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HEAVY METALS EXPOSURE AND RISK ASSESSMENT OF COOKED RICE FROM THE FIELD NEAR THE OLD DUMPSITE IN INDONESIA

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ABSTRACT: The lack of implementation of spatial planning and landfill site planning in several areas of Indonesia in the past has led to the case of the rice field directly bordering the open dumping site. High intensity of rainfall, leachate-contaminated irrigation, and the open dumping site with steep slopes create a high risk of rice pollution. This study aims to identify the concentrations and the exposure of heavy metals consist of Cr, Cd, Cu, Fe, Mn, Zn, and Pb in the cooked rice which is consumed by residents around the open dumping site, the rice, and the water using for rinse the rice. In this research, rice also compared between two zones which are upstream site zone and downstream site zone. Thus, applicable quality standards and analysis of estimated metal intake will be conducted. The results of this work demonstrate the heavy metals in the downstream zone concentrations are higher than the upstream zone. Besides, there are several samples whose exceeds the quality standard. Based on the test results obtained heavy metal concentrations in rice samples are higher than heavy metal concentrations in cooked rice. The higher Pb content in adult (Hazard Quotient value > 1) and Cd content in children (Excess Cancer Risk value > 10^{-4}) suggest the risk of the health of the people near the site.

Keywords: Exposure, Heavy Metals, Open Dumping, Rice, Risk Assessment

1. INTRODUCTION

Every day, human activities produce waste. Almost all sectors of human activity always produce waste. With the increase in the number of residents will increase the percentage of the amount of solid waste. With the times will change lifestyle patterns. With these changes will also affect the increase in the amount of waste generated. Whether it is domestic, electronic, industrial waste and others. In Indonesia, the percentage of waste transported to the landfill is still very high without prior treatment, such as the sorting of solid waste from a waste source. So that with a large amount of garbage transported to the landfill, over time, the solid waste will continue to accumulate in the landfill without any management [1].

The Gunung Tugel dumpsite operated in 1983 and was closed because it was considered to have been overloaded. In 2016, therefore the Gunung Tugel dumpsite was no longer used. However, the Gunung Tugel dumpsite is still prone to landslides and garbage fires that occur every dry season. The Gunung Tugel dumpsite itself now has a land area of 5.3 hectares by accommodating waste from Purwokerto with a more significant percentage of organic waste. Every day, the Gunung Tugel dumpsite can provide 300-350 m^3 of garbage.

The Gunung Tugel dumpsite uses an open dumping method in which existing waste was not being processed. With the application of the open dumping method, it was high possibility that leachate originating from the degradation of the waste from the landfill will enter the soil pores, which then will subsequently enter to the groundwater. With the groundwater that has been contaminated with leachate even with slow groundwater flow, the heavy metal pollutants will still be exposed to the environment around the Gunung Tugel dumpsite [2].

Heavy metals that are in the soil can be sourced from nature and also anthropogenic. In soils that are still not utilized, heavy metals can be contained in soil parent materials, geochemical and pedological processes in soil formation [3]. Ballistic soil naturally contains heavy metals Cu, Zn, Ni, and Cr . In anthropogenic processes, heavy metals can enter through the addition of chemicals such as pesticides and also the use of fertilizers, motor vehicle pollution [4, 5].

Around the Gunung Tugel dumpsite, there is a rice farm owned by residents with an irrigation channel just below the landfill. Rice produced from rice fields around the Gunung Tugel dumpsite will be consumed by themselves for daily food by residents around the Gunung Tugel dumpsite. The presence of heavy metals in the environment, such as in soil and irrigation, can be hazardous to human health. There is other study in the open dumping site that found the concentration of heavy metals in soil and water around the landfill were higher than the permissible limit because of the leachate migration [6]. Even some plants those are in the landfill could be a promising trace metals contamination indicator for heavy metals [7]. For rice plant, also can adsorb the heavy metals so that there is high content in the rice grains and cause the risk for the human health [8]. The entry of heavy metals from the environment into the food chain can cause the concentration of heavy metals that are higher and higher, because of difficulty nature heavy metals properties to decompose and to be deposited on the surface of the soil that can be absorbed by the surrounding organisms.

Therefore, to identify whether the Gunung Tugel dumpsite has a role in the entry of heavy metals in an agricultural land owned by residents around the landfill or not. So, this research was conducted to identify the magnitude of the concentration of heavy metal content contained in water, rice and also in the cooked rice consumed by residents from the rice field around the Gunung Tugel dumpsite.

2. MATERIALS AND METHODS

2.1 Location

This study was conducted at the Gunung Tugel Dumpsite, Banyumas Regency, Central Java. The local government closed this site approximately in 2016. The object of research carried out consisted of the water using for rinse the rice, the rice itself and the cooked rice. The rice was used for research originating from rice fields belonging to residents around the landfill, and they consumed it directly. For the water using for rinse the rice, the residents are devided into two groups, who use of tap water from local water company and from ground water. The map of research locations can be seen in Fig. 1.

The location of the rice and water sampling in this study was divided into two zones for each test sample. The first zone is the paddy field zone with irrigation flow before the landfill landslide occurred. The second zone is the paddy area zone with irrigation flow after landfill landslide. The water sampling zone was also divided into two zones. The first and second zones are based on the residence of the rice field owner at the location of the rice sampling point (See in Fig.2). For the rice and the water samples in zone 1, there are eight sampling points for each house and rice field. For the second zone, there are three sampling points for each house and rice field. In this study, the number of 12 sample points was based availability of the farmers in the fields and the using water in the rice fields is from the irrigtion flow which contaminated with leachate especially within and after zone 2 of rice field.

2.2 Sample Preparation and Laboratory Analysis

The rice is taken from the rice field around the Gunung Tugel Dumpsite, and residents themselves consume the rice. The water sample taken in this study is from the well water or tap water that is used by residents to cook the rice every day.

The sampling method used in this study is stratified Sampling method. Considerations taken in the sampling of rice and water in the form of residents around the Gunung Tugel Dumpsite who

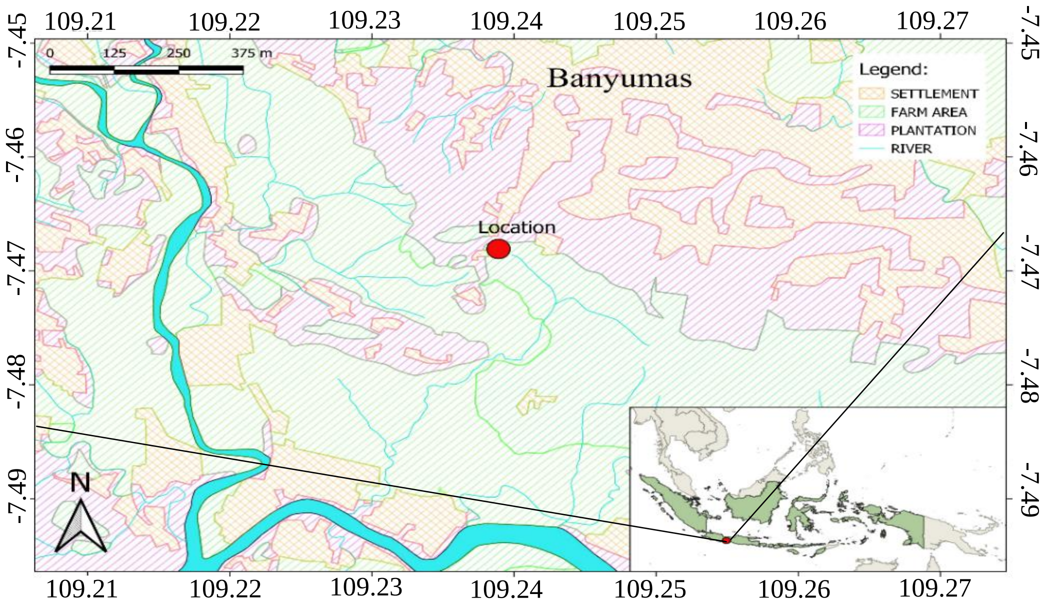

Fig 1 Site Location of Gunung Tugel Dumpsite

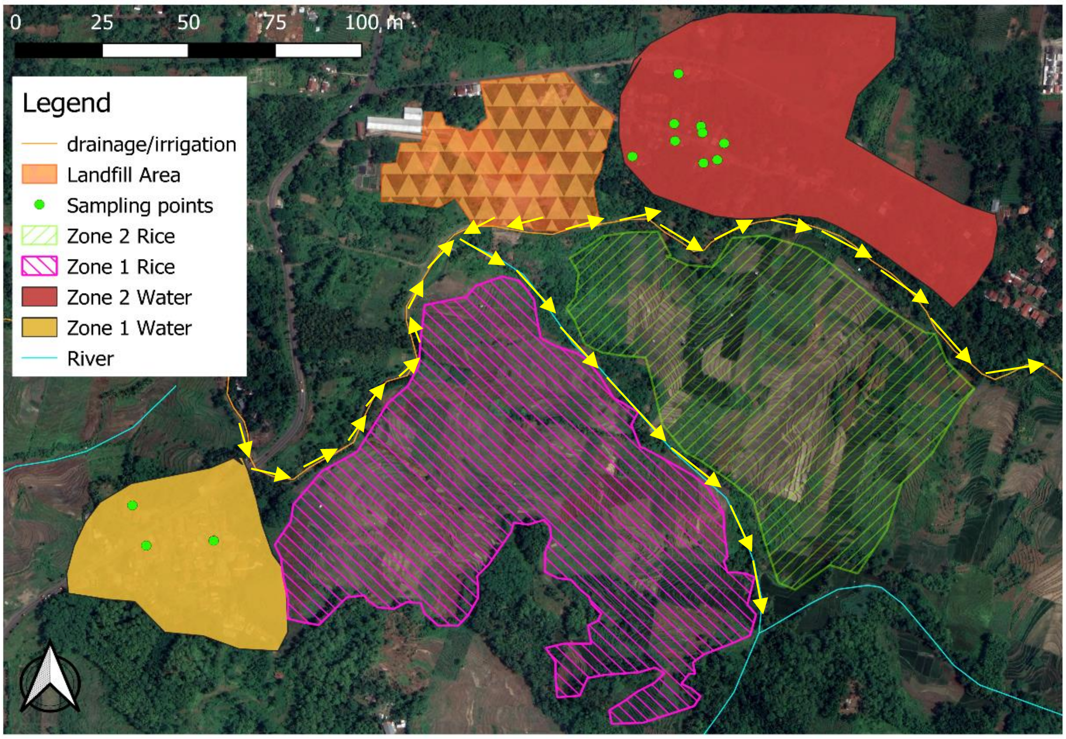

Fig. 2 Water and Rice Sampling Location

have rice fields, consume rice from the harvested rice fields around the landfill and live around the site. Samples taken in the form of rice and water are used for cooking rice at the Gunung Tugel Dumpsite. A sampling of the water is done based on SNI 6989: 58: 2008 Concerning Groundwater Sampling Methods .

Physical observations carried out in the form of conditions from topography, irrigation flow for irrigating rice fields. Then the primary data is also in the way of data from the results of heavy metal tests. Interviews and questionnaires to residents of rice fields around the Gunung Tugel dumpsite are also conducted. Interview data were made in the way of how many times people consume rice in a day, how many times people cook rice in one day, how many times people rinse rice, what kind of water is used.

For the equipment or detecting the heavy metals this research use Flame-Atomic Absorption Spectroscopy (AAS) instruments. Samples that have been taken from the field will be tested and analyzed in the Environmental Engineering Laboratory of the Universitas Islam Indonesia. Samples that were tested were carried out in destruction process until the volume decreased up to 10 ml and then extracted to 25 ml. In testing, this sample is carried out under applicable Indonesia National Standard and no modification of sample testing. In the metal test, the sample was added with a 65% concentrated nitric acid.

Table 1 Description of Variables in Formulas

Symbol	Definition
I_{nk}	Total concentration of risk agents (mg / kg.day)
C	Concentration of risk agents in clean water / drinking or food (mg / kg)
R	The rate of consumption or the amount of weight of food that enters the human body (g / day)
fE	The duration or number of days a year occurs (days/years)
Dt	The duration or number of years the exposure occurred (years).
Wb	Human weight (kg)
tavg	The average period for carcinogenic and non-carcinogenic effects (days). For non-carcinogenic (30 years x 365 days) for carcinogenic (70 years x 365 days)
HQ	Hazard agent reference value in ingestion exposure
RfD	The dose/concentration of daily non-carcinogenic risk agent exposure is estimated to have no detrimental effect even though the exposure occurs throughout life (for life)
ECR	The magnitude of the risk expressed infractions multiples of rank 10 - (exponents)
SF	The reference value of risk agents with carcinogenic effects

2.3 Data Analysis

Exposure analysis or usually referred to as exposure assessment or commonly also called contact assessment which aims to identify the path of heavy metal exposure through food or risk agents so that the amount of intake received by potentially risky individuals can be calculated. By using the calculation formula refer to Eq.1, 2, & 3 [9].

$$I_{nk} = \frac{C \times R \times fE \times Dt}{Wb \times tavg} \quad (1)$$

$$HQ = \frac{I_{nk}}{RfD} \quad (2)$$

$$ECR = I_{nk} \times SF \quad (3)$$

Based on the Hazard Quotient (HQ), it is found that there are health risks stated if the HQ value > 1. If we assume that there are other paths of exposure, especially from drinking water and vegetables, so that HQ < 0.2 is thought to be acceptable. Based on the value of Excess Cancer Risk (ECR) Risk level is expressed in exponent numbers without units (example: 1.3E-4). The level of risk is said to be acceptable or safe if the ECR ≤ E-4 (10^{-4}) based on guidelines for Environmental Health Risk Analysis issued by the Indonesian Ministry of Health and Health in 2012. The level of risk is said to be unacceptable or unsafe if ECR> E-4 (10^{-4}).

3. RESULT AND DISCUSSION

3.1 Heavy Metals in the Water Used for Rinsing the Rice

The concentrations of heavy metals in the water used for rinsing the rice for Gunung Tugel dumpsite followed the decreasing order of Fe > Mn > Zn > Cr > Pb > Cd > Cu. Based on the AAS, Cr, Cd, Fe, and Zn test results exceed the quality standards at all sampling points. The rest, other heavy metals namely Mn, Pb, and Cu exceed quality standards at several points (See Fig. 3 & Fig. 4).

The amount of Pb in tap water caused by pipes used to distribute the water, are made from polyvinyl. This plastic containing Pb stearate. It shows the occurrence of Pb leaching into the water when water is overnight in the water pipe. For Fe, Zn and Mn are naturally present in the environment and at specific concentrations also needed by the body. The rest, such as Cu, Cd, Cr may be present because of seepage of leachate into wells for those whose source of water is from well water, and also seepage of leachate water to piped water network for those whose source of water is from tap water.

3.2 Heavy Metals in the Rice

The concentrations of heavy metals in the rice for Gunung Tugel dumpsite followed the decreasing order of Fe>Cu>Zn>Mn>Pb>Cr>Cd. Based on the results of the AAS test, the concentrations of Mn, Cr, and Zn did not exceed the maximum allowable value. For the concentrations of Cu, Pb, Fe, and Cd, there were several

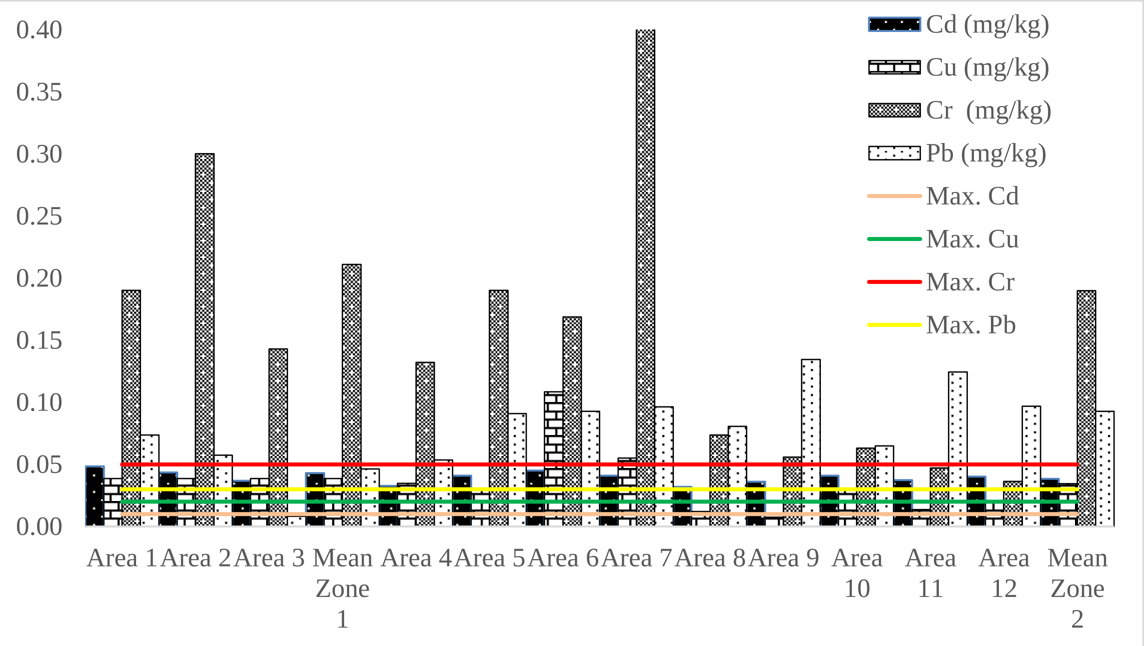

Fig. 3 Concentration of Cd, Cu, Cr & Pb in the Water

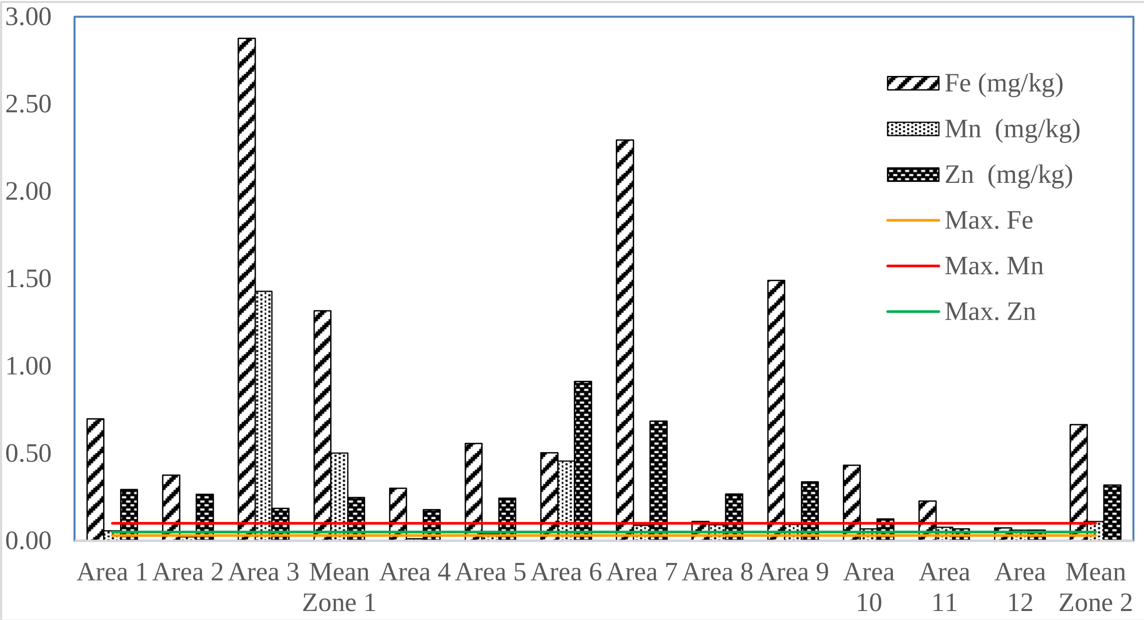

Fig. 4 Concentration of Fe, Mn, & Zn in the Water

sampling points which the values exceed the quality standard (See Fig. 5 & Fig. 6). Pb, found in the most sampling points that exceeded the quality standard is likely to occur due to the location of paddy fields in zone 2 close to the landfill with irrigation flow entering zone 2 being hit by a landslide from landfill so that leachate containing heavy metals Zn, Cu, Fe, Co, Mn, Hg, Cd, Pb, and Cr [10]. Entering the irrigation channel and mixed with irrigation water, but apart from coming from irrigation water that has been buried by landslides.

There is also a possibility that is caused by the use of pesticides and TSP fertilizer used by farmers. Excessive use of pesticides can also contribute to the accumulation of heavy metals in agricultural land. In a study, it was found that the pesticides contained heavy metals As, Cu, Zn, Mn, Hg, and Pb with Pb metal content had a higher concentration compared to other heavy metals which are around 11 - 60 ppm [11].

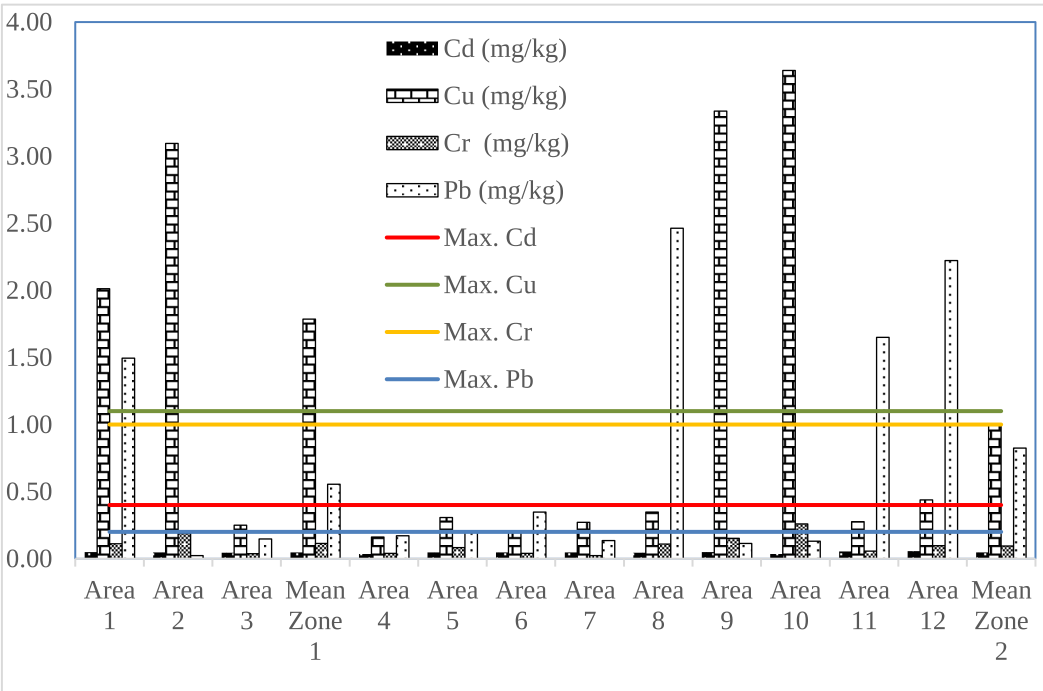

Fig. 5 Concentration of Cd, Cu, Cr & Pb in the Rice

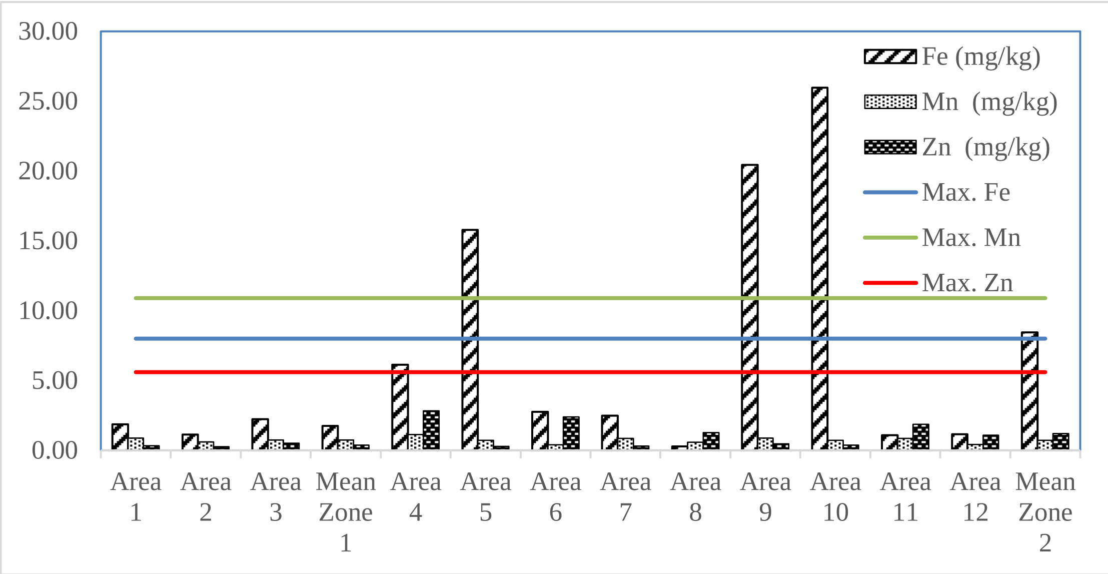

Fig. 6 Concentration of Fe, Mn, & Zn in the Rice

3.3 Heavy Metals in the Cooked Rice

The concentrations of heavy metals in the cooked rice for Gunung Tugel dumpsite followed the decreasing order of Zn>Pb>Fe>Cu>Mn>Cr>Cd. Based on the results of the AAS test, the Pb concentration exceeds the quality standard that have been set at all sampling points (See Fig. 7). This can be possible in the cooked rice accumulation of Pb metal from water and also cooked rice. It was found that the concentration of Pb in zone 1 is higher than the concentration of Pb in zone 2. It can be said that the accumulation of rice by heavy metals Pb occurs because there is already Pb metal in rice and accumulates with Pb metal in hydrolyzed water entirely when cooking rice so hydrolyzed water will make the heavy metal enter and be absorbed entirely into cooked rice. And there is also a possibility because of the tools used to cook rice. For the concentration of Cd and Zn, several sampling points exceed the quality standard. As for the concentrations of Fe, Mn, Cr, and Cu, no concentrations at all were found that exceeded the quality standard at all sampling points.

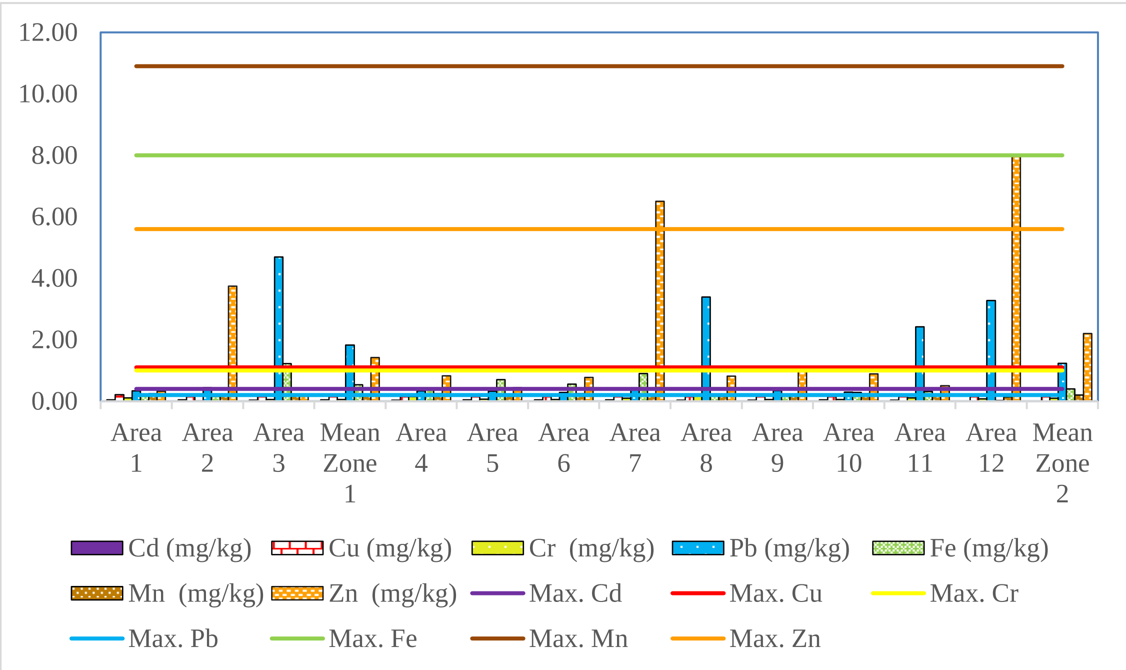

Fig. 7 Heavy Metals Concentration in the Cooked Rice

Table 2 The level of Risk Quotient from all Heavy Metals

No	Heavy Metal Para-meters	Heavy Metal concen-tration (mg / kg)	Age	(Dt) Non carcino-genic year period (yr)	(Wb) Weight (kg)	Rfd (mg/kg.day)	Exposure Intake (mg / kg.day)	Hazard Quotient (HQ)
1	Cr	0.089	Adult	30	55	0.003	0.0003	0.0917
			Children	6	15	0.003	0.0002	0.0672
2	Cd	0.048	Adult	30	55	0.001	0.0001	0.1484
			Children	6	15	0.001	0.0001	0.1088
3	Cu	0.03	Adult	30	55	0.141	0.0001	0.0007
			Children	6	15	0.111	0.0001	0.0006
4	Pb	1.202	Adult	30	55	0.0035	0.0037	1.0615
			Children	6	15	0.0035	0.0027	0.7784
5	Mn	0.196	Adult	30	55	0.14	0.0006	0.0043
			Children	6	15	0.14	0.0004	0.0032
6	Fe	0.445	Adult	30	55	0.7	0.0014	0.0020
			Children	6	15	0.7	0.0010	0.0014
7	Zn	1.962	Adult	30	55	0.3	0.0061	0.0202
			Children	6	15	0.3	0.0044	0.0148

3.4 Estimation of Heavy Metal Intake

The path of heavy metal intakes can come from various kinds, but in this study rice consumption is the primary intake of heavy metals into the human body [12]. Heavy metal intake is estimated by the level of daily consumption with the metal content in rice [13].

Based on the results of interviews with residents of agricultural land owners who are used for sampling it is estimated that in 1 day adults will consume 170 g of rice / person / day, with an estimated adult weight of 55 kg and for children of 15 kg of the estimate based on Technical Guidelines for Environmental Health Risk Analysis for 2012. Duration time (Dt) for non-carcinogenic intakes is estimated for 30 years for adults, and six years for children and carcinogenic Dt intakes for 70 years it is based that for carcinogenic the effect that can be caused to be a symptom of cancer requires a long duration to the symptoms of cancer, the value is taken based on the 2012 Technical Guidelines for Environmental Health Risk Analysis—used as an evaluation of daily intake and hazard quotient. In calculating the estimated intake is done by calculating the intake or exposure analysis and also calculating the risk characteristics.

In this study, the path of exposure comes from oral exposure (rice consumed by residents around the Gunung Tugel Dumpsite) in the Guidelines for Environmental Health Risk Analysis [14], Ministry of Health 2012 called intake ingestion. In the estimation of intake estimates based on the, the Environmental Health Risk Analysis Guidelines Ministry of Health 2012 with Reference Dose (RfD) and Slope Factor (SF) values obtained from USEPA, WHO and USDOE IRIS (Integrated Risk Information System) 2011. Exposure analysis is an evaluation of exposure to the organism, system, or sub/population, and this exposure analysis is step 4 of Environmental Health Risk Analysis (EHRA). While the calculation of risk characteristics itself is a qualitative and quantitative calculation which includes the probability of potential adverse effects from exposure to organisms, systems, or sub-populations to determine the level of risk whether risk agents at certain concentrations will pose a risk of causing harm to the health of the community or not.

Based on the calculation results in Table 2, it is found that the concentrations of heavy metals Cr, Cu, Mn, Fe, Zn, Cd have a safe risk value because they have an HQ value of ≤ 1. While for heavy metals Pb metal for adults, has a risk level value which is not safe with an HQ risk level value > 1. The level of risk for carcinogenic effects is expressed as Excess Cancer Risk (ECR). The level of cancer risk is acceptable or safe if the ECR value is ≤ E-4 (10^{-4}) and is declared unacceptable or unsafe if the ECR value> E-4 (10^{-4}). Based on the Table 3 obtained for heavy metal Cd, children have the potential to become cancerous cases because they have an ECR value> E-4 (10^{-4}).

4. CONCLUSION

It was found that the concentration of heavy metals in upstream zone (zone 2) has an average higher than downstream zone (zone 1). This is following the division of zones wherein zone 2, the distance is closer to the landfill than zone 1 and according to the direction of the contaminant flow

Table 3 The level of Excess Cancer Risk (ECR) from All Heavy Metals

No.	Heavy Metal Parameters	Heavy Metal concentration (mg / kg)	Age	(Wb) Weight (kg)	Carcinogenic exposure (mg / kg.day)	SF (Slope Factor) mg/kg.day	Excess Cancer Risk (ECR)
1	Cr	0.089	Adult	55	0.000275	0.5	1.38E-04
			Children	15	0.001009	0.5	5.04E-04
2	Cd	0.048	Adult	55	0.000148	6.3	9.35E-04
			Children	15	0.000544	6.3	3.43E-03
3	Cu	0.03	Adult	55	0.000093	-	-
			Children	15	0.000340	-	-
4	Pb	1.202	Adult	55	0.003715	0.0085	3.16E-05
			Children	15	0.013623	0.0085	1.16E-04
5	Mn	0.196	Adult	55	0.000606	-	-
			Children	15	0.002221	-	-
6	Fe	0.445	Adult	55	0.001375	-	-
			Children	15	0.005043	-	-
7	Zn	1.962	Adult	55	0.006064	-	-
			Children	15	0.022236	-	-

it is directly flow to zone 2

Based on the established quality standards for the water, rice and cooked rice test samples obtained consecutively the concentration of Cu, Cr, Cd, Pb, Zn, Mn, and Fe are 33%, 28%, 58%, 78%, 39%, 6%, 42% of sample points that exceed the quality standard of the total sample size. Based on the test results obtained heavy metal concentrations in rice samples are higher than heavy metal concentrations in rice.

Obtaining the result of the calculation of Hazard Quotient (HQ) on the prediction of adult Pb metal risk having an HQ value> 1, it can be concluded that there is a potential risk which is necessary to control, and obtaining an ECR value for the metal Cd of children> 10^{-4} , it can be concluded that there is a potential to be a symptom of cancer.

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