Analysis of impaired kidney function in the community around the Morosi nickel mines

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Abstract. Preliminary studies showed that almost 50% of the people around the Morosi nickel mining industry had very high creatinine levels (26 mmol/l). High creatinine levels indicate impaired kidney function. This study aims to analyze the determinants of high creatinine levels in the urine of people around the Morosi nickel mines. There were 61 participants who were interviewed and urine samples were taken to test their creatinine levels. High levels of creatinine indicate kidney disorders. Measurement of creatinine levels used urine reagent strips 13G. Then it was connected between the condition of water sources, houses, solid and liquid waste management with the participants' creatinine levels with the multinomial regression statistical test. The house condition and liquid waste management had significant association with creatinine levels (P=0.005 and P=0.026, respectively). More than 80% of people lived in houses with good condition and had very low creatinine levels (≤0.9 mmol/l). Most of them had done appropriate liquid waste management (63.9%). However, water sources and solid waste management had no association with creatinine levels (P=0.195 and P=0.130, respectively). The majority of them had used good water sources such as piped and gallon water (80.3%). There were only 19.7% of them who used dug wells and 60.7% who throw their solid waste into the river or burn it. This study concludes that house condition and liquid waste management determine of the high urine-creatinine levels of people leaving around the Morosi Nickel Mining Industries.

Introduction

The nickel mining industry is spread across provinces in Indonesia, including two biggest industries in Morosi Sub-district, Konawe District, Southeast Sulawesi Province (1) The existence of the Morosi nickel mines have had a positive and negative impact on the surrounding community (2). The positive impacts include opening up opportunities for small and micro businesses and job opportunities for people around the mining industries (3). Thus, the families' income around the industry increased by about 20.5% (2). The negative impact is that the nickel mining industries have contributed to the low quality of the environment, including the water, soil and air sources (4). The pollution index was examined approximately 7.20 PI. As we know, the nickel mining industry has carried out processing and refining of nickel and nickel ore (smelters). The illegal sand mining, plantations and agriculture also contributed to the low environmental quality in the Morosi District area.

This poor environmental condition has clearly disrupted the community health. The water sources used to daily activities certainly affect the body's metabolism or organs, such as kidney damage (5). The kidney damage result in the inability of the glomerular kidney to filter and reabsorb food substances, such as protein. One of the constituents of the human body is protein, in the body protein is stored in the muscles. This muscle cell metabolism is converted into creatinine in the blood. Then, the kidneys remove creatinine from the blood into the urine. Therefore, creatinine in the urine becomes higher than the normal value (6). An increase in creatinine level indicates a decrease in creatinine clearance and a decrease in the Glomerular Filtration Rate (7).

Looking at the natural conditions in the nickel mining industry, it seems that the community has the opportunity to be exposed to low environmental quality, which results in an increase in body fluids or the glomerulus rate. However, the effect of the water source quality and the environmental condition around the industry on decreased kidney function is not yet clearly known in Morosi District. Based on the preliminary study in June 2022 in Tanggobu Village, Morosi District, it was showed that 40% of 25 urine samples had high creatinine levels (26 mmol/l) (8). This was followed by a level of 8 mmol/l (28%), a level of 17 mmol/l (16%), and 12% at a level of 4 mmol/l (12%), and only 4% had low serum creatinine (0.9 mmol/l). However, the initial study did not know exactly what caused the high creatinine levels in the community around the Morosi nickel mine. Therefore, several questions arise and need further research, including; are the condition

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of water sources, housing conditions, solid and water waste management can damage communities' kidney function in Morosi nickel mining industry area? Thus, this study aims to analyze the determinants of high creatinine levels in the urine of people around the Morosi Nickel Mines.

Materials and methods

Ethical considerations. This research has received ethical approval from the research ethics committee of the University of Mandala Waluya No. 039/KEP/UMW/V/2022, on 16th May 2022. There is no compulsion of respondents to be involved in this research. The respondent's written consent is with the informed consent. The responden identity is kept confidentially, where all documents become anonymous. The respondent's participation is quaranteed very minimal risk.

Materials. This study was conducted in Tanggobu, Porara and Morosi Villages in Morosi Nickle Mining area from July to August 2022. There were two approached conducted in this study, namely interview and urine test to understand the creatinine level. Interview used questionnaire including identity of the respondent and the independent variable such as water sources, house conditions, solid and liquid waste management. The materials used to test creatinine levels were urine POT, plastic pipette, micro tube, 500 ul micro pipette, and Urine Reagent Strips (URIT 13G) and a microscope.

Methods

This quantitative method used a cross sectional study design. This study recruited 61 respondents aged 20-59 years. The inclusive criteria of the sample were they who had lived in the village for at least 1 year and were not seriously ill. The dependent variable is creatinine levels. While the independent variables are water sources, house conditions, solid waste management and waste water management.

The criteria for creatinine levels calculated per mmol/l with categories: very low (≤0.9 mmol/l), low (1-4.4 mmol/l), moderate (4.5-8.8 mmol/l), high (8.9-26.3 mmol/l), and very high (≥26.4 mmol/l). Water sources are divided into good of tab water or gallon water, and bad of dug well. The house condition is categorized into good and bad. Good condition is if the walls of the house have walls, tiled floors, zinc roofs, more than 2 of number of windows and bedrooms and latrine with a goose neck type. The bad house condition is if the walls are made of boards, cement floors, zinc or asbestos roofs, the number of windows and bedrooms is less than 2, and does not have a family latrine or has a family latrine with a cemplung type.

Solid waste management is divided into two criteria, namely qualify and not eligible. Qualify means if household solid waste is managed properly, including being dumped in the trash and then transported by the garbage officer, dug up and buried or burned. Meanwhile, not eligible means if household solid waste is thrown away or thrown into the river.

The waste water management is also divided into two, qualify and not eligible. Qualify means the waste water discharged from the house is made a channel and infiltration or enters a public sewer. Meanwhile, not eligible is if the waste water from the house is thrown away and makes the surrounding environment inundated with wastewater.

The data analysis used descriptive and inferential with Statistical test of Multinomial Logistic Regression with a significance level of 95%.

Results

The average age of the respondents involved was 42 years old. The most of age goup was 30-49 years old (62.2%). The age group of 20-29 years old was slightly (11.5%) (Table I). Female, married, and elementary school educated were the most dominant respondents involved (70.5, 83.6, and 45.9%, respectively).

Most of the respondents had low creatinine levels, aroung 1-4.4 mmol/l (32.8%) (Table II). However, the proportion of high creatinine levels (8.9-26.3 mmol/l) was almost close to the low levels. The rest were 4.5-8.8 mmol/l of the creatinin levels. Meanwhile, respondents with very low (≤0.9 mmol/l) and very high (≥26.4 mmol/l) creatinine levels were the least. Lots of respondents have used good water sources and waste water management (80.3 and 63.9%, respectively). Responden who live in good and bad house condition was almost the same (50.8 and 49.2%, respectively). However, the majority of them did not manage well their solid waste (60%).

The test showed that only the house condition and wastewater management had a significant effect on the urine creatinine levels (P<0.001 and P<0.026, respectively) (Table III). The house condition and waste water management can affect creatinine levels by 54.3%. This means there were 45.7% of other factors influencing the creatinine level which were not included in this study.

Based on Multinomial Logistic Regression, the effect of water source conditions, housing and solid or water waste management on creatinine levels is explained as follows:

$$Ln = \frac{P(\text{Very low})}{P(\text{Very high})} = -35.198 - 17.108\,\textit{water source} + 35.582\,\textit{house condition} - 18.903\,\textit{solid waste management} + 36.191\,\textit{waste water management} \quad \text{[Regression Equation 1]}$$

Regression equation 1 shows that there is no significant difference between the proportion of respondents with very low (≤0.9 mmol/l) and very high (≥26.4 mmol/l) creatinine levels even though there is a good quality clean water source (P=0.996). However, if there are good housing conditions and the waste water management meets the requirements, then the probability of having a creatinine level ≤0.9 mmol/l is higher than that having a creatinine level ≥26.4 mmol/l (P<0.000). Meanwhile, if there is solid waste management that meets the requirements, then the probability of having creatinine levels ≤0.9 mmol/l is lower than those having creatinine levels ≥26.4 mmol/l (P<0.000).

$$Ln = \frac{P(\text{Low})}{P(\text{Very high})} = 19.006 + 1.902\,\textit{water source} - 1.403\,\textit{house condition} - 20.059\,\textit{solid waste management} + 1.075\,\textit{waste water management} \quad \text{[Regression Equation 2]}$$

Regression equation 2 shows that if there is a good water source and housing conditions, as well as solid waste and waste management that meets the requirements, then the probability of having a creatinine level ≥26.4 mmol/l is very high (B=19.006, P<0.000). Specifically, if there is solid waste management that meets the requirements, the probability of

Table I. Characteristics of respondents in Tanggobu, Porara and Morosi villages, Morosi sub-district.

Characteristics	Frequency (n=61)	Percentage (%)
Age:		
20-29	7	11.5
30-39	19	31.1
40-49	19	31.1
50-59	16	26.2
Mean ± SD	42.2±9.9	
Gender:		
Female	43	70.5
Male	18	29.5
Marital status:		
Single	5	8.2
Marry	51	83.6
Widow	5	8.2
Education:		
No school	2	3.3
primary school	28	45.9
Junior high school	11	18.0
Senior High School	15	24.6
Diploma	1	1.6
Bachelor	4	6.6
Total	61	100.0

SD, standard deviation.

Table II. Distribution of creatinine level, water and santiation variable in Tanggobu, Porara and Morosi Villages.

Variable	Frequency (n=61)	Percentage (%)
Creatinin level:		
Very low	5	8.2
Low	20	32.8
Moderate	12	19.7
High	19	31.1
Very High	5	8.2
Mean ± SD	2.98±1.15	
Water source:		
Good	49	80.3
Bad	12	19.7
House condition:		
Good	31	50.8
Bad	30	49.2
Solid waste management:		
Qualify	24	39.3
Not eligible	37	60.7
Waste Water management:		
Qualify	39	63.9
Not eligible	22	36.1

SD, standard deviation.

having a creatinine level of 1-4.4 mmol/l is lower than that of having a creatinine level of ≥26.4 mmol/l (B=-20.059, P<0.000). Meanwhile, the presence of water sources, housing conditions and liquid waste management did not show a significant difference in probability between respondents who had creatinine levels of 1-4.4 mmol/l and ≥26.4 mmol/l.

$$Ln = \frac{P\,(Moderate)}{P\,(Very\ High)} = 18.973 + 2.395\,water\ source - 2.980\,house\ condition - 18.356\,solid\ waste\ management - 0.413\,waste\ water\ management \quad \text{[Regression Equation 3]}$$

Regression equation 3 also shows the same thing as the second equation, namely if there is a good water source and housing conditions, as well as solid waste and waste management that meets the requirements, then the probability of having a creatinine level ≥26.4 mmol/l is very high (B=18.973, P<0.000). If there is only solid waste management that meets the requirements, then the probability of having a creatinine level of 4.5-8.8 mmol/l is lower than that of having a creatinine level of ≥26.4 mmol/l (B=-18.356, P<0.000).

$$Ln = \frac{P\,(High)}{P\,(Very\ high)} = 19.042 + 2.751\,water\ source - 1.709\,house\ condition - 19.157\,solid\ waste\ management - 0.280\,waste\ water\ management \quad \text{[Regression equation 4]}$$

Likewise, the regression equation 4 is also the same as the regression equations 2 and 3, namely if there is a good water source and housing conditions, solid waste and waste water management that meets the requirements, then the probability of having a creatinine level ≥26.4 mmol/l is very high (B=18.973, P<0.000). Especially, if there is waste management for those who meet the requirements, then the probability of respondents having levels of 8.9-26.3 mmol/l is lower than those having levels ≥26.4 mmol/l (B=-19.157, P<0.000). While the presence of water sources, housing conditions and good waste water management there is no significant difference for the probability of respondents having high levels (8.9-26.3 mmol/l) and very high (≥26.4 mmol/l).

Discussion

The results of this study indicate that the majority of respondents in the Morosi mining industrial area had creatinine levels above 4 mmol/l (85.2%). Where is the house condition and waste water management which has a significant effect on the respondent's creatinine levels. However, after adjusting for all variables, the solid waste management also affects the creatinine levels. These three variables are not fully determinants of high creatinine levels, there are still 45.7% other determining factors. Several previous studies stated that the determinant of high creatinine levels is like tobacco intake (9), alcohol (10), uncontrolled lipied diet, sodium, and insufficient fruit and vegetable intake vegetables that contain lots of antioxidants (11), and lack of food intake that contain high fiber (12). Physical activity is also a determinant of creatinine levels (13). Physical activity affect also

Table III. The effect of water source and sanitation on high urine creatinine levels.

Effect	Model fitting criteria -2 log likelihood of reduced model	Likelihood ratio tests			Pseudo R-square Nagelkerke
		Chi-square	df	Sig.	
Intercept	54.643[a]	.000	0	.	.543
Water.Source	60.696	6.053	4	.195	
House.condition	69.582	14.939	4	.005	
Waste.management	61.751	7.108	4	.130	
Waste water.management	65.710	11.066	4	.026	

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0. [a]This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

to building bone density. Likewise, muscle mass and body weight were also correlated with serum and urine creatinine levels (14,15). Prolonged infectious diseases with severe dehydration and inappropriate drug use are also triggers for high urine creatinine levels (16). In detail, the influence of water sources, housing conditions and solid and liquid waste management on creatinine levels in Morosi nickel mining industry is explained below.

Water sources and creatinin level. Water sources were found to have no effect on creatinine levels, because most of the people in the three villages around the Morosi nickel mining industry already used clean water sources that met the requirements (80.3%). Where, for daily needs such as cooking, bathing, washing using water sources from pipes built by the nickel mining industry. As for drinking needs, many respondents use gallons of water. Where, respondents who use gallons have more creatinine levels below 5 mmol/l (81.3%) compared to users of tap water (27.3%) and dug wells (25.0%). This evidence shows that respondents who use gallons of water for their daily needs have healthier kidneys, when compared to respondents who use tap water and dug wells. It is known that the depot water treatment process with gallons uses O3 pressure, namely Ozonization and uses an ultraviolet light filter that kills microorganisms (17).

In this area, there are still a small number of people who use dug wells (19.7%), because they have difficulty connecting the pipe from the main pipe made by the nickel company to their house. When viewed from the urine creatinine levels in users of dug wells, it is around 75% high. It can be said that the dug well is polluted with dangerous metals from nickel management waste. Nickel ore is generally associated with other heavy metals such as copper (Cu), arsenic (As), iron (Fe), and platinum (Pt) (18). Fe, As, Cu, and Pt wastes cause growth failure of living things, in addition to an increase in total protein, alkaline bisides creatinine levels (19).

House condition and urine creatinine. The house condition around the nickel mining industry has a very important role for the health of its inhabitants. More than 80% of the respondents live in good houses condition. They tend to have very low creatinine levels (≤0.9 mmol/l) (20,21). However, the effect of the existence of the house condition was only on respondents who had very low creatinine levels, and it was not in the group of respondents who have creatinine levels above 1 mmol/l. Generally, a proper house is a place to protect its inhabitants from air pollution around it. However, it should be noted that nickel mining companies, including their smelters, carry out several activities to obtain quality nickel production. This will result a negative impacts include dust, ash, NOx gas, CO and SOx. This because this pyrometallurgical process starts from drying, reduction and calcination, smelting to purification and granulation, will produce different emissions at every step (22). For example, the combustion process will produce dust/ash and the NOx, CO and SOx gases. In the smelting and purification processes produce slag which is a hot liquid and when it will become solid after cooling. However, the current study shows there were another factors which influence the high creatinine levels. As we known that for the past 2 years, since 2020, the Covid-19 pandemic has occurred in the world, including in Indonesia. Where a house with high humidity often becomes a breeding ground for microorganisms such as the SARS-CoV Virus. This virus can cause damage to organs in the human body, including the kidneys (23). The SARS-CoV virus and SARS-CoV-2 have similarities in biochemical interactions and pathogenesis. Nucleic acids from the virus were also found in urine in 4 out of 58 cases (6.9%), suggesting that the kidney may be the target organ of this coronavirus. Cytokine Storm Syndrome may also play an important role in the multi-organ dysfunction syndrome in this case.

Solid waste management and creatinine levels. Most of the respondents did not manage their solid waste properly, such as throwing it into rivers or burning it which produces smoke (60.7%). It is proven that solid waste management in this study has a very significant effect on the respondents' creatinine levels. However, the relationship was negative on creatinin level. That means that people who managed their solid was well, they had higher creatinine levels. This happen can be explained that most of the respondents came from outside the Morosi sub-district. They rented boarding houses around the morose mining company. Where, most of the boarding houses are permanent and provide trash bins. Therefore, they disposed of their garbage were already well.

However, why did they have high creatinine levels? The other explanation is that the respondens worked in the different units in the nickel mining. For example, female respondents work in the administration section, while male respondents are scattered in several sections, including dump trucks, excavator operators, and smelters (22). Where each part of the process produces different emissions and will affect worker's health condition differently. In the drying, calcination, reduction and granulation sections, diesel and coal are used as fuel in the smelting process. This unit uses high-voltage electricity as a source. The environment around the high-voltage electricity will produce a magnetic field and induce the human body (24). Even though the exposure is small but for a long time, it will also have a negative effect on the health of the workers. The very high frequencies ranging between 10-300 GHs will result in excessive tissue heating and acute biological effects on the worker health (25). Therefore, the appropriate solid waste management is not certain for respondents health condition because there are other factors, including diet and physical activity.

Based on the interviews, several male workers usually buy food from stalls around their boarding house or stores durable food ingredients, such as salted fish or packaged food including instant noodles. Frequent intake of salted fish also affects gastric organs including stomach ulcers and the risk of stomach cancer (26,27). The foods that contain high salt also increase the risk of hypertension and kidney disease (28,29). Furthermore, as nickel mining workers, especially men, of course, they use a lot of their physical organs. Several studies have stated that it has an impact on kidney function (21). although, other studies state the opposite of the effect on kidney function (30). The above description, of course, can clearly explain why respondents who have managed their waste properly have high creatinine levels.

Waste water management and creatinine levels. The waste water management effected significantly on the creatinine levels in the Morosi nickel mining industrial area. The majority of respondents still have not implemented these household wastewater safety standards. The respondents who live in a home where wastewater is managed properly, they tend to have very low creatinine levels (≤0.9 mmol/l). However, the responden who had high creatinine level (>4.4 mmol/l) were not caused only by the appropriate waste water management. There are several other factors that play an important role in this case. As we known that the waste water contains many pathogenic germs that make people sick (31). Domestic waste water can be polluted by livestock, bird droppings, or human waste. Household wastewater that is not channeled into sewers will contaminate the groundwater surface including dug wells.

The Indonesian Government has issued guidelines of household waste water managemen. Every household needs to carry out the separation of household liquid waste channels through infiltration wells and sewerage channels (32). Household liquid waste form faeces and urine is channeled into a septic tank equipped with an infiltration well. Meanwhile, household liquid waste from bekar water generated from kitchen, bathroom and hand washing facilities is channeled into the sewerage channel. Principlely, to protect household liquid waste, bathroom and kitchen waste water should not be mixed with water from the latrines. Then it cannot be a vector breeding place, must not smell, must not have puddles and must be connected to a public sewer or infiltration well.

Limitations

This study did not measure the respondent's urine protein, so the difference between creatinine and urine protein was not known. Where, these two parameters become benchmarks of impaired kidney function (33). This research only relates to the type of water source used by the community, and does not measure the level of contamination of the water source. Therefore it is important for future researchers to continue their studies using protein urine as an indicator of impaired kidney function, as well as conducting pollution tests in water bodies that are used by the community.

Conclusions

The determinants of creatinine levels of the people in the villages around the Morosi Nickel mine are the house condition, solid and liquid waste management. Meanwhile, water source has no effect on creatinine levels. This is because many communities around the mine already use piped water sources from the mining industry. Most people already have proper housing and manage their liquid waste according to standards, but most still throw their garbage into ditches, rivers or on roadsides.

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Availability of data and material

The data presented in this study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

Ethical approval was obtained from from the research ethics committee of the Mandala Waluya University, Numbers 039/KEP/UMW/V/2022, on 16th May 2022.

Informed consent

Informed consent was obtained from all respondents and confidentiality was ensured.

Contributions

TT, conceptualization of the research, writing the original draft, review and editing; S, analysis and interpretation of data; TT, S, funding acquisition. Both authors approved the final version to be published.

Conflict of interest

The authors declare no potential conflict of interest.

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