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Original Research

Risk Microbiological Contamination in Well Water Around the Morosi Industrial Area, Southeast Sulawesi, Indonesia

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Abstract
Background: Dug wells located near industrial areas have a higher contamination levels compared to wells far from industrial areas. Previous research has shown metal contamination in wells near industrial area. This gap highlights the need for further research that address the microbiological safety of water sources affected by industrial activities.
Objectives: This study investigates the risk of microbiological contamination in well water surrounding the Morosi industrial area in Southeast Sulawesi, Indonesia.
Methods: The type of research is quantitative observational design; this research analyzes 52 dug wells across four villages. Key variables examined include the distance of wells from septic tanks and the physical condition of the wells, assessed through microbiological testing using the Most Probable Number (MPN) method.
Results: Majority of well samples (94.2%) did not meet microbiological quality standards, with a notable presence of *E. coli* in 44.2% of samples. Statistical analysis indicates a moderate relationship between the physical condition of wells and *E. coli* presence, as well as a significant association between proximity to septic tanks and contamination risk.
Conclusion: There are various factors that contribute to the well's contamination. Statistical analyses demonstrate the vulnerability of water sources around the Morosi industry to microbial contamination due to inadequate sanitation practices.

Keywords: Microbiological contamination; dug well; Most Probable Number (MPN)

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Background

Contaminated clean water sources are a health issue prevalent worldwide, including in Indonesia. The condition of clean water sources, particularly dug wells in industrial areas used by the community for daily needs, including drinking water, requires attention. Groundwater, often utilized as a drinking water source, must meet specific quality standards to ensure it is safe for consumption. Research indicates that the quality of groundwater, including dug wells, can be affected by industrial activities such as waste disposal and chemical use, which may increase the risk of microbial contamination (Mudatsir, 2007; Gandri et al., 2023; Izzati et al., 2019).

Dug wells near industrial areas are particularly vulnerable, showing higher contamination levels compared to those farther from pollution sources (L.E. & M.A, 2023; Gnimadi et al., 2024). Poor sanitation and inadequate water management practices also contribute to the risk of microbial contamination, as improper waste management can lead to groundwater pollution, thereby impacting public health (Nur et al., 2021; Prasetyo, 2022; Kitole et al., 2024).

Condition in Morosi Southeast Sulawesi, the proximity of industrial zones to community water sources raises concerns. Microbiological contamination can arise from domestic waste, industrial effluents, and agricultural run off. Research indicates that water quality in industrial areas can be influenced by various factors, including industrial waste disposal and chemical use, which may increase the risk of microbial contamination (Babuji et al., 2023; Ditia, 2024; Emmanuel-akerele & Peter, 2020; Irvan et al., 2021). A study in Kenya indicated that the bacteriological quality of drinking water could be compromised by leaks in the distribution network, allowing contaminants to enter the water supply system (Nduku et al., 2022).

The risk of microbiological contamination in the areas surrounding the Morosi industrial zone may increase due to poorly managed industrial waste. Research conducted in Lesotho demonstrated that inadequate sanitation and hygiene practices around water sources could heighten the risk of bacterial contamination (Gwimbi et al., 2019). A study by Bukhari et al. showed that industrial waste could contaminate water and food sources (Hussain et al., 2020).

Microbiological agents that can contaminate water sources include various coliform bacteria, such *as Escherichia coli, Salmonella typhi*, and *Shigella dysenteriae* (Tulchinsky, 2018)(Nurhajawarsi & Haryanti, 2023). Previous research has shown that *E. coli* is often found in well water located near contamination sources, such as septic tanks and domestic waste. A study in Trivandrum, India, revealed a significant relationship between the presence of E. coli in drinking water and the proximity of wells to septic tanks, which is a primary factor rendering well water unsafe for consumption (Sruthi et al., 2022). Furthermore, earlier studies have indicated that Escherichia coli serves as a fecal indicator in water sources. In Metro City, Lampung, it was found that 72% of water sources were contaminated with *E. coli*, with 36% of them at highly risky concentrations (Jannah & Putri, 2021).

Various previous studies have demonstrated water contamination due to industrial waste; however, most of these studies have focused primarily on heavy metal contamination and other hazardous chemicals. Research conducted by Haroun, which assessed the presence of heavy metals in waste and water, did not include a comprehensive microbiological analysis (Mahdi Haroun, 2021). Study by Tasnim and Sunarsih regarding impaired kidney function in areas surrounding nickel mining in Morosi indicated a relationship between water quality and kidney health (Tasnim & Sunarsih, 2023). However, this research did not directly link microbiological contamination in water to health impacts.

These conditions highlight the critical importance of monitoring the presence of *E. coli* in well water, particularly in areas affected by industrial activities, such as around the Morosi industrial zone. Therefore, this study will examine microbiological contamination in dug well water in relation to the physical conditions of the wells and the distance of pollutant sources to the wells. This research is expected to provide significant contributions regarding public health risks associated with water quality in industrial areas and assist in the development of more effective mitigation strategies.

Methods

Study design

This research employs a quantitative observational study design with a cross-sectional framework. The study was conducted in four villages located in the Morosi sub-district of Konawe Regency, which is an area surrounding the Morosi industrial zone, there are Paku Village, Paku Jaya Village, Tanggobu Village, and Besu Village.

Data collection

Data collection was conducted from August to October 2024, during which 52 households and selected dug wells were interviewed and water samples were taken. The primary data collection technique used was observation sheet, water sampling, and laboratory examination Most Probable Number (MPN) Coliform Method. The research variables included the dependent variable microbiological quality (MPN coliform), while the independent variables were the distance from septic tanks to dug wells and the physical structure of the dug wells.

Data analysis

The univariate data analysis technique aimed to describe the parameters of coliform index, distance from septic tanks, and the physical structure of dug wells, while bivariate analysis was used to determine which variables were related to the microbiological quality of well water (total coliform). Data analysis was conducted using statistical tests to assess the relationship between variables, employing the Chi-Square statistical test if $p \leq 0.05$.

Results

Observation the Physical Condition of Dug Well

Table 1. Observation of the Physical Condition of the Dug Well

Physical Condition of Dug Well	Does not meet criteria	Percentage	Meet criteria	Percentage
Septic Tank Distance				
Paku Village	4	25	4	25
Paku Jaya Village	5	25	15	75
Tanggobu Village	3	20	12	80
Besu Village	3	33.33	6	66.7
Total	15	28.84	37	71.15
Physical Structure of Dug Well				
Paku Village	2	25	6	75
Paku Jaya Village	8	40	12	60
Tanggobu Village	6	40	9	60
Besu Village	3	33.33	6	66.67
Total	19	36.54	33	63.46

Table 1 shows the differences in the number of wells that meet the criteria versus those that do not. In Desa Paku, there are 4 wells that meet the criteria and 4 that do not; in Desa Paku Jaya, there are 5 wells that meet the criteria and 15 that do not; in Desa Tanggobu, there are 3 wells that meet the criteria and 12 that do not; while in Desa Besu, there are 3 wells that meet the criteria and 6 that do not. Regarding the observation of the physical structure of the dug wells, it is evident that only 19 wells (36.54%) meet the criteria out of 52 dug well samples, whereas 33 wells (63.46%) do not meet the criteria.

Test Most Probable Number (MPN)

The description of the microbiological quality of the dug well water in Desa Paku, Desa Paku Jaya, Desa Tanggobu, and Desa Besu, as assessed by the MPN Index, is presented in the table below.

Tabel 2. Description quality microbiological dug weel water based on MPN indeks

Cluster	Dug well sample Code	Value MPN per 100 ml in dug well water samples Does Not Exceed Contamination Limit (per 100 ml)	Exceed Contamination Limit (per 100 ml)
Paku Village	1,2,3,4,5,6,7,8	Sample 2 (0/100 ml)	Sample 1,3,4,5,6,7,8,9 With MPN index: (5/100 ml, 5/100 ml, 2/100 ml, , 2/100 ml, 2/100 ml, 9/100 ml , 2/100 ml)
Paku Jaya Village	9,10,11,12,13,14, 15,16,17,18,18,20 21,22,23,24,25,26, 27,28	Sample 21 (0/100 ml)	Sample 9,10,11,12,13,14,15, 16,17,18,19,20,22,23,24,25,26, 27,28 With MPN index: (5/100 ml, 9/100 ml,5/100 ml,17/100 ml,17/100 ml, 9/100 ml,12/100 ml, 5/100 ml, 2/100 ml ,9/100 ml,17/100 ml,9/100 ml,5/100 ml,2/100 ml,2/100 ml,2/100 ml,2/100 ml,5/100 ml,5/100 ml).
Tanggobu Village	29,30,31,32,33,34, 35,36,37,38,39,40, 41,42,43	there were no samples that met microbiological criteria	Sample 29,30,31,32,33,34,35,36 37,38,39,4041,41,43 With MPN index: (9/100 ml, 9/100 ml,67/100 ml,9/100

Besu Village	44,45,46,47,48,49, 50,51,52	Sample 44 (0/100 ml)	ml,17/100 ml,5/100 ml, ,<979/100 ml,<979/100 ml,/100 ml, <979/100 ml, <979/100 ml, 84/100 ml, 265/100 ml, 27/100 ml, 17/100 m; Sample 45,46,47,48,49,50,51,52 With MPN index: (12/100 ml, 5/100 ml,2/100 ml,2/100 ml,2/100 ml,9/100 ml,5/100 ml,9/100 ml)

Based on the table above, it is known that of the 52 samples, there were 49 water samples that did not meet the microbiological quality requirements (Total coliform), while 3 samples met the microbiological quality requirements (Total coliform) which were determined in accordance with the Indonesian Minister of Health Regulation number 416 of 1990.

The next stage of the MPN test is checking for the presence of *E. coli* bacteria in the EMBA (Eosin Methylen Blue Agar) media. The results of recognizing the presence of *E. coli* bacteria can be seen in the table 3 below

Table 3. Percentage of the presence of *E. coli* bacteria and other coliform bacteria

Cluster	Percentage sample positive bakteria *E.Coli*	Percentage sample positive others Coliform bacteria	Percentage Sample not found coliform bacteria
Paku Village	12.5	37.5	50
Paku Jaya Village	50	40	10
Tanggobu Village	46.67	46.67	6.67
Besu Village	0	55.56	44.44

Table 3 shows that the percentage of *E. coli* bacteria in well water samples is different at each sampling location. In water samples taken from the wells of Paku village residents, it was seen that the E. coli sample was 12.5%, in Paku Jaya Village it was 50%, Tanggobu Village was 46.67%, while in Besu Village no *E. coli* bacteria were found but were identified. the presence of other coliform bacteria was 55.56%.

Statistical test results of the relationship between the septic tank distance variable, the physical condition of the dug well and the MPN value and the presence of E. coli bacteria

In this research, statistical analysis was carried out to find out relationship between the distance from the dug well to the septic tank and the MPN value. Analysis of the distance from the dug well to the septic tank with the MPN value can be seen in the table following.

Table 4. Analysis of the relationship between the distance from the dug well to the septic tank and the MPN value

Septic tank distance	MPN Value				Total		Fisher's Exact Analysis
	DNMC		MC				
	n	%	n	%	n	%	
DNMC	35	97.2	1	2.8	36	100	p-value = 0.221 α = 0.05
MC	14	87.5	2	12.5	16	100	
Total	49	94.2	3	5.8	52	100	

Note: DNMC: Does not meet the criteria. MC: Meet the criteria

Based on the table above, it shows that of the 36 respondents whose distance from the dug well to the septic tank did not meet the requirements, there were 35 (97.2%) respondents' wells with an MPN value that did not meet the requirements and 1 (2.8%) respondent's well with an MPN value qualify. Meanwhile, of the 16 respondents whose distance from the dug well to the septic tank met the requirements, there were 14 (87.5%) respondents' wells with an MPN value that did not meet the requirements and 2 (12.5%) respondents' wells with an MPN value that met the requirements.

Based on statistical test results Fisher's Exact value obtained p-value = 0.221, with α = 0.05, then p-value > α which means H0 accepted and Ha rejected. This shows that there is no relationship between the distance from the dug well to the septic tank and the MPN value.

Statistical calculation relationship between the physical condition of the dug well and the MPN value can be seen in the following table.

Table 5. Analysis of the relationship between the physical structure condition of dug wells and the MPN value

Physical structure Condition dug wells	MPN Value				Total		Fisher's Exact Analysis
	DNMC		MC				
	n	%	n	%	n	%	
DNMC	34	100	0	0	34	100	p-value = 0.037
MC	15	83.3	3	16.7	18	100	α = 0.05
Total	49	94.2	3	5.8	52	100	phi = 0.340

Note: DNMC: Does Not Meet The criteria. MC: Meet The Criteria

Based on the table above, it shows that of the 34 respondents whose physical structure condition of dug wells did not meet the requirements, all or 34 (100.0%) of the respondent's wells with MPN values did not meet the requirements. Meanwhile, of the 18 respondents whose physical structure condition of dug wells meets the requirements, there are 15 (83.3%) respondents' wells with MPN values that do not meet the requirements and 3 (16.7%) respondents' wells with MPN values that meet the requirements.

Based on statistical test results Fisher's Exact value obtained p-value = 0.037, with α = 0.05, then p-value < α which means H0 rejected and Ha accepted. This shows that there is a relationship between the physical structure condition of the dug well and the MPN value. From the results of the relationship closeness test, values are obtained phi = 0.340, which means that there is a weak relationship between the physical condition of the dug well and the MPN value. Analysis of the condition of the distance from the dug well to the septic tank with the presence of *E. Coli* can be done seen in the following table.

Table 6. Analysis of the relationship between the distance from the dug well to the septic tank and the presence of *E. Coli*

Distance Septic Tank to dug well	Presence E. coli				Total		Analysis Chi Square
	Positive		Negative				
	n	%	n	%	n	%	
DNMC	21	58.3	15	41.7	36	100	p-value =
MC	2	12.5	14	87.5	16	100	0.006
Total	23	44.2	29	55.8	52	100	α = 0.05 phi = 0.426

DNMC: Does Not Meet The criteria. MC: Meet The Criteria

Based on the table above, it shows that of the 36 respondents whose distance from the dug well to the septic tank did not meet the requirements, there were 21 (58.3%) of the respondent's wells where *E. coli* was found and 15 (41.7%) of the respondent's wells were not found. presence of *E. coli*. Meanwhile, of the 16 respondents whose distance from the dug well to the septic tank met the requirements, there were 2 (12.5%) respondents' wells where *E. coli* was found and 14 (87.5%) respondents' wells where *E. coli* was not found.

Based on statistical test results Chi Square value obtained p-value = 0.006, with α = 0.05, then p-value < α which means H0 rejected and Ha accepted. This shows that there is a relationship between the distance from the dug well to the septic tank and the presence of *E. coli*. From the results of the relationship closeness test, values are obtained phi = 0.426, which means that there is a moderate relationship between the distance from the dug well to the septic tank and the presence of *E. coli*.

Based on the table 7, it shows that of the 34 respondents whose physical structure condition of dug wells did not meet the requirements, there were 20 (58.8%) respondents' wells where E. Coli was found and 14 (41.2%) respondents' wells where *E. coli* was not found. *E. coli*. Meanwhile, 18 respondents had the physical structure condition of the well digging that met the requirements, there were 3 (16.7%) respondents' wells where *E. coli* was found and 15 (83.3%) respondents' wells where *E. coli* was not found.

Based on statistical test results Chi Square value obtained p-value = 0.009, with α = 0.05, then p-value < α which means H0 rejected and Ha accepted. This shows that there is a relationship between the physical structure condition of dug wells and the presence of *E. coli*. From the results of the relationship closeness test, values are obtained phi = 0.404, which means that there is a moderate relationship between the physical condition of the dug well and the presence of *E. coli*.

Table 7. Analysis of the Relationship between the Physical Structure Condition of Dug Wells and the Presence of E. Coli

Physical Structure Condition	Presence E. coli				Total		Chi Square Analysis
	Positive		Negative				
	n	%	n	%	n	%	
DNMC	20	58.8	14	41.2	34	100	p-value = 0.009
MC	3	16.7	15	83.3	18	100	α = 0.05
Total	23	44.2	29	55.8	52	100	phi = 0.404

DNMC: Does Not Meet The criteria, MC: Meet The Criteria

DISCUSSION

Based on Table 1, the observation results indicate a significant difference between the number of wells that meet the criteria and those that do not, based on distance to the septic tank and the physical condition of the wells. Overall, 28 wells (84%) have a distance that meets the criteria from the septic tank, while the total number of wells with a compliant distance to the septic tank is 28, representing 84%. From the observation of the physical condition of the wells, 36.4% of the wells meet the criteria, while 63.46% do not.

Research by Wijayanti et al. shows that a distance of less than 10 meters between wells and septic tanks can increase the risk of well water contamination by pathogenic bacteria, including E. coli, which can cause diarrheal diseases (Sidik et al., 2020). This aligns with the findings of this study, where non-compliant wells are likely to be exposed to contamination from nearby septic tanks. Furthermore, Kamari emphasizes that the infiltration of waste from poorly managed septic tanks can contaminate groundwater, posing health risks to the community (Alvarez-Holguin et al., 2022)(Kamari et al., 2023). Research by Nkem et al. reinforces that proximity to poorly managed septic tanks can elevate the risk of bacterial contamination, including *E. coli* (Nkem et al., 2021). This is consistent with the finding that non-compliant wells have a higher likelihood of fecal contamination exposure.

Additionally, Emeka et al. highlight that shallow groundwater depth and close proximity between septic tanks and dug wells increase the likelihood of groundwater contamination by pathogenic bacteria (Emeka et al., 2021). Therefore, the physical conditions of non-compliant dug wells, such as shallow depth and poor design, may contribute to a high risk of E. coli contamination. The MPN (Most Probable Number) test in water analysis is a standard microbiological method for detecting and estimating the number of pathogenic microorganisms, particularly coliform bacteria, in water samples. Coliforms are often used as biological indicators of water quality because their presence signifies potential fecal contamination, which can be a source of harmful pathogenic microbes, such as Escherichia coli, Salmonella, and various other pathogens.

The MPN test is also employed to assess potential health risks to humans. Water contaminated with coliforms can harbor pathogens that pose health risks, leading to diseases such as diarrhea, gastrointestinal infections, and cholera. The MPN test aids in implementing preventive measures or additional treatments to ensure water safety, particularly for drinking water. MPN utilizes a probabilistic method to estimate the number of bacteria by culturing them in a series of dilutions on selective media (in this case, Lactose Broth or LB). In the context of the 5-1-1 method used in this examination, water samples are tested at three dilution levels: 5 x 10 ml, where five tubes are used to hold 10 ml of water from the original sample; 1 x 1 ml, where one tube is used to hold 1 ml of water from the diluted sample; and 1 x 0.1 ml, where one tube is used to hold 0.1 ml of water from a further dilution. Research by (Kamari et al., 2023; Shayo et al., 2023) indicates that the presence of total coliforms measured through the MPN index can be directly associated with an increase in the incidence of gastrointestinal diseases in the community.

The statistical analysis of the relationship between the distance of dug wells to septic tanks and the MPN index indicates that, although there is a tendency for wells closer to septic tanks to have a higher risk of contamination, the statistical analysis does not support a significant relationship. This aligns with the research by (Nkem et al., 2021), which states that while the distance between wells and septic tanks can affect water quality, other factors such as the physical condition of the wells, waste management, and sanitation practices also play a crucial role in determining the microbiological quality of water. Additionally, research by (Keleb et al., 2022) demonstrates that, although distance may be a risk factor, water quality is influenced not only by physical distance but also by other environmental factors, such as soil type, well depth, and sanitation management in the surrounding area.

In the analysis of the relationship between the physical condition of the wells and the MPN values, it is evident that non-compliant physical conditions of dug wells are directly associated with higher MPN values. Previous research by (Keleb et al., 2022) indicates that poorly constructed wells that are not protected from contamination pose a higher risk of being contaminated by pathogenic bacteria, including coliforms and *E. coli*. Although the analysis shows a significant relationship, the phi value of 0.340 suggests that this relationship is relatively weak. This means that, while there is a connection between the physical condition of the wells and the MPN values, other factors may also contribute to water quality. Research by (Nkem et al., 2021) emphasizes that, in addition to the physical condition of the wells, factors such as sanitation management, proximity to pollution sources, and community hygiene practices are also important in determining the microbiological quality of water.

The results of the statistical test examining the relationship between the distance of wells to septic tanks and the presence of *E. coli* bacteria indicate that wells located near septic tanks (TMS) have a higher likelihood of contamination by E. coli. Previous research by (Keleb et al., 2022) demonstrates that the proximity of wells to pollution sources, such as septic tanks, can increase the risk of microbiological contamination, including *E. coli*. This aligns with findings that 58.3% of wells not meeting the distance criteria were detected to contain *E. coli*, whereas only 12.5% of wells that met the distance criteria were contaminated. A phi value of 0.426 indicates a moderate relationship between the distance of dug wells to septic tanks and the presence of *E. coli*. This suggests that as the distance between wells and septic tanks decreases, the likelihood of contamination by E. coli increases. Research by (Nkem et al., 2021) also supports this finding, stating that inadequate distance between wells and septic tanks can lead to waste infiltration into water sources, thereby increasing health risks for communities relying on well water.

The results of the statistical test examining the relationship between the physical structural condition of dug wells and the presence of *E. coli* bacteria show that wells with non-compliant physical conditions are more likely to be contaminated by *E. coli*. Previous research by Keleb et al., (2022) indicates that poor physical structural conditions of wells, such as shallow depth, inadequate design, and lack of protection from contamination, can lead to an increased risk of microbiological contamination, including E. coli. From the obtained data, 58.8% of non-compliant wells were detected to contain *E. coli*, whereas only 16.7% of compliant wells were contaminated. This indicates that good physical conditions of wells contribute to a reduction in the risk of microbiological contamination. A phi value of 0.404 suggests a moderate relationship between the physical condition of dug wells and the presence of *E. coli*. This indicates that while there is a significant relationship, other factors may also influence the presence of *E. coli* in well water, such as sanitation management, proximity to pollution sources, and community hygiene practices.

Conclusion

The study highlights a critical public health risk in the Morosi industrial area, with 52 of well water samples failing microbiological quality standards and 44.2% testing positive for *E. coli*. The proximity of wells to septic tanks and poor physical conditions of the dug wells significantly contribute to this contamination. These findings underscore the urgent need for improved sanitation practices and water management strategies to protect community health.

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The authors declared no competing interest

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Author contributions
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