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Analysis of Residential Well Water Quality Around People's Gold Mines in the Tourist Area of Dusun Selindungan

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Abstract: The Sekotong area has natural charm and potential mining. This area is one of the preferred destinations for visits by local and foreign tourists. However, apart from that, the Sekotong area is also famous as a community gold mining area. Mining activities carried out still use traditional methods, which are very far from environmentally friendly principles, so they can have impacts, including causing a decrease in the quality of residential well water. This research was conducted to determine the water quality of residential wells around community gold mining in the tourist area of Dusun Selindungan Eleven well water samples were taken using a purposive sampling method based on the distance of the well to the source of gold mining waste disposal and are still used by residents to meet their daily needs. Physical, chemical and biological water quality parameters of water samples were investigated in the laboratory, except temperature and pH were measured directly in the field. Data for each water quality variable was analyzed to determine the pollution index. The results show that DO, TDS, content of phosphate, E. Coli bacteria and total coliforms in well water from the study area generally exceed quality standardsWell water in an area that is a different distance from the people's gold mining waste disposal site has each been contaminated with manganese and mercury, although it is still below quality standards.

Keywords: Tourist area of Dusun Selindungan; Traditional gold mining area; Well water quality

Introduction

Sekotong is one of the sub-districts in West Lombok Regency, West Nusa Tenggara Province, which has natural resources that have the potential to be a driver of new economic growth, namely natural tourism and mining areas. The natural tourist area of Selindungan Beach is one of the tourist destinations in Sekotong that is attractive for foreign and local tourists to visit. Selindungan Beach has a beautiful panorama and is a link to other tourist areas via crossings to small islands such as Gili Gede, Gili Nanggu and Gili Petagan.

The location of this tourist area is close to the people's gold mining area. Related to this, Suripto et al. (2022) have reported, that in the Sekotong area of West Lombok there are many community gold mining sites. In connection with this, also Arif et al. (2020), González-Vásquez et al. (2023), Donkor et al. (2024), and Rahayu et al. (2016) had also stated that traditional gold mining processing is usually done traditionally, namely by amalgamation techniques using mercury. Waste resulting from processing using this technique is immediately thrown onto open land and seepage water can directly accumulate in the soil and also be absorbed in ground water, which can have a negative impact on water quality in the area.

People in the Selindungan use well water to meet their daily needs. Most of the locations of residents' wells in this area are very close to community gold processing locations, which can cause a decline in the quality of well

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water because it is contaminated by the gold mining processing waste mentioned above (Meutia et al., 2022; Kazapoe et al., 2023; Casso-Hartmann et al., 2022). Until now, people in the community gold mining area still use well water for their daily needs, but these people generally do not know the quality of their well water (Rahayu et al., 2016). The impact of gold mining on well water quality and on the health of people in the area has never been studied. Therefore, the quality of residents' well water in the area needs to be known and evaluated.

In addition, the relationship between variations in well water quality and distance from the gold processing site also needs to be studied immediately. This is important because variations in the quality of well water that are indicated to be contaminated with mercury are closely related to variations in distance from the gold processing site (Shrestha et al., 2023; Meride & Ayenew, 2016; Addisie, 2022; Lewoyehu, 2021). Physical, chemical and biological water quality can be determined using various standard methods which refer to quality standards for various designations. Based on the background of the problem above, this research was carried out with the aim of knowing the quality of well water according to variations in distance from the people's gold mining waste disposal site in the tourist area of Dusun Selindungan, Sekotong.

Method

Determining the Area and Taking Well Water Samples

Eleven dug wells which are still used by residents to meet the residents' daily needs were selected from all the wells spread across Selindungan Hamlet (Figure 1).

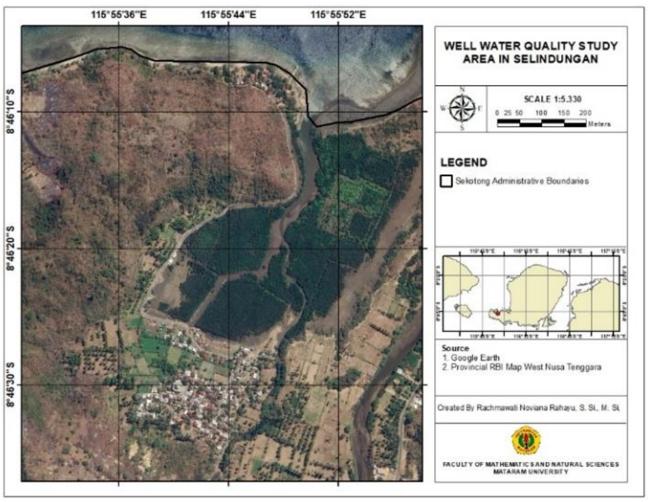

Figure 1. Water quality study area in the tourist area of the Dusun Selindungan

This image was taken from the ArcGIS 10.8 Base Map and the borders of the study area were inserted based on the results of direct observations in the field. The distribution of selected wells is divided based on the distance from the community gold mining waste disposal site into three distance categories, as used by Pramaningsih et al. (2023), Haseena et al. (2017), and Xiao et al. (2019), namely categories 1, 2, and 3 (Table 1). Parallel to the time of taking well water samples, observations were also made of the environmental tone and processing activities of the people's gold mine using direct observation methods and interviews with the local community.

Table 1. Distance Category between the Well and the Gold Processing Waste Disposal Site

Category	Distance from the well to the waste disposal site
1	< 10 m
2	10 m < x < 200 m
3	> 200 m

Measurement of Well Water Quality Variables

The physical, chemical and biological quality of well water samples were investigated in the laboratory, while the temperature and pH were measured directly in the field. The water quality parameters measured were suitable for determining water quality standards according to applicable regulations, namely safe for consumption (class A), safe for bathing and washing (class B) and safe for agriculture and fisheries (class C) (Asryadin et al., 2023; Purwono et al., 2019; Supardiono et al., 2024). The measured water quality parameters and quality standards can be seen in Table 2.

Table 2. Measured Water Quality Parameters and Applicable Safe Standards

Parameters		Unit	Standard
Physical	Temperature	^{0}C	Temperature (±3°C)
	TDS	mg/L	< 300
	Turbidity	NTU	< 3
Chemical	pH		6.50-8.50
	DO	ppm	-
	BOD	mg/L	-
	Ammonia	mg/L	-
	Ferrum	mg/L	0.2
	Phosphate	mg/L	0.2
	Manganese	mg/L	0.1
	Mercury	mg/L	0.001
Biological	*Escherichia coli*	CFU/100ml	0
	Coliform total	CFU/100ml	0

Data Analysis

Each well water quality variable data was processed to produce a pollution index. The pollution index was then used to determine air quality status. The pollution index (PI) was calculated using the formula, which has been used by Clasen et al. (2015), Supardiono et al. (2024), and Hanif et al. (2020), namely as follows:

$$PI = \frac{\sqrt{(Co/Cq)^2\ M + \ (Co/Cq)^2\ A}}{2} \quad (1)$$

Where:
PI= Pollution index
Co = Concentration of pollutant x that observed
Cq = Concentration of pollutant x is based on the quality standards designated for class q
M = Maximum value
A = Average value

An outline of the work flow chart for observing the quality of well water around smallholder gold mining can be seen in Figure 2.

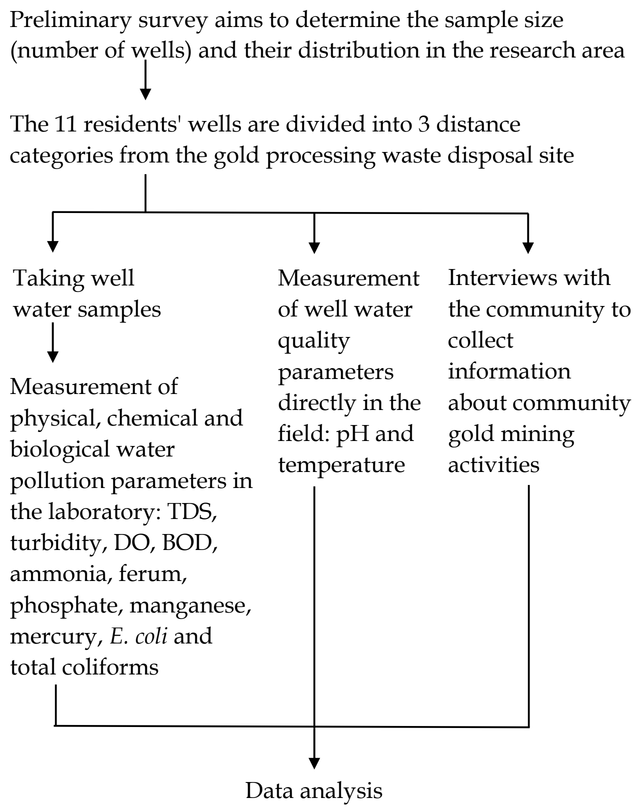

Figure 2. Work flow chart for observing the quality of wells around community gold mining in tourist area of Dusun Selindungan

The methodology for optimizing the determination points is seen based on the decline in water quality based on general location as well as the decline in health quality (Ardila et al., 2024). The level of sample water pollution was determined based on the criteria for the water pollution index (Chen et al., 2019; Chowdhary et al., 2020; Razmjoo et al., 2017; Kaur et al., 2021). The criteria for determining the level of pollution can be seen in Table 3.

Table 3. Pollution Index Criteria

Price PI	Information
$0 < PI < 1$	Meet quality standards
$1 < PI < 5$	Lightly polluted
$5 < PI < 10$	Moderately polluted
$PI > 10$	Heavily polluted

Result and Discussion

Physical Quality of Well Water

The results show that the physical quality of well water in the Dusun Selindungan tourist area generally does not meet the quality standards for health, both for consumption and for bathing and washing (hygienic and sanitary), especially based on TDS and turbidity (Table 4).

Table 4. Physical Quality of Well Water in the Dusun Selindungan

Variable (unit)	Quality standards	Well distance category from waste disposal sites		
		1	2	3
Temperature (^{0}C)	Air temperature (±3°C)	20.21	20.23	20.32
TDS (mg/l)	< 300	1587.44*	790.08*	1135.83*
Turbidity (NTU)	< 3	1.57	2.43	3.49*

* did't meet quality standards

High TDS and turbidity of well water are usually caused by the composition of soil types that have too much water infiltration. High TDS content in water can cause scale in household appliances and cause an unpleasant taste of water such as a metallic taste (Nuraini et al., 2019). Turbidity in residents' well water in residential areas can generally be caused by waste from daily resident activities or industrial activities that have not undergone treatment or that have been processed. Water turbidity can also be caused by the presence of suspended solid substances, both organic and inorganic, with varying sizes, namely colloidal to coarse. TDS and water turbidity can be reduced by physical remediation, such as using filter media with the right material composition (sand, gravel, palm fiber and charcoal) or using a single media, activated charcoal (Abrauw & Alfons, 2023; Addisie, 2022).

Chemical Pollution of Well Water

The DO levels, phosphate and ammonia content of well water in the Dusun Selindungan area had exceeded the quality standard threshold. Meanwhile, other chemical contents, such as BOD, iron, manganese and mercury, were still below the quality standard threshold (Table 5).

Table 5. Chemical Pollution of Well Water in the Selindungan Area

Variable (Unit)	Quality standards	Well distance category from waste dumps		
		1	2	3
pH	6-9	6.88	7.01	6.99
DO (ppm)	6	7.28*	7.35*	6.99*
BOD (mg/L)	2	1.52	2.11	1.51
Ammonia (mg/L)	0.50	0.12	1.44	2.300*
Ferrum (mg/L)	0.30	0	0	0
Phosphate (mg/L)	0.20	3.400*	3.025*	3.300*
Manganese (mg/L)	1	0.0600	0.100	0.0750
Mercury (mg/L)	1	0.0008	0.0010	0.0008

* did't meet quality standards

Low DO of dug well water (below quality standards) is usually caused by a lack of aeration in the wellbore. When well water is drawn to the surface of the well and transferred to another container, oxygen from the air is dissolved into the water body due to shaking and splashing, causing DO to increase. This mechanism for dissolving oxygen in water bodies has been reported by Pratiwi et al. (2023). The presence of ammonia compounds in groundwater is part of the nitrogen cycle in nature. Sources of nitrogen in groundwater come from various forms of materials such as crushed organic matter, domestic waste, industrial waste, livestock waste and fertilizer. The high content of ammonia and phosphate in well water (above the quality standard) may be caused by organic pollution in the surface water around the well. Sources of ammonia and phosphate pollution include livestock waste, where there are many livestock pens and grazing areas (El-Kowrany et al., 2016; Schullehner et al., 2018; Lai, 2017).

The high phosphate content in waters can also be caused by organic material pollution from household, industrial and agricultural waste which has accumulated intensively. The natural nitrogen content of groundwater usually comes from the reduction of free nitrogen (N_2) to ammonia or nitrite by various nitrogen-reducing microbes, such as fungi (*Mycorrhiza*), microalgae (*Anabaena*, *Nostoc* and *Oscillatoria*) and bacteria (*Rhyzobium* and *Azotobacter*). Well water in the Selindungan area also contains manganese, but the levels were still below quality standards. Manganese pollution usually comes from the active substance in batteries, where old or used batteries are thrown into rivers or coasts. Apart from that, manganese pollution can also come from mining, especially in atomic mine channels. The content of manganese compounds in water can cause washed clothes to change color and washed equipment to rust easily (Emilia et al., 2021; Nurhayati et al., 2022; Abrauw & Alfons, 2023).

The presence of mercury (Hg) content in well water (although still below the quality standard threshold) in the Selindungan area, may be caused by mercury contamination in runoff water above ground level, such as rivers and ditches around wells. This mercury pollution may come from waste processing from smallholder gold mines, which is carried out in many places in the area. The contamination of drilled well and dug well water by mercury from running water above it or from surrounding rivers is generally caused by soil types with high infiltration (Wu et al., 2020; Mulyani et al., 2023). In the gold panning process, mercury is used as a chemical agent to separate gold from chunks of soil. The waste from gold processing is a mixture of water and soil which contains mercury. This waste is discharged into surrounding water channels which then enter the river (Rahayu et al., 2016; Mangallo & Oktaviani, 2023; Agustikawati et al., 2022).

Exposure to mercury in mining activities is not exclusive, so it can result in a cumulative risk of mercury exposure which has an impact on health (Saldaña-Villanueva et al., 2022). The impact that mercury has on health is characterized by feelings of nausea in the stomach and a feeling of wanting to vomit, tremors in the limbs such as the arms and legs, and a feeling of sensitivity on uncovered skin. Over a long period of time, mercury can cause inflammation of the gums (gingivitis), disorders of the nervous system, mild tremors (shaking) and parkinsonism which is also accompanied by tremors in voluntary muscle function (Rahayu et al., 2016; Astuti et al., 2023; Raharini & Yuniarti, 2023; Zahra et al., 2023).

Biological Pollution of Well Water in the Dusun Selindungan Area

Water from residents' wells in the Dusun Selindungan tourist area at various distances from the gold processing waste disposal site generally contains biological contamination above the threshold for class 1 water quality standards. These data are the average of a number of replications (number of wells) in each distance category (Table 6).

Table 6. Biological Pollution of Well Water in Dusun Selindungan Tourist Area

Variables (unit)	Standard quality	Distance category (the well to waste disposal site)		
		1	2	3
E. coli (CFU/100 ml)	0	0	1.33	13.47
Total Coliform (CFU/100 ml)	0	0	1.33	13.50

Biological water quality is one of the main indicators of water pollution (Essa et al., 2024). Contamination of well water by *E. coli* and other species of bacteria (total coliform) usually comes from animal feces on the ground surface or in water bodies on the ground surface such as rivers, ditches and puddles around wells. It has also been reported, waters that have high phosphate content almost always contain high coliforms and this usually occurs due to the large amount of animal waste or human waste in the surrounding waters that (Lin et al., 2022).

Well Water Pollution Index in the Tourist Area of Dusun Selindungan

Based on the results of the water pollution index calculation, it was known that water pollution by DO, TDS, phosphate content, *E. coli* and total coliforms parameters in well water in the Dusun Selindungan tourist area does not meet the applicable water quality standards, with levels of light to weight (Table 7).

Table 7. Well Water Pollution Index (PI) in the Dusun Selindungan Area

Pollution variables	Distance category	PI	Pollution level
DO	1	1.46	Light
	2	1.53	Light
	3	1.51	Light
TDS	1	2.66	Light
	2	2.08	Light
	3	2.04	Light
Phosphate	1	26.84	Heavy
	2	24.01	Heavy
	3	27.70	Heavy
E. coli	1	22.11	Heavy
	2	213.44	Heavy
	3	2040.6	Heavy
Coliform total	1	22.11	Heavy
	2	213.52	Heavy
	3	2040.7	Heavy

Variations in the distance of the well to the community gold mining processing site did not appear to be a determinant of differences in the level of well water pollution in the Dusun Selindungan tourist area. Several wells in the farthest distance category (> 200 m) from people's gold processing sites also showed that their water was lightly polluted for DO and TDS parameters and heavily polluted with phosphate, E. coli and total coliform content. Perhaps the lack of public understanding and awareness of the importance of environmental management is one of the factors causing the low quality of well water in the area. According to Mroczko et al. (2022) and Landrigan et al. (2019), the low level of public awareness of the importance of maintaining health and preserving the environment is closely related to their economic and educational levels.

Conclusion

Residential well water in the Dusun Selindungan tourist area contains manganese and mercury but the levels are still below the applicable water quality standards, lightly polluted for DO and TDS parameters and heavily polluted with phosphate, *E. coli* and total coliform content. Variations in the level of well water pollution did not appear to be related to differences in the distance of the well to the community gold mining processing site.

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Author Contributions

Conceptualization, R.N.R..; methodology, H.A., R.N.R. and S.; software, H.A. and R.N.R.; validation, H.A.. R.N.R. and S.; formal analysis, R.N.R.. and S.; investigation, H.A. and R.N.R..; resources, R.N.R. and S.; data curation, H.A., R.N.R and S.; writing—original draft preparation, R.N.R. and S. writing—review and editing, H.A., R.N.R. and S.; visualization, R.N.N and H.A..; supervision, R.N.R., H.A. and S.; project administration, R.N.R..; funding acquisition, R.N.R. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that there is no conflict of interest, either internally between the authors or between each author and external parties, both in carrying out the research and in the publication.

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