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Heavy Metal Contamination in Dug Wells: Drinking Water Safety in Pesarean Village, Indonesia

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Abstract: Rapid industrial growth faces a number of challenges in dealing with environmental issues. Pesarean Village has heavy metal industrial activities that are growing rapidly enough to cause water pollution, especially for residents who still use dug well water to meet their daily needs. This study relates to the achievement of Sustainable Development Goals (SDGs) 3 and 6, namely ensuring good health and clean water availability. The objectives of the study include analyze the characteristics of dug wells, iron (Fe) contamination in dug well water, and the relationship between the characteristics of dug wells and the value of Fe for consumption. This study used a quantitative approach with a sample size of 34 dug wells using stratified random sampling technique. Data analysis techniques used were descriptive and comparative. The results showed that 39% of dug wells had characteristics that were not in accordance with well construction requirements.Fe contamination showed 29.41% did not meet the established quality standards. Comparison between dug well characteristics and heavy metal contamination showed 26.47% of wells were categorized as unfit for consumption. The conclusion of this study is that the characteristics of dug wells that meet the standards have a lower level of contamination and there is a relationship between the characteristics of the depth of the dug well and the level of Fe contamination. Suggestions that can be given are to provide simple water filtration tools that are easy to use by the community to minimize contamination caused by Fe.

Keywords: Dug wells; Well water quality; Iron contamination; Drinking water; Groundwater pollution risk; Well characteristics; Heavy metal industry; Heavy metal content in water

1 Introduction

Water pollution is one of the main environmental problems in Indonesia along with the rapid growth of industry [1]. Industrial development in Indonesia experiences a number of challenges in dealing with the maintenance of water quality in the vicinity. This is caused by uncontrolled and poorly managed industrial waste disposal activities. According to data from the Ministry of Environment and Forestry (KLHK) shows that 59% of clean water sources or rivers in Indonesia have experienced industrial waste pollution which has resulted in a decrease in water quality.

Population growth in Indonesia is quite high and is growing rapidly, which is around 2.3% to 5.4% per year. This causes an increase in the need for housing infrastructure and residential environment and housing procurement, especially regarding the problem of groundwater demand [2]. Indonesia is a developing country with the problem of increasing the scarcity of clean water due to pollution which has an impact on the lack of clean drinking water [3]. One form of water pollution comes from industrial waste that contaminates drinking water sources has become an important concern today [4, 5]. Industrial areas that do not have wastewater treatment plants experience a higher risk of contamination of surrounding water sources [6]. This results in waste pollution of water sources becoming contaminated and cloudy which is not suitable for consumption.

Groundwater pollution occurs when water conditions have been polluted by harmful substances originating from households (domestic), industry, agriculture, to human or animal waste that enter the groundwater [7]. he geological condition of the region is one of the factors that play an important role in the risk of groundwater pollution, especially in alluvial soil layers [8]. Alluvial soils have a large porous rock structure and a shallow aquifer, making them vulnerable to groundwater pollution [9]. The drainage process in alluvial soils runs quickly which risks the entry of pollution from above ground level.

The problem of industrial waste pollution of clean water sources has occurred in Indonesia, namely in Kalikabong Village, Purbalingga Regency, where most of the area is located in an industrial area. It is known that 33% of water pollution in the area comes from industrial waste in the vicinity. Water sources become polluted as evidenced by 48% of well water having an odor, 38% taste, 33% color, and 29% turbidity [10]. The existence of clean water sources located in industrial areas has an influence on poor water quality due to industrial waste pollution. Therefore, the existence of clean water sources close to industrial areas has a high risk of pollution to the water quality.

The heavy metal industry has adverse impacts that contribute to the pollution of the surrounding environment [11, 12]. The waste produced by the heavy metal industry contains chemicals that are harmful when polluting clean water sources, so it has a serious impact on the population in using water for daily needs who still depend on these water sources [13]. Contained heavy metals such as iron (Fe) can accumulate into groundwater and surrounding water sources and are dangerous if intended for daily consumption [14, 15]. This condition has occurred in Ceper District, Klaten Regency which has an industrial area and there has been Fe metal pollution contaminating several wells with the highest value of Fe of 0.87 mg/l and lead (Pb) of 4.83 mg/l [1]. These pollution conditions can affect the characteristics of well water so that there is a decrease in water quality that is not suitable for consumption.

The quality of water intended for daily drinking water must meet the clean water requirements set by the government, namely in Minister of Health Regulation No. 492/Menkes/PER/IV/2023 concerning drinking water quality requirements [13]. The water quality standard shows the threshold limit value of a water source by reviewing several water quality parameters, thus ensuring that the water is safe when used for consumption [16, 17]. Well water is one of the water sources that is still used by the community for consumption and other household purposes [18]. The existence of well water is located below the ground surface which is supplied by rainwater flow through the soil infiltration process and accumulates in the aquifer layer (layer of soil that contains water), so that the environmental conditions around the well determine the risk of contamination of the well water [19, 20].

Pesarean Village is one of the villages in Adiwerna Sub-district, Tegal Regency, which has a number of heavy metal industries, including metal smelting and metal casting industries with 14 industries spread across the village area. Products produced from the heavy metal industry include kitchen utensils, automotive components and industrial machinery, electrical equipment, and other metal equipment. Waste generated from the heavy metal smelting industry is in the form of solid powder that can pollute the environment and potentially contaminate the clean water sources of the surrounding population. One of the contents contained in heavy metal waste is Fe which has strong toxic properties even at low concentration values [21, 22]. Water that has excess Fe levels can cause disease and have an impact on human health such as intestinal damage, poisoning that causes nausea, diarrhea, dysentery, cholera, and impaired kidney function [23].

The source of clean water that is still often used by most residents in Pesarean Village is from dug wells with an average depth of up to 15 meters below ground level. The depth of the wells in the village is influenced by the condition of the geological structure in the Pesarean Village area, which consists of alluvium rock formations, so it has a high porosity level and is vulnerable to pollution entering the soil layer. The characteristics of dug wells have a role in maintaining the quality of well water from pollution that comes from outside [24]. The condition of dug wells should be adjusted to the requirements of good dug well construction in order to minimize the risk of pollution entering the well water [25, 26]. Therefore, the problem of water pollution of people's dug wells caused by heavy metal industrial waste can be caused by the inadequate characteristics of people's dug wells [25, 27].

The phenomenon of dug well water conditions in Pesarean Village that experience water contamination due to heavy metal industrial waste in the vicinity is an important problem today. The availability of clean water is very necessary for residents to meet their water needs, one of which is for daily consumption [28]. Therefore, the author tries to examine the phenomenon of dug well water conditions contaminated by heavy metal industrial waste by analyzing the characteristics of dug wells and well water quality against the feasibility for consumption, so that it is hoped that this research will be an insight for residents and local governments in improving the maintenance of water resources and better waste management.

2 Method

2.1 Research Location

The location of the research conducted in this study is in Pesarean Village, Adiwerna Subdistrict, Tegal Regency (see Figure 1) which is astronomically located between 6°55′ 24″ to 6°58′ 58″ N.E. and 109°07′16″ L.S. to 6°58′ 58″ L.S. and 109°07′16″. Administratively, Pesarean Village is bordered to the north by Talang Subdistrict, to the east by Lemahduwur Village, to the south by Ujungrusi Village, and to the west by Kaliwadas Village. Based on data from Statistics Indonesia, Pesarean Village has an area of 130.83 m2 which includes 8 administrative units, with a population of 13,651 people and 3,339 households in 2024 [29].

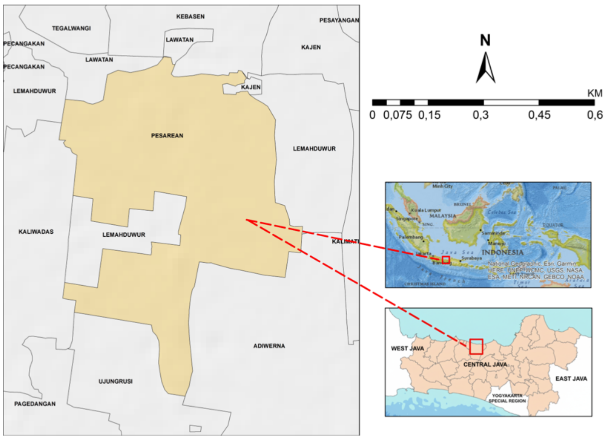

Figure 1. Research location
Source: Digital Globe Image, ESRI 2025

2.2 Research Design

This study used a quantitative approach with a descriptive analytic research design. The approach is to describe the characteristics of dug wells and the quality of dug well water systematically, and to compare the results of water quality measurements with the applicable drinking water quality standards. The research design was chosen to evaluate the influence of dug well characteristics and well water quality for drinking water consumption.

2.3 Research Population

The population used in this study included all dug wells in Pesarean Village, Adiwerna Subdistrict, Tegal Regency. The population was taken and determined in accordance with the research objectives, namely the characteristics of dug wells and the quality of dug well water to obtain information or data needed during the research. The characteristics of the dug well population in this study are having the criteria of well depth in the range of 5–15 meters below ground level and using a well cover that has a water pump installed, while the characteristics of the population are in the form of family heads as users of dug well water.

2.4 Sample Determination

The sampling technique in this study used a stratified random sampling method to obtain data that represents the condition of dug well water based on the distance of the well from the industrial site. Samples of dug wells are divided into two strata, namely >100 m and <100 m from the industrial site taken randomly up to 34 wells which are considered sufficient to represent the condition of the study area based on the principle of efficiency in the theory of law of diminishing returns, so that increasing the number of samples at a certain point does not provide significant information.

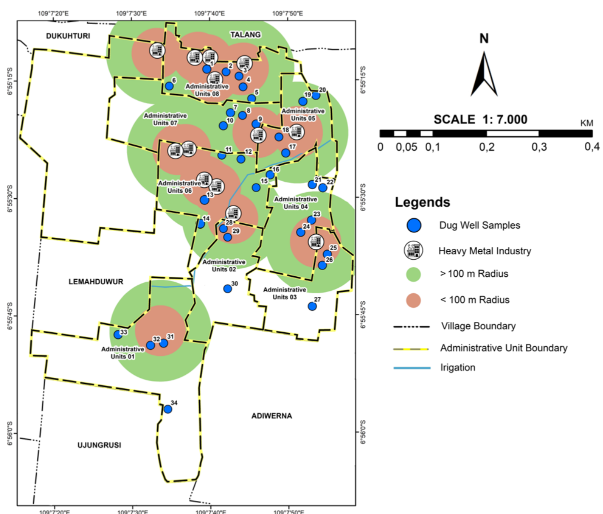

Figure 2. Distribution map of dug well samples

In addition, a sample size of 34 was considered sufficient for parametric statistical analysis based on the Central Limit Theorem (CLT) [30]. Samples of dug wells were taken within a radius of <100 m and >100 m to obtain representative results regarding the distribution of Fe contamination in dug well water near and far from industrial sites. Sampling points of dug wells follow the distribution of industrial locations which can be seen in the well sample distribution map in Figure 2.

2.5 Data Collection

2.5.1 Observation

The research instrument used in this study was an observation sheet that was prepared based on the suitability of dug well characteristics with well construction requirements set by the minister of public works regulation on construction requirements for dug wells. The observation sheet includes an assessment of well characteristics indicators such as well dimensions, physical condition of the well, and sanitation conditions around the well. The well characteristics indicators have each parameter assessed with four category options that indicate the level of compliance with well construction.

2.5.2 Sampling of dug well water

Well water sampling was carried out on the dug well water of residents in Pesarean Village which was taken with a container in the form of a 350 ml plastic bottle. The dug well water sampling technique is taken through the place where the well water comes out or the mouth of the faucet which is then put into the sample bottle. Water samples that have been taken are closed using a tight and airtight cover and given a sample identity which is then taken to the health laboratory to test the quality of Fe chemical parameters.

2.5.3 Water laboratory test

The water laboratory test stage is carried out to test the levels of chemicals in each well water sample that has been taken. Laboratory tests on water samples aimed to determine the value of chemical parameters in the form of Fe dissolved in water with the provision of water to be tested should not exceed the time limit of 3 days after the water samples were taken from the well. Testing of well water samples was carried out at the Tegal City Regional Health Laboratory, while for the measurement of pH, TDS, temperature, EC parameters in well water samples using tools such as pH meters and TDS meters.

2.6 Data Analysis

2.6.1 Descriptive analysis

Descriptive analysis is a data analysis that emphasizes the collection of data in accordance with the actual situation. The research data that has been obtained is then analyzed in the form of data presentation in the form of tables or diagrams so that it can be understood easily, and describes the actual condition of the problems that occur in the field. The analysis serves to describe the field conditions of the data obtained through data visualization in the form of tables or diagrams.

In this research, descriptive analysis is applied to the data obtained by the author during the research. Data that have been obtained through well observation, well characteristics questionnaire, and well water quality are then presented in the form of frequency tables to provide an overview of the distribution of data for each sample of dug wells in Pesarean Village. The presentation of the data aims to simplify and simplify the data in knowing the overall data distribution pattern.

2.6.2 Comparative analysis

Comparative analysis is an analysis used to compare research data with predetermined provisions. In this study, comparative analysis is used to assess the suitability between the requirements of dug wells that meet construction standards and the established water quality standards. The construction requirements of dug wells also need to be reviewed in accordance with the provisions to determine the ability of wells to minimize pollution entering the water. Requirements regarding the construction of dug wells can be seen in Table 1.

The dug well water quality that has been obtained is analyzed comparatively using the provisions of drinking water quality standards. The comparative analysis is by comparing the measured water quality data with water quality standards according to its designation by referring to Minister of Health Regulation No. 492/Menkes/PER/IV/2023 concerning drinking water quality requirements. The following quality standards for dug well water quality in terms of physical and chemical parameters can be seen in Table 2.

Drinking water quality standards are the threshold limits of water quality standards that refer to the Minister of Health Regulation No. 2/MENKES/PER/I/2023 concerning drinking water quality requirements. The regulation states that parameters such as physical and chemical in water have a maximum allowable level, so that if a water source has met the quality standard requirements, the water is classified as suitable for daily drinking water consumption.

Table 1. Dug well construction requirements

Indicator	Characteristic Parameters	Terms
Well dimensions	Dug well depth	>10 m
	Diameter of dug well	2 m
	Dug well wall height	0.8 m
	Dug well cover thickness	0.1 m
Well accessibility	Existence of dug wells	Closed room
	Ease of access dug well	Easy to access
	Functioning of dug wells	Works well
Physical condition of the well	Pipe condition	No leakage
	Cover type	Thick material
	Cover condition	Able to close the well
	Pump type	Engine pump
	Pump condition	Function to remove water well
	Storage area	Has a separate storage area
	Water filter condition	Well installed
Condition around the well	Soil conditions around the well	Dry
	Existence of sanitation facilities	Sanitation facilities are well managed
	Presence of dug wells with septic tanks	>10 m
	Presence of industrial activities with dug wells	>100 m
	Presence of solid waste around the well	No waste around the well
	Condition of sewage treatment system around the well	Good waste treatment system

Source: Minister of public works regulation on construction requirements for dug wells (2020)

Table 2. Drinking water quality standard

No.	Water Parameters	Quality Standard	Unit
1	TDS	<300	mg/l
2	Temperature	Air temperature ± 3	°C
3	EC	<300	μS/cm
4	pH	6.5–8.5	-
5	Fe	0.2	mg/l

2.7 Research Flow

The research flow is a series or systematic stages carried out in this study to achieve research results. In this study, the research flow can be seen through the flow chart in Figure 3.

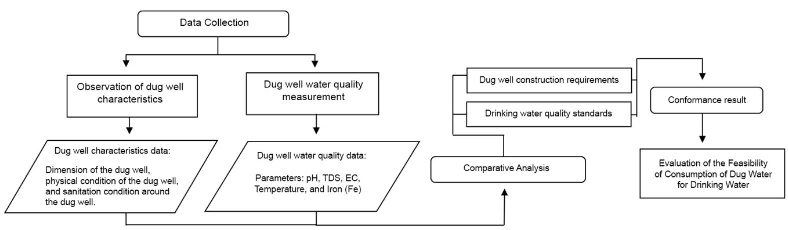

Figure 3. Research flow chart

3 Research Results

3.1 Analysis of Dug Well Characteristics

The water sources observed in this study were dug wells of residents in Pesarean Village. The observation results obtained from 34 dug wells in Pesarean Village show that each well has different characteristics according to the geological conditions and aquifers in the Pesarean Village area in reaching groundwater sources. One of the characteristics of the dug wells is in terms of well dimensions, namely the depth of the well which can be seen in Table 3.

Table 3. Depth of dug wells in Pesarean Village

Well Depth (m)	Frequency	Percentage (%)
4–7	4	11.76
8–11	22	64.72
12–15	8	23.52

The depth of dug wells in Pesarean Village is characterized by a depth in the range of 4 to 15 meters below ground level. Based on the data obtained, most of the dug wells have a depth in the range of 8–11 meters with a total of 22 wells or 64.72% of the total dug well samples. Furthermore, there are 8 wells with a percentage of 23.5% having a depth of 12–15 meters, and 4 wells with a percentage of 11.76% having a depth of 4–7 m. Table 4 shows the distance from dug wells to industrial sites in Pesarean Village.

Table 4. Distance of dug wells to industrial sites in Pesarean Village

Well Distance to Industrial Site (m)	Frequency	Percentage (%)
<100	19	55.88
>100	15	44.12

The dug wells in Pesarean Village are categorized as <100 m and >100 m radius from the surrounding industrial sites. The analysis shows that 44.12 % of dug wells are within a radius of <100 m, while 20.59 % of dug wells are within a radius of >100 m from industrial sites. The existence of dug wells mostly has a radius of <100 m because dug wells that are in a close radius to heavy metal industrial sites have a higher risk of Fe pollution.

The characteristics of the dug wells in Pesarean Village were assessed through compliance with the standard dug well construction requirements that have been set, including indicators of well characteristics such as well dimensions, physical condition of the well, and sanitation conditions around the dug well. Based on the results of the suitability assessment in Table 5, it shows that most of the 24 dug wells have a suitable well depth with an average Fe level of 0.31 mg/l which is classified as unfit for drinking. The diameter of the observed dug wells shows that 25 wells have a diameter that is suitable for drinking with an average Fe level of 0.14 mg/l, which is considered suitable for drinking. The height of the dug well wall showed that 29 wells were in accordance with the construction requirements and the average Fe level was 0.06 mg/l which is considered suitable for consumption. The thickness of the dug well cover shows 23 wells are in accordance with construction requirements and the average Fe level is 0.08 mg/l which is considered suitable for consumption.

The physical condition of the dug wells includes the presence of dug wells showing 28 wells are in a closed room and the average Fe content of 0.17 mg/l which is classified as suitable for consumption. Well accessibility shows 30 wells are easily accessible and the average Fe level is 0.11 mg/l which is considered suitable for consumption. The functioning of the dug wells shows 23 wells are functioning properly and the average Fe level is 0.18 mg/l which is considered suitable for consumption. The condition of the pipes in dug wells is 21 wells have leaking pipes and the average Fe level is 0.25 mg/l which is classified as unfit for consumption.

The type of cover used by most of the dug wells, 28 wells have a cover made of concrete/cement in good condition and the average Fe level is 0.12 mg/l which is considered suitable for consumption. The type of pump used in the dug wells shows 33 wells use engine pumps and the average Fe level is 0.06 mg/l which is considered suitable for consumption. The condition of the pump in the dug wells shows that 24 wells have pumps that function properly and the average Fe level is 0.15 mg/l which is considered suitable for consumption. The condition of the water filter in the dug wells, most of the wells or 30 dug wells do not have a properly installed water filter and the average Fe level is 0.49 mg/l which is classified as not suitable for consumption.

Sanitary conditions around dug wells include soil conditions around the wells show 27 wells are not in accordance with the construction requirements of dug wells and the average Fe content of 0.33 mg/l which is classified as suitable for consumption. Sanitary facilities around the dug wells obtained 20 wells have good sanitation and the average Fe level of 0.16 mg/l which is classified as suitable for consumption. The distance between dug wells and septic tanks obtained 34 wells do not meet the requirements of well construction and the average Fe level of 0.10 mg/l is classified as suitable for consumption. The distance between dug wells and industrial sites showed 19 wells did not meet the well construction requirements and the average Fe content of 0.47 mg/l which is classified as unfit for consumption.

Table 5. Conformance of dug wells with well construction requirements

Indicator	Well Characteristic Parameter	Number of Dug Wells Conformance Requirements Appropriate	Inappropriate	Conformity of Requirements (%)	Iron (Fe) (mg/l)	Feasibility
Dug well dimensions	Well depth	10	24	70.59	0.31	Unacceptable
	Diameter of dug well	25	9		0.14	Acceptable
	Dug well wall height	29	5		0.06	Acceptable
	Dug well cover thickness	23	11		0.08	Acceptable
Physical condition of dug wells	Presence of dug wells in enclosed spaces	28	6	59.56	0.17	Acceptable
	Easy accessibility of dug wells	30	4		0.11	Acceptable
	Functioning of dug wells is good	23	11		0.18	Acceptable
	Condition of pipes in dug wells	13	21		0.25	Unacceptable
	Concrete/cement cover type	28	6		0.12	Acceptable
	Good well cover condition	28	6		0.12	Acceptable
	Type of water pump in the form of an engine	33	1		0.06	Acceptable
	The condition of the pump that functions to deliver water properly	24	10		0.15	Acceptable
	Clean and maintained well water storage	25	9		0,17	Acceptable
	Condition of water filter installed properly	4	30		0.49	Unacceptable
Sanitation condition around the dug well	Soil conditions around dry dug wells	7	27	48.82	0.33	Unacceptable
	Sanitation facilities are good	20	14		0.16	Acceptable
	Presence of dug well with septic tank >10 m	-	34		0.10	Acceptable
	Presence of industrial with dug wells >100 m	15	19		0.47	Unacceptable
	No solid waste around the well	27	7		0,13	Acceptable
	Sewage treatment system around the well is functioning properly	21	13		0.15	Acceptable
	Percentage	**61.47%**	**39.26%**			

The presence of waste around the dug wells resulted in 27 wells with no solid waste and an average Fe level of 0.13 mg/l which is considered suitable for consumption. The waste treatment system around the wells shows 21 wells have a good waste treatment system and the average Fe level is 0.15 which is considered suitable for consumption. The dug wells in Pesarean Village are in accordance with the well construction requirements set by 61.47%, while the dug wells that are not in accordance with the well construction requirements are compared to the dug wells by 39.26%.

3.2 Analysis of Heavy Metal Contamination in Dug Well Water

Analysis of heavy metal contamination dissolved in dug well water is carried out through observation of the physical condition of water and measurement of water parameters. It is necessary to observe the water condition and measure the water quality of the well water to determine the level of well water quality. The dug well water that has been taken amounting to 34 wells is observed regarding the physical condition of the water and the measurement of water quality in each well water. The results of the analysis of the physical condition of each dug well water sample that has been carried out on 34 well samples can be seen in Table 6.

Water from 34 dug wells in Pesarean Village showed the results of observations of water conditions based on physical parameters of water including color, odor, and taste. The results obtained from the water color conditions are 67.65% of wells have clear water conditions, while 32.35% of wells have water conditions with a slightly yellowish color. Based on these results, the condition of dug well water in Pesarean Village mostly has clear water color, but there are a small number of wells that have water conditions that change color to yellowish, so they are classified as not in accordance with the requirements of clean water quality standards.

Table 6. Physical condition of dug well water in Pesarean Village

Physical Condition of Water	Water Condition	Frequency	Percentage (%)
Color	Clear	23	67.65
	Slightly yellowish	11	32.35
Smell	No odor	17	50
	Unpleasant odor	15	44.12
	Strong odor	2	5.88
Taste	No flavor (tasteless)	16	47.06
	Has a slight flavor	18	52.94

Odor conditions in dug well water that have been observed from 34 wells are obtained at 50% of wells have water conditions that have no odor, while 44.12% of wells experience well water conditions with unpleasant odors, and 5.88% of wells experience well water conditions with pungent odors. So, the results of observations of the condition of dug well water that have been obtained are that most of the dug well water in Pesarean Village has no odor, but there is well water that has an unpleasant odor. This is influenced by the large concentration of substances dissolved in well water due to waste from the heavy metal industry, so that well water that has good quality has no odor at all and indicates that the water is maintained in quality.

The taste condition of the observed dug well water is 52.94% of the wells have a slight taste, while 47.06% of the wells have fresh well water conditions. The results of these observations indicate that most of the dug well water in Pesarean Village has a slight taste caused by the concentration of dissolved heavy metal chemicals, resulting in changes in the taste of the well water. The change in taste that occurs in the condition of the well water indicates that the water has experienced pollution which causes a decrease in the quality of well water.

The measurement of water quality of dug wells in Pesarean Village was measured through physical and chemical parameters of water. The measurement aims to determine the level of water quality of dug wells in Pesarean Village. The water quality measurement process was carried out on 34 well water samples taken from various administrative units in Pesarean Village. The results of the water quality measurements that have been obtained in terms of physical and chemical parameters of water can be seen in Table 7.

Table 7. Water quality measurement results of dug wells

Water Parameters	Quality Standard	Conformance to Quality Standard	Frequency	Percentage (%)
pH	6.5–8.5	Non-compliant	-	-
		Compliant	34	100
Temperature	±3°C	Non-compliant	-	-
		Compliant	34	100
TDS	<300 mg/l	Non-compliant	34	100
		Compliant	-	-
EC	<300 μS/cm	Non-compliant	34	100
		Compliant	-	-
Fe	0.2 mg/l	Non-compliant	10	29.41
		Compliant	24	70.59

The results of the dug well water quality measurements were analyzed using comparative analysis, namely comparing the measurement results with the suitability of the applicable quality standards. Water quality measurements that have been carried out on 34 well water samples include measurements of physical water parameters such as pH, temperature, TDS, and EC, then compared the results with the threshold value of drinking water quality standards set by the government in regulation No. 492/Menkes/PER/IV/2023 concerning drinking water quality requirements. The comparison results found that the pH and temperature parameters showed that all samples met the quality standard limits, while the TDS and EC parameters of all well water samples did not meet or exceed the threshold limits of the established quality standards.

Measurement of Fe chemical parameters in the quality of dug well water in Pesarean Village is done through water laboratory testing. Measurement of Fe parameters was tested on 34 dug well water that had been taken by the author. The results of measuring the value of Fe content in each dug well water in Pesarean Village were analyzed comparatively to determine the level of conformity with the quality standards set in Minister of Health Regulation No. 2/MENKES/PER/I/2023. The distribution of Fe values in dug well water in Pesarean Village can be seen in Figure 4.

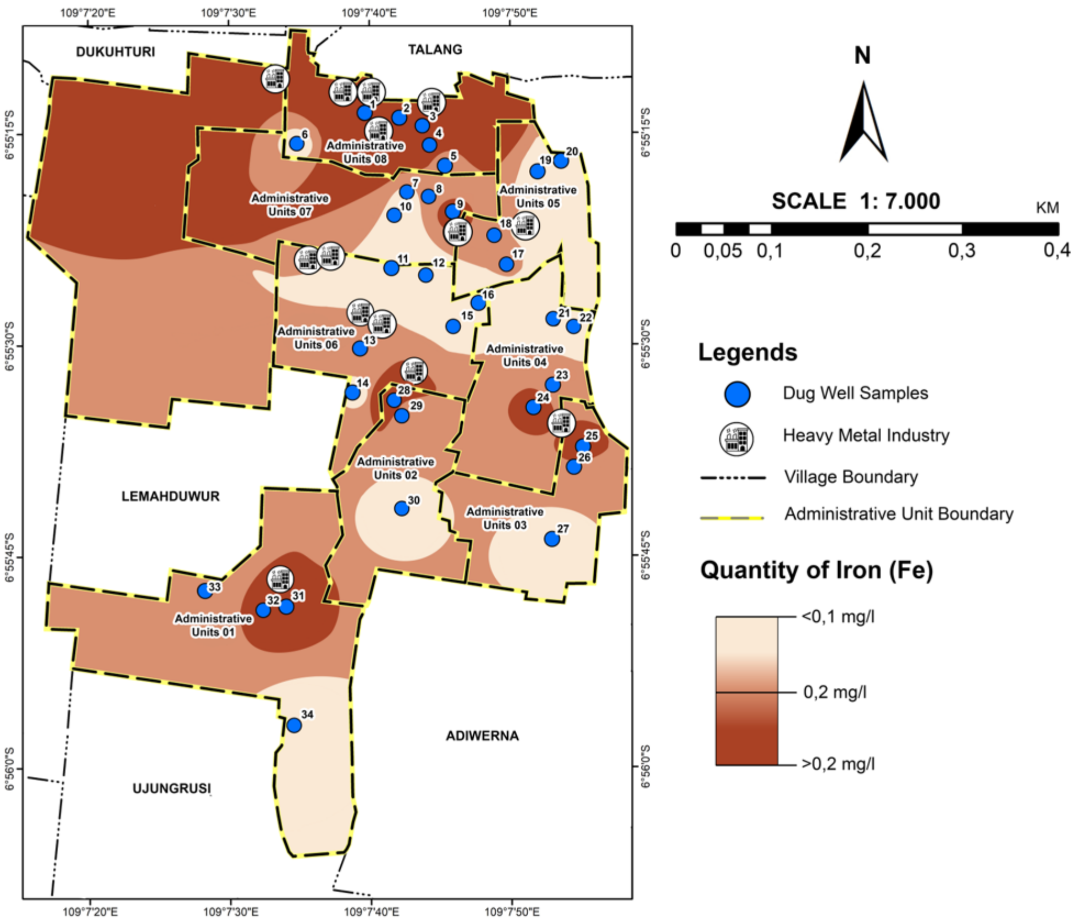

Figure 4. Map of distribution of iron (Fe) levels in dug well water

The results of the measurement of Fe levels in the water quality of dug wells in Pesarean Village showed that most of the samples, namely 24 dug wells, had Fe levels that were in accordance with the quality standards. However, there were 10 dug wells that exceeded the threshold limit value. Based on the provisions stipulated in Permenkes No. 2/MENKES/PER/I/2023 concerning drinking water quality requirements, it is known that the maximum limit of Fe content is 0.2 mg/L. A dug well that has an Fe level above the threshold indicates that the heavy metal contamination dissolved in the well water is high. Therefore, the pollution, especially the Fe element, causes the water to not meet the specified quality standards, making it unfit for consumption.

Based on the distribution map of Fe values above, it shows information about the value of Fe levels in dug well water which is categorized into 3 levels, namely <0.1 mg/l, 0.1–0.2 mg/l, and >0.2 mg/l. The difference in the level of Fe content in well water can be seen in the color hue if it is darker, then it shows a high Fe value at the sample point. The areas that have the highest Fe levels in dug well water with a classification of >0.2 are mostly in the Administrative Units 08 area, while the classification of <0.1 is mostly in the Administrative Units 05 and 06 areas. The results of the study included various parameters of well characteristics and heavy metal concentrations found in each sample. This analysis aims to serve as a basis for evaluating heavy metal contamination of dug well water quality conditions and the feasibility of water for daily consumption.

Dug well water is generally influenced by the characteristics of the well and the surrounding conditions. The characteristics of dug wells can affect the quality of the water in them as evidenced by the value of Fe heavy metal contamination. Factors such as well depth, well distance from pollution sources (industrial sites and septic tanks), presence of covers, and maintenance conditions play a significant role in determining the suitability of well water for consumption. Therefore, the construction of dug wells should be considered in maintaining water quality from heavy metal contamination that can determine the suitability of well water for consumption.

Wells that have standardized construction, such as optimal depth, safe distance from pollution sources, sturdy covers, and good maintenance conditions, tend to have low Fe levels and are categorized as suitable for consumption [28]. Wells that do not meet the established well construction requirements, such as being too close to pollution sources, without adequate cover, or poor maintenance, show higher Fe levels, making them unfit for use as a drinking water source [29].

3.3 Correlation Between Dug Well Depth and Fe Contamination Level

The relationship between the depth of the dug well and the level of Fe contamination was analyzed through the Pearson Product Moment (PPM) correlation statistical test. The correlation statistical test is processed through IBM SPSS software which is used to determine the level of relationship between research variables determined by the correlation coefficient (r) value. The results of the relationship between the dug well depth variable and the level of iron contamination PPM correlation statistical test can be seen in Table 8.

Table 8. Pearson product moment correlation statistical test results (PPM)

		Dug Well Depth	Fe Contamination Level
Dug well depth	Pearson Correlation	1	-0.910**
	Sig. (2-tailed)		0.001
	N	34	34
Fe contamination level	Pearson Correlation	-0.910**	1
	Sig. (2-tailed)	0.001	
	N	34	34

The results of the PPM correlation statistical test show a significance value of 0.01. The two variables are declared to have a significant relationship or correlation when the significance value is <0.5. Therefore, the variables of dug well water quality and population health risk are stated to have a significant relationship between the two variables of dug well depth and Fe contamination level.

The correlation coefficient between the two research variables is obtained from the pearson correlation (r) value, which is strong if the r value is close to 1. The pearson correlation (r) value that has been obtained is -0.910, which shows a strong correlation level and the opposite direction of the relationship. This can be interpreted that the deeper the dug well, the lower the level of Fe contamination.

4 Discussion

4.1 Characteristics of Dug Wells

The results of the assessment of the characteristics of dug wells in the well dimension indicator obtained 29% of wells have a depth that does not meet the specified requirements. The depth of the dug well is influenced by the condition of the geological structure of the region as a determinant of the depth of the groundwater aquifer zone [7, 31]. Pesarean Village is included in the lowland area with the formation of geological structures in the form of alluvial plains with sandy loam rock material [32]. Therefore, the condition of the geological structure in Pesarean Village, which consists of sandy clay rock, is one of the factors causing the depth of the dug wells to not meet the specified requirements.

The physical condition of the dug wells resulted in 40% of the wells having well construction that meet the dug well requirements. The construction of well construction in accordance with the requirements requires relatively more expensive costs [25, 33]. The limited cost experienced by the population is one of the inhibiting factors in building well construction with a quality well material structure [19, 34]. The condition of the physical structure of dug wells in Pesarean Village that does not meet the requirements is due to the limited cost factor in the construction of wells using sturdy materials and quality water pumping machines.

Sanitary conditions in dug wells obtained the results of 51% of wells have sanitation around wells meet the specified requirements. The moist soil conditions of the wells result in a sanitation facility system that makes it easy for pollution to enter the well water [35, 36]. The lack of awareness of the population in supervising sanitation facilities is a factor that causes sanitation facilities to be poorly maintained [3]. Therefore, the poorly maintained sanitation condition around the dug well is caused by the lack of awareness of the local population in cleaning and maintaining sanitation facilities regularly.

The distance between the dug wells and the pollutant source resulted in 56% of the wells having a distance that did not meet the specified requirements. The dug wells in Pesarean Village are mostly located at a relatively close distance to industrial sites and septic tanks due to the lack of awareness of the population in the risk of pollution [3, 37]. This is influenced by the lack of knowledge of residents in building dug wells according to the stipulated requirements, so that they are close to the source of pollution [38, 39]. Therefore, the distance between the dug well and the source of pollution does not meet the specified requirements, which is caused by the lack of knowledge of the population in the process of building the location of the dug well that has not paid attention to the impact of pollution around it.

The mismatch between the construction of dug wells and the characteristics of dug wells in Pesarean Village is caused by factors such as the lack of awareness of residents in managing and maintaining dug wells to limited costs to build dug wells that meet good construction standards. The suitability of requirements is very important in maintaining well water to minimize water pollution, especially in areas where there is a lot of industrial activity

[32, 40]. Thus, the characteristics of dug wells that do not comply with established well construction requirements can have a high potential risk of well water contamination that results in water that is not suitable for consumption.

4.2 Heavy Metal Contamination in Dug Well Water

The results of observations of dug well water obtained 34% of wells have physical water conditions not in accordance with the requirements of drinking water quality standards. Changes in the natural physical condition of water can be prone to occur in water sources that are close to pollutant sources [41]. It is influenced by the condition of the water natural physical changes in water when it is close to the source of pollutants changes in the physical condition of the water [42]. The physical condition of dug well water in Pesarean Village that does not meet the drinking water quality standards is caused by the presence of industries that are close to dug wells, resulting in contamination of well water that can change the natural physical conditions of the water.

The results of the analysis of heavy metal contamination in dug wells in Pesarean Village obtained 24 wells or 70.59% of dug wells have water quality that meets the established quality standards, but there are 10 dug wells or 29.41% of wells that do not meet the quality standard limits. The existence of industrial activities has an adverse impact on environmental pollution, one of which is in the form of pollution of clean water sources in the vicinity which has the potential to cause a decrease in water quality [6, 43, 44]. The Pesarean Village area has a heavy metal industry that is growing quite rapidly, which is one of the factors causing pollution of the dug well water of the residents in the vicinity. In addition, the soil around the dug wells in Pesarean Village where there are several wells has moist soil conditions around the wells, so it can potentially pose a risk of contamination of pollution from outside into the dug well water. The structure of the soil layer around the well has a role in the infiltration process so that water is contaminated by polluting substances caused by pollution in the surrounding environment that can enter the well water [40, 45, 46]. Therefore, dug wells in Pesarean Village that do not meet the threshold limit of water quality standards are caused by factors such as moist or inadequate soil conditions around the well and the large number of industrial activities that have great potential for pollution risks resulting in a decrease in the quality of dug well water.

4.3 Associations Between Dug Well Characteristics and Heavy Metal Contamination in Dug Well Water

The results of the relationship between the characteristics of dug wells and heavy metal contamination in dug well water showed that 9 dug wells or 26% of all wells were not suitable for consumption. The characteristics of dug wells play a role in determining the level of heavy metal contamination that enters well water, especially in areas where there are many industrial activities in the vicinity [47, 48]. Dug wells with appropriate characteristics that meet applicable standards tend to have lower levels of contamination compared to dug wells that do not meet these requirements [49]. Therefore, dug wells that do not meet construction standards have inappropriate characteristics that can increase the risk of contaminants entering the well water, potentially affecting the condition of the dug well water.

Wells in unmaintained neighborhoods, such as those with damaged covers or without water filters, are more susceptible to heavy metal contamination [50]. Risk factors for well water pollution, such as the cleanliness of the surrounding environment and the presence of pollution sources, contribute to worsening well water quality [51, 52]. Wells that meet the characteristics in accordance with established construction requirements can produce water that is suitable for consumption [53, 54]. Thus, good characteristics of dug wells, such as optimal depth, safe distance from sources of pollution, use of sturdy covers, and regular maintenance, are essential for maintaining water quality and minimizing heavy metal contamination.

5 Conclusions

The characteristics of dug wells in Pesarean Village are that 71% of wells have a well depth that is in accordance with the established well construction requirements. The physical condition of dug wells is 60% of wells have adequate physical structure and 49% of wells have sanitary conditions in accordance with the well construction requirements. The distance between dug wells and pollutant sources is 44% of wells have adequate distance and in accordance with the well construction requirements. The physical condition of dug well water in Pesarean Village is 66% of the wells have clear water conditions and are in accordance with clean water quality criteria. The water quality of dug wells in Pesarean Village is 70.59% of wells have water quality that meets the established quality standard threshold. The relationship between the characteristics of dug wells and heavy metal contamination obtained 74% of dug wells categorized as suitable for consumption, so most of the dug wells in Pesarean Village are still classified as suitable for consumption. Therefore, the characteristics of dug wells that meet the applicable standards tend to have lower levels of contamination compared to dug wells that do not meet these requirements. Recommendations can be given for residents who use dug well water to install a water filtration system based on local materials such as sand as a tool to filter Fe levels in well water.

Author Contributions

Conceptualization, D.L.S.; methodology, D.L.S.; validation, P.H.; formal analysis, D.L.S.; data curation, D.L.S.;

writing—original draft preparation, G.S. and W.A.B.N.S.; writing—review and editing, G.S. and W.A.B.N.S.; final Approval, P.H. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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