercury in soils impacted by alluvial gold mining in the Peruvian Amazon. J Environ Manage. 2021;15(288):112364. https://doi.org/10.1016/j.jenvman.2021.112364
    PMid:33774565