Arsenic in Gold Mine Tailing and Agricultural Soil in Buru Island of Maluku

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ABSTRACT

Contamination of heavy metal including Arsenic (As) due to mining activities decreased ecosystem quality. The objective of this study was to determine the arsenic level of tailing and agricultural soil, and evaluate the spatial distribution of As in closed gold mine and nearby agricultural area in Buru Sub-district of Maluku. Tailing and soil samples were taken by purposive method based on mining and agricultural activities. Arsenic level in tailing and soil samples was determined by Atomic Adsorption Spectrophotometer after mixed acid extraction. The study showed that gold mine increased As level in the top soil and tailing but soil of nearby agricultural area was not contaminated by As. Increased concentration of As in tailings has been verified. pH level of the agricultural area was neutral hence lowered As availability for plant.

Key words: Arsenic, Gold mine, Soil, Spatial distribution, Tailing

1. INTRODUCTION

The anthropogenic activities and global development cause environmental pollution that affects the quality of agriculture ecosystems. Heavy metal contaminations due to mining are reported elsewhere. Increased level of toxic heavy metal arsenic (As), cadmium (Cd), nickel (Ni), lead (Pb), copper (Cu), zinc (Zn), cobalt (Co) and mercury (Hg) was detected in gold mining area in Portugal (da Silva et. al., 2004). Soil under plant succe-ssor contains Pb, Zn and Co in the closed lead mine in Zaida of Marocco (Baghdad et. al., 2006). In Indonesia, increased level of heavy metal in mine area has been studied. Lead content in water dan total soluble solid exceeded the standard quality for heavy metal in environment but Cd and Zn content were below said standard (Wahyuni et al., 2013). Enrichment factor of Pb verified that the closed bauxite mining was heavily polluted but the area was only moderately contaminated by chrom (Putra and Apriadi, 2013).

Gold mining by using mercury (Hg) to extract the precious metal has been proven to contaminate soil that surrounds the mine. Tailing that contain heavy metal is a source of contamintion since tailing was disposed unproperly in certain mine area. Illegal gold mine in Botak Mountain of Buru Island in Maluku, Indonesia has been establish at the beginning of year 2010 and closed by local government at 2016. Illegal gold miner did not only throw tailings away into rivers but also piled it up in productive paddy fields. The previous study demonstrated that the level of Hg in the mine area and river nearby was 9.92 - 166.10 mg/kg but the Hg level in the topsoil of paddy field nearby was low (Hindersah et. al., 2018).

Based on the regulations of the Indonesian Ministry of Agriculture No. 1 year 2019, the most risky heavy metals in soil were As, Cd, Cr, Hg, and Pb. The toxicity of the mentioned five heavy metals is classified as higher over other metals so that it will have negative consequences for public health (Tchounwou et. al., 2012). Naturally, the soil contains heavy metal originating from parent materials such as phosphate sediments rocks, conglomerate, and coal (Sukar, 2003; Alexakis and Gamvroula, 2014). Many scientist studied that the content of As in soil world was 0,1-40 mg/

kg depend on soil genesis and parent material (Alloway, 1995; Bradl, 2005).

Soil properties and heavy metal valence determine heavy metal concentration in plants. Acidity (pH) and oxigen level in soil are important to change their availability. In the studied area, the dominant vegetation is lowland rice. The mobility of arsenic, such as other heavy metal, is might be limited by neutral soil of paddy field. In soil with the pH of > 5, As become immobile (Smith and Huyck, 1999). Arsenat (AsO_4^{3-}) is mobile and available in aerobic soil but only 15-40% will be available in waterlogging soil (Wan et. al., 2015).

High level of As in agricultural area will threaten the food web and plant production, so the study to delineate As level in abandoned gold mine is important. The objective of this study was to determine the arsenic level of tailing and agricultural soil near abandoned gold mine and delineates the arsenic in studied area for evaluating the As spatial distribution in studied area.

2. METHODS

The study was carried out in May-June 2016, a year after the mine is officially closed. The studied area was the closed gold mine of Botak Mountain in Buru Regency of Maluku Province (Fig.1), and in nearby agricultural area located in Waelata, Waeapo and Lolong Guba sub-district. The land use was mainly irrigated paddy field.

Figure 1 Study location in Gunung Botak of Buru Regency, Maluku Province and agricultural area nearby

A total of seven tailing and three soil samples were taken from the contaminated area and 71 soil sample were collected from agricultural soil. All sample collection location were selected by purposive method based on mining and agricultural activities in studied area. Tailing samples were collected from 60 cm depth by using auger while soil samples were taken up from top soil at the depth of 30 cm. Weeds and litters at the surface of sampling spots was removed prior to collection. Tailing and soil sample were collected from 4 randomly sampling unit for each spot, then each composite sample was placed in plastic bag. In order to obtain homogenous sample, 1 kg of soil/tailing in the transparent plastic bag was mixed thoroughly prior to collection.

All soil samples were transported to Soil Laboratory of Agricultural Environment Research Centre in Pati, Central Java. Before As analysis, all soil samples were air dried and homogenized by grounding and passing through 0.5 mm sieve. A total of 5 mg soil or tailings sample were extracted with 1 mL of perchloric acid p.a. and 5 mL of nitric acid p.a. (Nasir et. al., 2018). Total As content in tailings and soils were measured by Atomic Adsorption Spectrophotometry.

3. RESULTS AND DISCUSSION

Arsenic levels in soil where the miners piled gold tailing up were lower over tailing (Table 1). All location depicted in Tabel 1 were supposed to be contaminated by As according to the communities and miners. Critical As content in soil is 20-50 mg/kg (Alloway, 1995). Only one sampling plot has lower As level than critical content. Tailings collected from Waelo 1, Waelo 2, Parbulu and Migodo village have As level at the critical upper limit, 50 mg/kg. The major mining site in Buru Sub-district was Botak Mountain where the rocks is believed by the locals to contain high concentration of gold.

Batu and Gogorea Mountains were minor gold mines where the miners taken up loose rocks and sell it to the people at said sub-districts. Scattered and rocks heaps on topsoil can increase As level in top soil. Location 5-10 (Table 1) were agricultural field where the communities extract the gold from Botak Mountain material. The tailings were disposed on the paddy soil surface or into the man-made huge hole. This study showed that As level in the tailing from those location is high. Soil in agricultural area contained lower As concentration than contaminated site (Table 2).

Table 1 Arsenic level in soil and tailing in gold mine area

Sampling plot	Location	Kind of Sample	Content of Arsenic (mg/kg)
1	Wamsait village	Soil	8.6
2	Batu Mountain	Soil	20.1
3	Gogorea Mountain	Soil	27.7
4	Botak Mountain	Tailing	35.4
5	Paddy field Waelo	Tailing	20.9
6	Waelo 1 Village*	Tailing	47.0
7	Waelo 2 Village*	Tailing	46.3
8	Anhoni Water shed	Tailing	21.2
9	Parbulu Village*	Tailing	45.0
10	Migodo Village*	Tailing	44.8

* Used for paddy field

Arsenic are found in igneous rocks that is formed through the cooling and solidification of magma from the active volcanoes. The parent material of soil of Buru Island was volcanic ash; Arsenic would be found in rocks of Buru Island. Normal arsenic levels in world soils are 0.1-40 mg/kg or 0.1-50 mg/kg (Alloway, 1995; Violante et. al., 2010). Although As in contaminated sites were increased, their mobility and availability are determined by soil pH and oxidation-reduction reaction (Violante et. al., 2010).

Our previous study showed that soil acidity of studied location was 6.31-7.25 (Hindersah et. al., 2018). Arsen immobilization in soil is begun when soil pH > 5 (Smith and Huyck, 1999). The rice fields in Buru are saturated with water until 10 days before harvest. Arsenate (AsO_4^{3-}) is mobile in aerobic soil but becomes less available for plants uptake in waterlogged soil (O'Neill, 1995). At aerobic condition, reduction of arsenate to arsenite by soil microbes reduced As mobility and limited plant uptake (Abbas et. al., 2018). The results, this study suggested that bioavailability of As in Buru Agricultural soil is low.

Table 2 Arsenic level in agricultural soil near closed gold mine area of Botak Mountain

No	Sampling Plot	Arsenic (mg/kg)	No	Sampling Plot	Arsenic (mg/kg)
1	11	30,40	37	67	1,91
2	13	7,43	38	68	6,12
3	14	24,12	39	69	6,28
4	15	43,95	40	70	8,10
5	22	53,97	41	79	9,30
6	23	18,71	42	80	9,84
7	26	9,20	43	81	12,19
8	27	5,96	44	82	8,22
9	28	3,99	45	84	19,65
10	29	5,09	46	85	18,85
11	30	5,75	47	86	11,79
12	31	2,45	48	87	14,91
13	33	6,00	49	88	10,79
14	34	16,47	50	89	5,41
15	35	5,04	51	90	7,06
16	40	7,96	52	91	1,82
17	43	6,77	53	92	3.17
18	45	17,94	54	93	Td
19	46	15,90	55	94	4,42
20	47	13,75	56	95	1,82
21	49	3,26	57	96	6,28
22	50	4,27	58	97	7,64
23	51	6,42	59	98	10,86
24	52	10,74	60	99	20,63
25	55	2,47	61	101	10,57
25	56	15,05	62	102	13,04
27	57	0,85	63	103	4,17
28	58	6,26	64	104	11,54
29	59	11,06	65	105	10,99
30	60	3,10	66	106	16,03
31	61	3,00	67	107	7,77
32	62	8,61	68	108	6,80
33	63	2,72	69	109	3,50
34	64	6,68	70	110	9,46
35	65	2,86	71	111	0,71
36	66	2,51			

Based on As concentration in each sampling point, the simple map of As distribution was depicted in Fig 2. Arsenic level was divided to three categories i.e. low < 20 mg/kg, medium (critical concentration) 20-50 mg/kg and high (contaminated level) > 50 mg/kg. The map clearly showed that the high level of As was in the hot spot of gold mine of Botak Mountain. We found only one sampling point that have the strong pollution risk. The sampling area was in the Botak Mountain where the concentration of As was up to 53,97 mg/kg (Table 2).

The presence of 20-50 mg/kg As in limited area of Waelata and Waeapo sub-district will possibly threten the production of food crops mainly rice in Buru. According to Kurniati et. al. (2019), agricultural sector contributed to one third of Buru's Gross Regional Domestic Products in 2016. In the study area, farmers grown food crops include rice, pulses, vegetable, tubers and fruits, but rice is a dominant and important crop for the communities as well as Buru Regency. Indonesian governence stated that Buru Regency is the centre of food (mainly rice) production in Eastern part of Indonesia. Comprehensive ecological risk assesment in Botak Maountain and agricultural area nearby should be carried out although the As level in agricultural area demonstrated no serious soil pollution of Arsenic. Hence, the communities might continue thei agricultural practice in the healthy soil.

4. CONCLUSION

Gold mine at Botak Mountain by rock crushing for gold extraction increases As levels in the top soil of contaminated area. However, As levels in agricultural land are low and might be considered as uncontaminated area. Gold mine tailings contain As at the upper limit of critical concentration. The presence of As in agricultural land doesn't threaten crop production because the neutral pH and waterlogging paddy soil limit As uptake by plant roots.

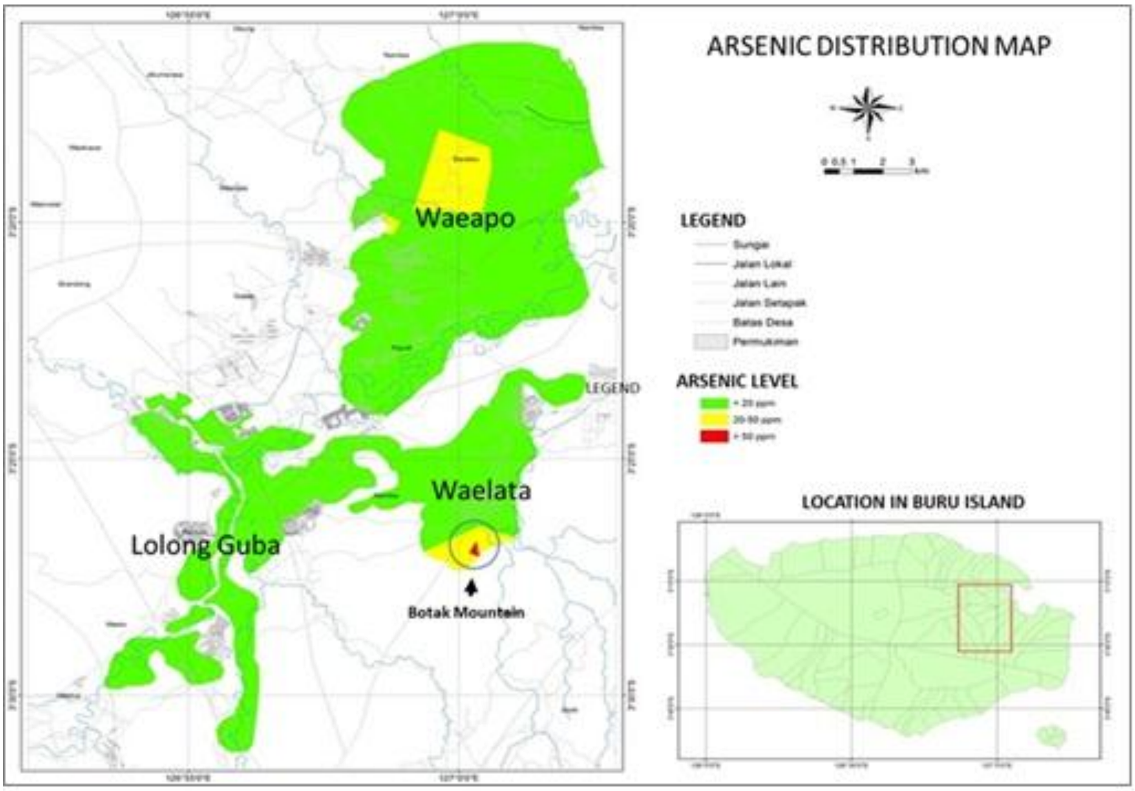

Figure 2 Spatial distribution of As in Waeapo, Waelata dan Lolong Guba Sub-district as well as in Botak Mountain.

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