Exposure Analysis of Heavy Metals in Dugs Well Water of Telutu Jaya Village Community, Tinanggae District, South Konawe Regency

Firdaus Firdaus, Ika Sartika Ambarsari, Erwin Anshari, Wahab Wahab, Irfan Saputra
Department of Mining Engineering, Halu Oleo University, Kendari, INDONESIA
E-mail: ikasartikaambarsari@uho.ac.id

| Submitted: November 21, 2023 | Revised: January 11, 2024 | Accepted: September 19, 2024 |

| Published: September 20, 2024 |

ABSTRACT

The ideal drinking water requirement is clean water that is colorless, odorless, and tasteless, doe not contain pathogenic germs, does not contain chemicals or heavy metals, does not endanger the health of living things, and is not economically harmful. The ARKL study is intended to calculate or predict the risk to human health, including identification of the presence of uncertainty factors, tracing to specific exposures, taking into account the inherent characteristics of the agent of concern, and the characteristics of specific targets. Based on the ARKL study, the minimum RQ and maximum RQ values for each risk agent are <1 (safe). This study used dug-well water from the community of Telugu Jaya Village. The purpose of the study was to assess the risk of exposure to heavy metals contained in dug-well water. Measurement parameters were carried out in the form of Ph, TSS, and nine heavy metal elements (Cu, Cd, Cr6+, CrT, Pb, Ni, Fe, Zn, and Co). After the measurement, the risk of heavy metal exposure to local community-dug well water was analyzed. The results showed that HI <1, so it was concluded that the level of heavy metal intake from the dug well was still below the *reference dose* (RfD), which means that the exposure limit was still safe.

Keywords: dug well water; heavy metal exposure; RfD/SF; heavy metal elements; ARKL.

INTRODUCTION

Southeast Sulawesi is one of the islands in Indonesia that is rich in nickel mining commodities, resulting in a lot of open land due to nickel mining operations. Water is a major problem that is often the result of mining activities such as decreased productivity, acid mine drainage, decreased groundwater levels, erosion and sedimentation, and water pollution. Wastewater is water that comes from a process or an activity. Most mining industries produce liquid waste from both mining and processing activities because water has an important role at every stage of the production process. Nickel mining activities can cause pollution of water quality, namely mineral ore tetroxide, due to mining activities dismantling layers of rock in the soil, which contains many metal minerals (ores), such as iron (Fe), nickel (Ni), and lead (Pb). Pollution in a water well can come from the surface of the land where the well is located or from the side that seeps following the flow of groundwater, both air groundwater and natural groundwater, due to differences in groundwater levels and well water levels due to well water extraction (Widowati et al., 2008:193).

Quality Standard for Nickel Mining Wastewater

The quality standard of wastewater from nickel ore mining businesses or activities is the limit or maximum level of pollutant elements and/or the amount of pollutant elements that are tolerated in wastewater that will be discharged or released to water sources from nickel ore mining businesses and/or activities.

Table 1. Nickel Ore Mining Wastewater Quality Standard

Parameters	Source	Mining	Processing
pH	-	6 - 9	6 - 9
Total Suspended Solids (TSS)	mg/l	200	200

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 3, October 2024, pp.686-692
DOI: http://dx.doi.org/10.32832/astonjadro.v13i3 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Cu	mg/l	2	2
Cd	mg/l	0,05	0,05
Zn	mg/l	5	5
Pb	mg/l	0,1	0,1
Ni	mg/l	0,5	0,5
Cr^{6+}	mg/l	0,1	0,1
Cr Total	mg/l	0,5	0,5
Fe	mg/l	5	5
Co	mg/l	0,4	0,4

Environmental Health Risk Analysis

ARKL (Environmental Health Risk Analysis) is an approach used to assess health risks in the environment with the output being a risk characterization (expressed as a risk level) that explains whether or not a risk agent or environmental parameter poses a risk to public health. The assessment parameter is the reference dose (RfD) value. If there is an increase in concentration that exceeds the quality standard, it will be able to disturb or endanger public health.

Table 2. RfD and SF values of some Ingestion pathway risk agents or chemical species

No. (RfD, SF)	Agent	Response Dose (mg/kg-day)	Crystallization and Reference Effects
1	Cu	$4{,}00.10^{-2}$	-
2	Cd	$5{,}00.10^{-4}$	Human chronic exposure proteinuria (USEPA, 1985)
3	Zn	$3{,}00.10^{-1}$	Decreased erythroyte Cu, Zn-Supuroxide Dismutase (ESOD) activity in male and female volunteers (Yadrck et al., 1989; Fischer et al., 1984; Davis et al)
4	Pb	$3{,}50.10^{-3}$	-
5	Ni	$2{,}00.10^{-2}$	-
6	Cr^{6+}	$3{,}00.10^{-3}$	1-year drinking water bioassay with rats (McKenzie et al, 1958) and drinking water exposure of Jinzhou residents (Zhang and Li, 1987)
7	Cr Total	$1{,}00.10^{+0}$	-
8	Fe	$3{,}00.10^{-1}$	Causes impaired oxygen uptake in the blood, characterized by dizziness, nausea. If consumed in high amounts can damage nerves.
9	Co	$2{,}90.10^{-4}$	-

RESEARCH METHODS
Research Location

This research was conducted in Telutu Jaya Village, Tinanggea Sub-District, South Konawe District, Southeast Sulawesi Province (Figure 1). Geographically, Telutu Jaya Village is located between 4° 26' 23.2" South latitude and 122° 10' 11.6" East longitude.

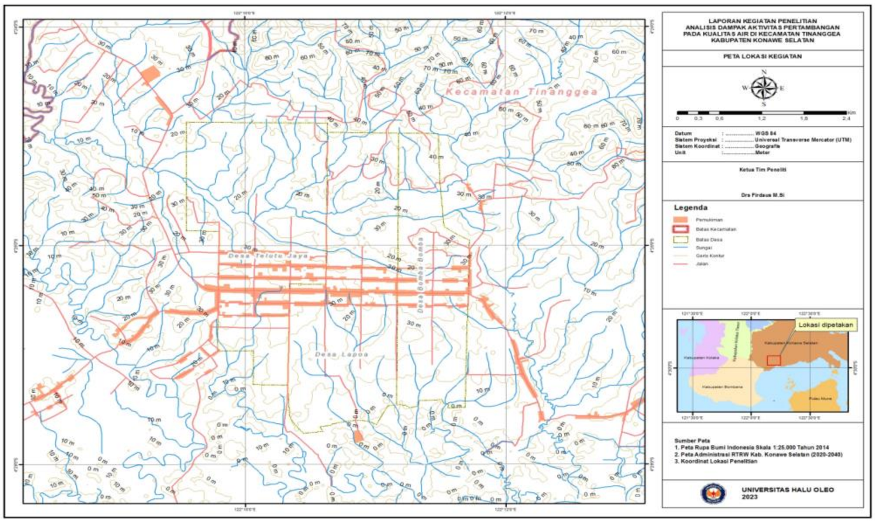

Figure 1. Research Location Map

Research Concept

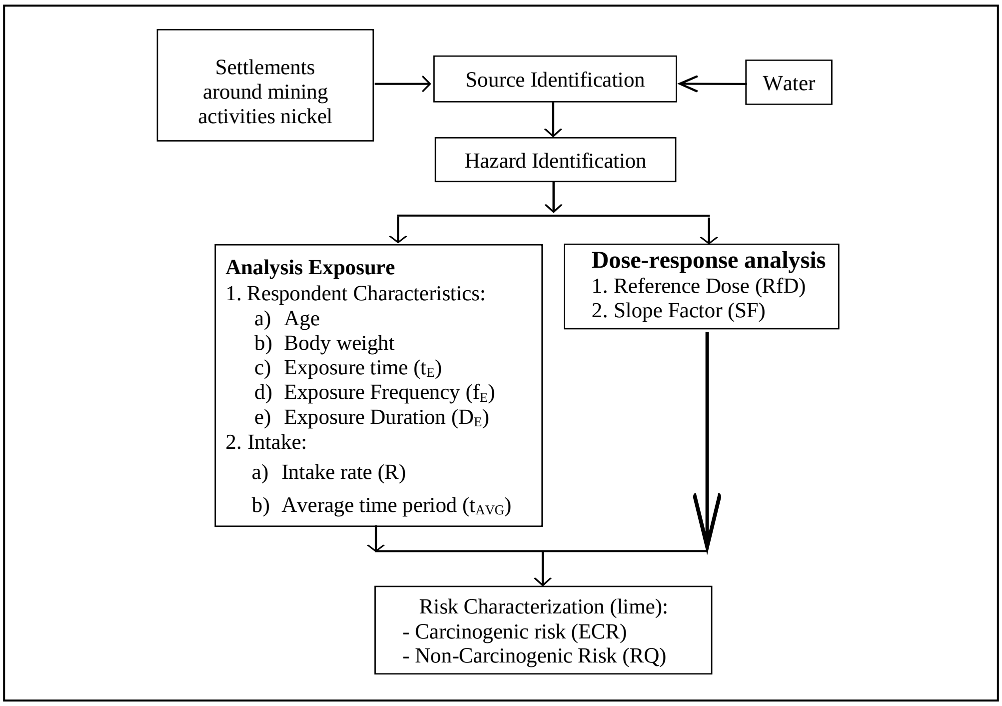

Figure 2. Research concept diagram

In this study, the variables studied were respondent characteristics (age, body weight (Wb), exposure time (tE), exposure frequency (fE), exposure duration (Dt), reference dose (RfD), average time (tAVG), non-carcinogenic risk (RQ), carcinogenic risk (ECR), slope factor (CSF), intake (I), and ingestion rate (R). The way of presenting research data is presented descriptively in the form of tables and narratives.

The implementation of ARKL includes four steps, namely:

1. Hazard Identification

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 3, October 2024, pp.686-692
DOI: http://dx.doi.org/10.32832/astonjadro.v13i3 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

The sample is the number of individuals in one household whose well water is used as a research sample with inclusion criteria, namely that residents' wells are 3-4 km from mining activities and their well water is used for drinking water.

2. Dose-Response Analysis (RfD)
   The reference dose and concentration, hereafter referred to ass RfD and RfC, are the values used as a reference for safe values for non-carcinogenic effects of a risk agent, while the SF (slope factor) is a reference for safe values for carcinogenic effects (Table 2).
3. Exposure Analysis

Exposure analysis is to measure or calculate the intake of the risk agent. Different equations or formulas are used to calculate intakes.

Intake on the ingestion route of exposure:

$$I_{nk} = \frac{C \times R \times f_E \times D_t}{W_b \times t_{avg}} \quad \text{.. (Formula 1)}$$

Description:

I_{nk} (Intake) : The amount of risk agent concentration (mg) that enters the human body with a certain body weight (kg) every day (mg/kg x day)

C (Concentration) : Concentration of the risk agent in clean/drinking water or in food (mg/I).

R (Rate) : Consumption rate or the amount of water volume or weight of food that enters every hour (liter/day)

F_E (*frequency of exposure)* : The length or number of days of exposure each year (Days/year)

D_t (*duration time)* : Length or number of years of exposure (year)

W_b (*weight of body)* : Weight of human body/population/population group (kg)

T_{avg} (nk) (*time average)* : Average time period for non-carcinogen effects (days).

Risk Characterization

Risk characterization is done by comparing or dividing the intake with the dose or concentration of the risk agent.

Calculation of non-carcinogenic risk level:

$$RQ = \frac{I}{RfD} \quad \text{... (Formula 2)}$$

Dscription:

Used to calculate the RQ for ingestion route exposure.

I (Intake) : Intake that has been calculated by the formula above.

RfD (Reference Dose) : Reference value of the risk agent at ingestion exposure.

The risk level is said to be **SAFE** when the intake is ≤ RfD or RfCnya or expressed by RQ ≤1.

The risk level is said to be **UNSAFE** when the intake > RfD or RfCnya or expressed by RQ >1.

RESULTS AND DISCUSSION

Respondent Characteristics

The parameters of respondents' characteristics from the population sample in Telutu Jaya Village, Tinanggea Subdistrict were age, body weight (W_b), and frequency of exposure (f_E). The measurement results are presented in the table below.

Table 3. Characteristic parameters of respondents in two groups residing in Telutu Jaya Village.

Respondent Characteristics	Children (0 - <12 years)	Adults (>18 years old)
Body Weight (kg)	15	58
Length of Stay (days/year)	350	350

Default values are used to measure the amount of drinking water intake, which for children with an average body weight of 15 kg is 1 liter/day, while for adults up to 58 kg is 2 liters/day.

Furthermore, conduct a dose-response analysis, namely finding the RfD value of the risk agent (the ARKL study) and understanding what effects the risk agent may have on the human body. Intake measurement (I_{nk}) uses formula 1 to find the value of the level of health risk caused by chemical agent pollution. The RQ value is calculated by comparing the intake or the amount of concentration of chemical agents that enter the human body with a certain body weight every day with the RfD (reference dose) value. The results of the intake and RQ measurements are presented in the table below.

Table 4. Intake and RQ Measurement Results in Telutu Jaya Village

Parameters	Reference dose unit (RfD) - mg/kg/day	Concentration (mg/l)	Intake (mg/kg/day)		Risk Level	
			Adult	Kids	Adult	Kids
Cadmium (Ca)	0.001	0.001967	0.000069	0.000126	0.068576	0.125723
Chromium val. 6 (Cr^{+6})	0.003	0.001767	0.000062	0.000113	0.020534	0.037646
Copper (Cu)	0.400	0.002600	0.000091	0.000166	0.000227	0.000416
Lead (Pb)	0.0035	0.001767	0.000062	0.000113	0.017601	0.032268
Zinc (Zn)	0.3	0.017867	0.000623	0.001142	0.002077	0.003807
Total chromium (Cr_{Tot})	1.0	0.001667	0.000058	0.000107	0.000058	0.000107
Iron (Fe)	0.3	0.026867	0.000937	0.001718	0.003123	0.005725
Nickel (Ni)	0.02	0.003100	0.000108	0.000198	0.005405	0.009909
Cobalt (Co)	0.00029	0.002233	0.000078	0.000143	0.268533	0.492311

Based on the results of the calculation of the Environment Health Risk Analysis (ARKL) that has been carried out from the previous stages, it is known that the resulting risk value is below the specified standard.

Table 3 and Table 4 show that minimum RQ and maximum RQ values for each risk agent are <1, which means that in adults such as workers in the risk group with an estimated body weight of 58 kg, the intake rate in adults in 2L/day for 350 days/year for the next 30 years is said to be safe when consuming dug well water as drinking water in Telutu Jaya Village, Tinanggea Subdistrict, South

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 3, October 2024, pp.686-692
DOI: http://dx.doi.org/10.32832/astonjadro.v13i3 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Konawe Regency with the concentration value of water chemical risk agents not more than the existing.

CONCLUSIONS

Risky chemical agents or heavy metal elements were measured in the parameters of community dug well water in Telutu Jaya Village, Tinanggea District, in the form of Cu, Cd, Cr6+, CrT, Pb, Ni, Fe, Zn, and Co. Exposure pathways of risky heavy mental elements that enter the human body through ingestion (swallowed). The RfD (Reference Dose) value is the value used as a reference for measuring the value of drinking water intake, where measurements are made in two groups, namely children (aged 0-<12 years) with an average body weight of 15 kg and water consumption of 1 liter/day, and adults (>18 years) with a body weight of 58 kg and water consumption of 2 liters/day. From the results of the calculation of risk characteristics in Telutu Jaya Village, Tinanggea Subdistrict, the RQ value of all test samples is <1. This means that exposure to heavy metal elements in community-dug well water is considered safe. The risk management that needs to be done related to dug well water is to strive to maintain the quality of dug well water consumed by the community, especially in Telutu Jaya Village, Tinanggea District, by conducting periodic checks and controlling the parameters of pollutants that exceed quality standards.

ACKNOWLEDGMENTS

The authors would like to thank LPPM Halu Oleo University for supporting this research with the Internal Basic Research scheme. The author would also like to thank the parties who have helped with the implementation of this research.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. *Toxicological Profile for Nickel.* U.S. Department of Health and Human Service. Online https://www.atsdr.cdc.gov/toxprofiles/tp15.pdf (Accessed on May 18, 2023)

Agustina, Linda. 2019. Environmental Health Risk Analysis of Drinking Water Parameters for Workers in Pasuruan Regency in 2017. MTPH Journal Vol 3:1

Directorate General of PP and PL. 2012. Environmental Health Risk Analysis Guidelines. Jakarta.

Effendi, H. 2003. Water Quality Assessment for the Management of Aquatic Resources and Environment. Yogyakarta: Kanisius Publisher 8th cet.

Irfandi, A, Ashar, T, Chahaya, I. 2013. Analysis of Cadmium (Cd) and Lead (Pb) Battery and Problems Health in the Community of Village, Bandar Khalipah Regency Dug Serdang in 2013 *Journal*. Environmental Health

Ministry of Lingkungan Environment and Forestry, Directorate of Management Hazardous Waste 2017.Getting to Know Metals Heavy Jakarta.

Indonesian Ministry of Health. (2012). Ministry of Health Directorate General of PP and PL. 2012. Guidelines for Environmental Health Risk Analysis. Jakarta.

Munfiah, S, Nurjazili and Setiani, O. 2013. Physical and Chemical Quality of Water from Dug Wells and Bore Wells in the Working Area of Guntur II Health Center, Demak Regency. *Journal*. Environmental Health. Volume 12:2

Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. 5 Year 2022. Wastewater Treatment for Mining Business and/or Activities Using the Artificial Wetland Method. Jakarta: Government Regulation

Regulation Minister of Environment No. 9 Year. 2006. Wastewater Quality Standard for Nickel Mining Activities. Jakarta: Government

Regulation Minister of Health No. 2 Year. 2023. Environmental Health. Jakarta: Government

Regulation Government No. 22 Year. 2021. Implementation of Environmental Protection and Management. Jakarta: Government

Regulation Government No. 82 Year. 2001. Management Quality Water and Control Pollution Water: Government

Ridhowati, S. 2013. *Getting to Know Various Metal Pollution*. Yogyakarta: Graha ilmu

Rusli, Muhammad. 2017. *Risk of Heavy Metal Exposure in River Water*. Journal of Environmental Health Vol. 14:2.

Sarudji, D. 2015. *Environmental Health*. Sidoarjo: Media Science

Suarsana, K.I. 2008. Effect of Nickel Plating Time on Copper din Plating Chrome m on Decorative Tingkat Brightness and Thickness Coating. Journal of TeMechanical Engineering. Volume 2:1

Trisnawulan et.al, 2007. Water Quality Analysis of Dug Wells in Sanur Tourism Area. OJS UNUD.ac.id

Widowati, W., Sastiono, A., & Jusuf, R. 2008. *Toxic Effects of Metals.* Yogyakarta: ANDI.