Journal of Public Health and Pharmacy
ISSN: 2775-4952
Website: https://jurnal.unismuhpalu.ac.id/index.php/jphp

Risk Analysis of Groundwater Contaminant in Rural Areas Using Spatial Distribution

Herawati Herawati[1*], Maria Kanan[2], Anwar Mallongi[3], Ramli Bidullah[4], Sandy N. Sakati[5], Dwi Wahyu Balebu[6]
[1]Department of Public Health, Faculty of Public Health, University of Tompotika, Luwuk Banggai, Indonesia
hera.naufal@gmail.com
[2]Department of Public Health, Faculty of Public Health, University of Tompotika, Luwuk Banggai, Indonesia
mariakanan829@gmail.com
[3]Faculty of Public Health, Hasanuddin University, Indonesia
rawnaenvi@gmail.com
[4]Department of Public Health, Faculty of Public Health, University of Tompotika, Luwuk Banggai, Indonesia
ramli.bidullah@gmail.com
[5]Department of Public Health, Faculty of Public Health, University of Tompotika, Luwuk Banggai, Indonesia
Sandy_novryanto@yahoo.com
[6]Department of Public Health, Faculty of Public Health, University of Tompotika, Luwuk Banggai, Indonesia
dwiwahyubalebu90@gmail.com

***Corresponding Author**: E-mail: hera.naufal@gmail.com

ARTICLE INFO

Manuscript Received: 04 Sept, 2024
Revised: 23 Oct, 2024
Accepted: 24 Oct, 2024
Date of publication: 05 Nov, 2024
Volume: 4
Issue: 3
DOI: 10.56338/jphp.v4i3.6032

KEYWORDS

SIG;
Water Pollution;
Risk Mitigation;
Groundwaters

ABSTRACT

Background: Water is a very important material for the life of creatures in nature and its function for life cannot be replaced by other compounds. Groundwater is an important resource for humans, especially in rural areas that depend on Groundwaters as the main source of clean water. However, the quality of groundwater in many areas has decreased due to pollution from human activities, such as agriculture and industry.

Method: This study aims to analyse the level of pollution risk of groundwaters in rural areas of Masama District, Banggai Regency using descriptive quantitative methods. Spatial analysis of pollution risk was conducted on 516 Groundwaters selected as samples. Spatial data is collected by recording the location of each well using GPS, which is then used to create a spatial map. The pollution risk analysis is based on the Sanitation Inspection results, using 11 key indicators.

Result: The results showed that 4 Groundwaters (0.78%) were in the very high pollution risk category, 115 Groundwaters (22.29%) were in the high-risk category, 204 Groundwaters (39.53%) were classified as medium risk, and 193 Groundwaters (37.40%) had low pollution risk. The results indicate that most Groundwaters in the study area are at moderate to high risk. Groundwaters with high and very high risk are dominated by Groundwaters located in Minang Andala, Purwo Agung and Kembang Merta villages, which are agricultural areas with sufficient area and most of the people have livestock around their homes which could potentially be a source of contaminants.

Conclusion: This study shows that the majority of Groundwaters in the study area have a moderate to high risk of pollution, with high and very high-risk categories found in villages that have agricultural and livestock activities. This emphasises the need for more intensive groundwater management and protection measures.

Publisher: Pusat Pengembangan Teknologi Informasi dan Jurnal Universitas Muhammadiyah Palu

INTRODUCTION

Groundwater is one of the most vital natural resources for human survival, especially in rural areas that often rely on groundwaters as the main source of clean water. The abundance and easy accessibility of groundwater makes it the first choice for domestic needs, agriculture and even local economic activities. However, while groundwater is relatively protected from direct surface pollution, the potential for contamination remains, especially from uncontrolled human activities.

The agricultural and livestock sectors have an important role in the Indonesian economy. In 2021, the agricultural sector grew 1.84% and contributed 13.28% to the national economy. Based on data from the 2019 census, it shows that the use of fertilizer in agriculture is dominated by the use of chemical fertilizers at 84.6% (1). In recent decades, groundwater quality in many regions has significantly deteriorated due to the uncontrolled increase in human activities. Intensive agricultural activities, for example, often involve the use of chemical fertilisers and pesticides that can seep into the soil and contaminate groundwater. These chemicals, when applied excessively or inappropriately, can be absorbed into the soil and leach into the groundwater table. Fertilizers containing nitrates, for example, can dissolve easily in water and pollute groundwater. Nitrates in drinking water pose a risk of causing health problems. Waste from livestock also contains pathogens and chemicals such as hormones and antibiotics, which can seep into the soil if not managed properly. When this waste enters the groundwater, dangerous pathogens such as E. coli and other bacteria can contaminate drinking water sources. In addition, other human activities, such as infrastructure development, land use, and waste management, can also affect groundwater quality. Use of land for development and housing without proper planning can disrupt the natural drainage system, causing increased seepage of contaminants into groundwater. Domestic and industrial waste that is disposed of incorrectly can pollute groundwater with heavy metals, organic chemicals and pathogenic microorganisms. In addition, untreated industrial, agricultural and domestic effluents also contribute to the increase of contaminants in groundwater water, such as heavy metals and harmful organic compounds (2-5). This condition is exacerbated by the lack of regulation and supervision of waste disposal practices, especially in rural areas that often lack adequate water treatment systems. As a result, groundwater pollution has become a serious problem that threatens public health and the sustainability of water resources in many regions (6).

Groundwater water pollution has a significant impact on public health, especially in rural areas where wells are often the only source of drinking water available (7). Contamination of groundwater by pathogens, toxic chemicals, or heavy metals can cause a variety of illnesses, ranging from gastrointestinal disorders to serious chronic diseases such as cancer and kidney disorders (8)(9). This risk is further increased when people are unaware of the contamination and continue to use contaminated water for everyday purposes, including drinking, cooking, and washing (10). Furthermore, the lack of alternative clean water sources in these areas exacerbates the problem, as communities have no choice but to use polluted water. Therefore, regular monitoring of water quality and implementation of mitigation measures are essential to protect public health and ensure a safe supply of clean water.

Groundwaters are widely used by communities to extract groundwater as a source of clean water. Groundwaters with an average depth of between 7-10 metres tend to be close to the ground surface, so they are easily exposed to contamination through seepage. Polluted water can contain pathogenic microorganisms or other harmful substances that have the potential to cause diseases and health problems such as diarrhoea, dysentery, cholera, skin diseases, allergies and other waterborne diseases. Water sources in the ground are potentially affected by pollution from waste left over from human activities, and absorb a certain number of pollutants that in a certain time the amount is excessive and the water becomes contaminated [10]. Several previous studies have shown that groundwater pollution is an increasing problem in various regions, especially those dependent on agricultural and industrial activities. In some rural areas of Indonesia, it has been shown that the overuse of chemical fertilisers contributes significantly to nitrate contamination in groundwater, which can adversely affect the health of local communities. In addition, the lack of domestic waste treatment infrastructure in rural areas in Central Java increases the risk of groundwater pollution by pathogenic bacteria, especially in areas with inadequate sanitation (11-13).

Groundwater management policy in Indonesia is regulated through Government Regulation No. 43 of 2008 on groundwater, which emphasises the importance of integrated and sustainable management to maintain groundwater quality and quantity. However, the implementation of this policy often faces challenges at the local level, especially in rural areas that still have limited resources. Some areas, such as in Central Java Province, have adopted groundwater protection programmes that focus on controlling the use of chemical fertilisers and improving sanitation facilities. However, there are still gaps in implementation at the village level, often due to a lack of community awareness and minimal supervision from the authorities. In Banggai District, a regulation on groundwater use has been established, namely a provision on groundwater use tax regulated in Regional Regulation No. 17/2011. This regulation is expected to be an effective effort to prevent unwise water use (14).

In rural areas, the risk of Groundwater water pollution is often higher than in urban areas due to several factors, including the lack of adequate water treatment infrastructure. Many rural areas do not have access to effective sanitation and sewage treatment systems, so domestic and agricultural waste is often directly discharged into the environment without treatment (15). In addition, the level of community awareness regarding the importance of maintaining Groundwater water quality tends to be low, leading to practices that could potentially contaminate groundwater, such as excessive use of fertilisers and pesticides, disposal of household waste near Groundwaters, and lack of regular Groundwater maintenance. This condition is exacerbated by the lack of supervision from the local government, leading to no control over activities that could contaminate groundwater. As a result, many Groundwaters in rural areas are at high risk of contamination, which calls for more intensive interventions in the form of education, regulation and infrastructure development to protect Groundwater water quality.

Despite groundwater being one of the most important natural resources for human life, many rural areas lack a structured and sustainable groundwater management programme, leading to an increased risk of pollution. This is exacerbated by the lack of strict regulations and adequate supervision from the authorities, which should play a role in ensuring that groundwater resources remain protected from potential contamination (6). In the absence of adequate protection, groundwater quality in rural areas continues to face threats from various sources of pollution, which in turn can jeopardise the health of people who rely on Groundwaters for their daily needs. This signals an urgent need to design and implement more effective protection strategies to safeguard the sustainability of groundwater in the future and as a result, groundwater quality continues to degrade, which can have long-term impacts on the availability of clean water and public health in areas that rely on groundwaters.

In many rural areas, the risk of Groundwater water contamination is increased due to the lack of adequate water treatment infrastructure and low levels of community education on the importance of maintaining water quality. Although the dangers of Groundwater water contamination are recognised, many rural areas lack effective water treatment facilities, so domestic and agricultural waste often directly contaminates nearby Groundwaters. In addition, a lack of knowledge and awareness among local communities about practices that can prevent pollution, such as Groundwater maintenance and safe waste disposal, further exacerbates this condition. Inadequate education also results in people not realising the health risks posed by using polluted groundwater water. This situation is exacerbated by the lack of supervision from the authorities, which causes the problem to go unaddressed and persist, jeopardising the health and Groundwater-being of rural communities. Previous studies have shown that water pollution of groundwaters comes from various sources, such as household waste, leaking septic tanks, pesticide runoff, and other activities. Inadequate septic tanks have the potential to leak E.coli into groundwaters in residential areas (16,17).

This study aims to analyse the spatial distribution of Groundwater water quality in Masama Sub-district, Banggai Regency, where there are still 2,975 groundwaters used by the community. The main focus of this research is the identification of pollution risk levels and mitigation efforts that can be applied. Through this approach, it is expected to gain a deeper understanding of the distribution patterns of Groundwaters with different levels of pollution risk, so that critical areas that require further attention can be identified. Spatial analysis was conducted to map the risk of pollution, by considering various environmental factors and human activities that can affect groundwater quality. The results of this analysis are expected to not only provide a comprehensive picture of the current condition of Groundwater water quality, but also be the basis for planning effective mitigation strategies to protect groundwater resources in the region. This research also aims to provide practical recommendations that can be implemented by local governments and communities in an effort to maintain the sustainability of water resources in rural areas.

METHOD

Research Design This study used a descriptive quantitative research design to analyse the spatial distribution of dug Groundwater quality in rural areas of Masama Sub-district, Banggai District. This research was conducted to analyse the level of risk of Groundwater water pollution and the factors contributing to the pollution, as Groundwater as to analyse the spatial distribution of the dug Groundwaters based on their level of pollution risk. The data collected were analysed descriptively to provide a clear picture of the risk of dug Groundwater pollution in the study area.

Population and Sample the sample in this study was 516 dug Groundwaters in Masama Sub-district, which were determined proportionally from 14 existing villages. The sampling technique was conducted using purposive sampling method by considering the location of Groundwaters based on potential pollution sources such as agricultural, industrial, and residential areas. This sample selection aims to ensure that the data obtained represents various levels of pollution risk in the region. To assess the level of pollution, 11 key indicators key from the Sanitation Inspection are utilized, which include the following: 1) The distance between the well and the septic tank. 2) The placement of latrines in relation to the well. 3) The proximity of the well to other potential sources, such as animal waste, garbage, and other contaminants. 4) The distance between waste disposal sites and the well. 5) The conditon and potential damage to the sewer line. 6) The structural integrity of the well walls. 7) The conditions of the well's floor. 8) The overall state of the well walls. 9) The condition of the well's floor. 10) The condition and cleanliness of the rope and bucket used for water collection. 11) The presence and effectiveness of protective measures for the well.

Data collection was conducted through observation and measurement of existing indicators to determine the level of risk of dug well pollution. Meanwhile, microbiological and chemical parameters were obtained through water sampling followed by laboratory analysis.

Pollution risk mapping Spatial distribution of pollution risk is done using Geographic Information System (GIS), with the following steps:

Determination of sampling points, these representative sampling points are selected based on the location of pollutant sources, whether from domestic, industrial, or agricultural activities.

Data collection, data collected in the form of water source quality data using observation data using sanitation inspection, and data on the coordinates of the sampling location. Water quality data is in the form of physical, chemical and microbiological quality measurements. This data can be obtained through direct monitoring at certain points or from existing secondary data. While the coordinate point data is taken using GPS.

Data Analysis Integration of Spatial and Non-Spatial Data (water source quality data and its coordinates). GIS is used to integrate spatial data (sampling point locations) with non-spatial data (water quality parameters).

Map creation, pollution risk mapping shows the distribution of water pollution based on the analysed data. The map can depict areas with good, moderate, or heavily polluted water quality, making it easier to identify locations that require more attention. Coordinate point determination uses a GPS device, Sanitation Inspection Instrument to collect basic information about the Groundwater and its environment. Data collection procedures are carried out through field surveys, where each Groundwater selected as a sample is taken at the coordinate point, then a survey of Groundwater construction conditions and the environment is carried out. The data obtained was then analysed to determine the level of pollution risk and then a spatial distribution map was made to visualise the results. The instrument used in this study is a dug Groundwater Sanitation Inspection sheet whose indicators include: 1). Distance between Groundwater and septic tank, 2). Location of latrines, 3). Proximity of the Groundwater to other sources of pollutants such as animal faeces, garbage, 4). Distance of waste disposal to the Groundwater, 5). Sewerage condition, 6). Groundwater wall condition, 7). Floor area of the Groundwater, 8). Groundwater wall condition, 9). Groundwater floor condition, 10). Condition of the lead, 11). Groundwater protection. Each indicator has a score value, so to determine the level of pollution risk is determined based on the existing score value with a range of values; Very High risk (score > 75%), High risk (score 51 - 75%), Moderate risk (score 25 - 50%), and Low risk (score < 25%). Furthermore, the mapping of pollution level was done to visually illustrate the Groundwaters in each village based on their pollution risk.

RESULTS

Distribution of groundwaters by village

The distribution of groundwaters by village can be seen in the following table:

Table 1. Distribution of Groundwaters by Village

Village	The Number of Groundwater	Sample (N)
Serese	227	43
Tangeban	291	51
Taugi	174	32
Cemerlang	220	41
Padangon	147	27
Eteng	171	33
Minangandala	271	45
Purwo Agung	186	36
Kembang Merta	193	37
Ranga-Ranga	126	24
Tompotika Makmur	138	26
Simpangan	151	29
Kospa Duata Karya	297	53
Duata Karya	203	39
Total	**2.795**	**516**

Source: (Tangeban Public Health Centre, 2022)

The table above shows that there are 2,795 groundwaters used by the community as a source of clean water in their daily lives. These facilities are spread across all villages in Kecamatan Masama. This data shows that there are 2,795 (77.6%) houses that still utilise groundwaters as a source of clean water. Thus, maintaining the quality of Groundwater water is one of the efforts to protect most people from water-related health problems.

Risk Level of Groundwater Pollution in the Masama Sub-district Area

Based on data analysis, the results of the Pollution Risk Level are shown in the following table:

Table 2. Pollution Risk Levels of Groundwater in Masama District

Contaminant Risk Level	Number	Presentage (%)
Very High	4	1
High	115	23
Medium	204	39
Low	193	37
Total	**516**	**100**

The data showed that of the 516 Groundwaters studied, most were in the medium to high pollution risk category, with 204 Groundwaters (39%) in the medium category and 115 Groundwaters (23%) in the high category. Only 193 Groundwaters (37%) were at low risk, while 4 Groundwaters (1%) had very high pollution risk.

Sanitation Inspection Indicator analysis results

Table 3. Indicators of Sanitation Inspection analysis results

Indicators of Sanitation Inspection	n	%
The distance between the well and the septic tank		
Risked	318	62
Not Risked	198	38

The placement of latrines in relation to the well		
Risked	6	1
Not Risked	510	99
The proximity of the well to other potential sources, such as animal waste, garbage, and other contaminants.		
Risked	71	53
Not Risked	445	47
The distance between waste disposal sites and the well		
Risked	98	19
Not Risked	418	81
The conditon and potential damage to the sewer line		
Risked	282	55
Not Risked	234	45
The structural integrity of the well walls		
Risked	71	14
Not Risked	445	86
The conditions of the well's floor		
Risked	199	39
Not Risked	317	61
The overall state of the well walls		
Risked	46	9
Not Risked	470	91
The condition of the well's floor		
Risked	140	27
Not Risked	376	73
The condition and cleanliness of the rope and bucket used for water collection		
Risked	89	17
Not Risked	427	83
The presence and effectiveness of protective measures for the well		
Risked	434	84
Not Risked	82	16
Total	**516**	**100**

Based on the analysis of the 11 Sanitation Inspection indicators, several key findings can be identified. The majority of wells (62%) are within a risky distance from septic tanks, which may increase the potential for groundwater contamination. However, the majority of wells (99%) are in safe locations from latrines. 53% of wells were also at risk of exposure to other sources of pollutants, such as animal waste and rubbish. Meanwhile, 84% of the wells were reported to have ineffective protection, and 55% of the drains showed potential damage. However, the walls and floors of the wells were not at risk in the majority of cases (91% and 73%, respectively), and the water pulling equipment (timba) was in good condition in 83% of the wells. Overall, these results indicate a high sanitation-related risk that needs to be addressed immediately to reduce the potential for groundwater contamination

Mapping Groundwater Pollution Risk

The mapping of the risk of pollution of groundwaters can be seen in the following spatial map:

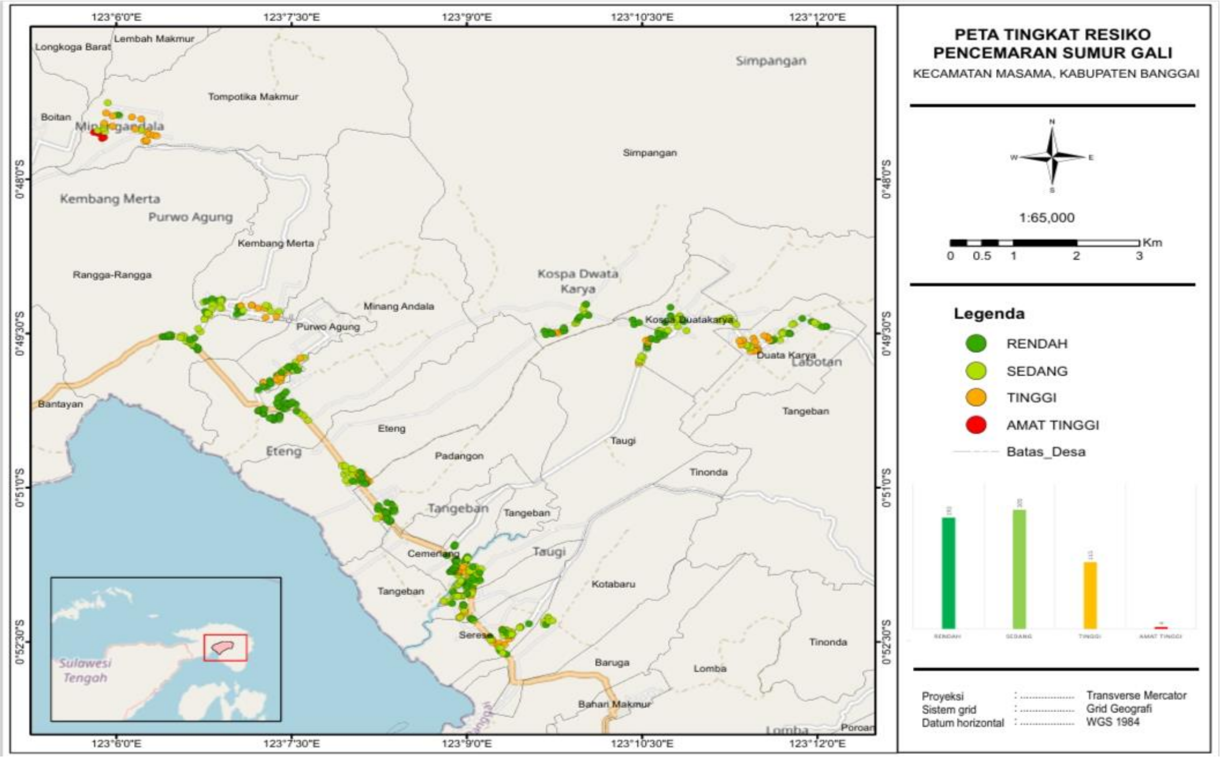

Figure 1. The mapping of the risk of pollution of groundwaters

The spatial distribution map shows that rural Groundwaters are at moderate to very high risk of pollution. High and very high risks are located in Minang Andala Village, Purwo Agung Village, and Duata Karya Village.

DISCUSSION

The results of this study indicate that although groundwater is an extremely important resource for life in rural areas, there has been no adequate effort to protect the quality of Groundwater water in Masama District, Banggai Regency. This highlights an urgent need to improve groundwater management and protection. The sustainability of groundwater resources heavily depends on proper management and public awareness of the importance of maintaining water quality. The spatial distribution of pollution risks found in this study could serve as a basis for local governments to design more effective groundwater management strategies, in line with the approaches recommended by hydrology experts in water resource management (14). The levels of pollution indicate conditions ranging from lightly to highly and very highly polluted waters, suggesting the presence of contaminants in the water sources. High pollution levels can occur in locations with significant inputs from household waste disposal channels (19).

Nowadays, the degradation of groundwater quality due to human activities such as agriculture and industry has not been fully addressed. This study reveals that 22.29% of Groundwaters in Masama District fall into the high pollution risk category, largely due to uncontrolled human activities. Intensive agricultural practices and industrial waste disposal are often the primary causes of groundwater contamination, especially in rural areas. Groundwater water contamination continues to pose a serious threat to public health, yet effective preventive measures are still rarely implemented. This study found that nearly 40% of Groundwaters in Masama District are classified as medium risk, indicating a potential hazard to public health if not properly managed. Most water pollutants originate from human activities (20).

Water from sources that do not meet construction standards has the potential to cause waterborne diseases, making control efforts necessary. Control refers to efforts to reduce or eliminate risk factors for diseases and/or health disorders. This Water Quality Monitoring activity is conducted as part of Environmental Quality Monitoring and is a routine activity. High-risk water sources may be contaminated by pathogenic bacteria that can cause disease. One of the diseases most relevant to water quality is diarrhea, which can be caused by the bacterium Escherichia coli. *E. coli* bacteria, originating from feces, effectively confirm the presence of fecal contamination in water bodies. Water contaminants like lead, pesticides, arsenic, perchlorate, and nitrates negatively impact children's health due to their sensitivity, emphasizing the importance of addressing pollution for overall well-being (21). Monitoring water quality and implementing preventive measures are essential to protect the health of communities that rely on groundwaters. Therefore, these findings strengthen the argument for the need to enhance public education and the implementation of effective preventive measures to prevent the negative impacts of Groundwater water contamination. Water contaminants negatively affect health by disrupting hormones, accelerating aging, and causing various ailments like neurological disorders, cancer, and reproductive issues in both men and women (22)(23). Water contaminants like sewage, industrial discharges, and pesticides lead to skin disorders, cancer, and diarrheal infections, especially in children, emphasizing the urgent need for advanced treatment and pollution control measures (24)(23)(25).

In many rural areas, inadequate water treatment infrastructure and low public education levels have led to a high risk of Groundwater water contamination. Adequate infrastructure and effective education are key to reducing contamination risks and maintaining groundwater quality. With the spatial distribution data generated from this study, more targeted interventions can be implemented to develop the necessary infrastructure and design better educational programs for the local community. The data obtained from this research provide strong evidence that stricter regulations and oversight are needed for activities that have the potential to contaminate groundwater, in order to prevent a decline in water quality in the future.

As a mitigation effort to maintain the quality of Groundwater water, it is recommended to improve Groundwater infrastructure management through adequate construction and maintenance, such as ensuring that Groundwaters have robust structures and are regularly inspected to prevent damage that could lead to contamination (5)(23,26,27). Additionally, education and raising public awareness are crucial to ensuring that local residents understand the importance of maintaining cleanliness around Groundwaters and actively participate in water quality monitoring. Regular water quality testing and monitoring should also be conducted, including checks on key parameters such as pH and the presence of harmful bacteria, as Groundwater as the implementation of an early warning system to detect potential contamination before it reaches dangerous levels. These efforts must be carried out in an integrated and sustainable manner to ensure that Groundwater water remains clean and safe for the community.

Several previous studies have emphasized the impact of septic tanks on groundwater quality, particularly in rural areas lacking adequate sewage treatment systems. In these regions, pollution sources often stem from domestic waste and agricultural activities, potentially degrading groundwater quality and posing a risk to public health. The use of chemical fertilizers and poor management of agricultural effluents are frequently cited as major contributors to contamination, especially when these pollutants infiltrate groundwater sources. This leads to an increased concentration of harmful substances such as nitrates and pathogenic microorganisms in well water, which is commonly used for drinking purposes (28–30).

Another study highlighted groundwater contamination from household waste in rural communities, particularly in the South Asian region, and its associated health risks. Poor management of solid and liquid waste contributes significantly to groundwater pollution, allowing hazardous chemicals and biological contaminants to accumulate in drinking water supplies. This can lead to a variety of health problems, including digestive disorders and waterborne diseases. These findings underscore the critical need for improved waste management systems in both domestic and agricultural settings, as well as stronger preventive measures to safeguard groundwater quality in rural areas (31).

CONCLUSION

The conclusion of this study indicates that the quality of Groundwater water in Masama District, Banggai Regency, is at risk of contamination that could pose potential dangers to the community, with most Groundwaters falling into the medium to high-risk categories. This underscores the need for more intensive management actions, the development of water treatment infrastructure, and the enhancement of public education to protect groundwater sources. Recommendations for future research include a deeper investigation into the specific factors affecting Groundwater water contamination, including the impact of climate change and land use dynamics, as Groundwater as the development of predictive models that can assist in mitigating contamination risks. Further studies should also explore the effectiveness of various groundwater management strategies implemented in other rural areas, so they can be adopted as best practices for ensuring the sustainability of water resources in the future.

Local governments can take strategic policy measures to control the pollution of dug wells by focusing on improving sanitation infrastructure and waste management. Firstly, setting safe distances between dug wells and pollution sources, such as septic tanks, should be strictly enforced through local regulations. Secondly, capacity building programmes are needed for communities to understand the importance of well maintenance and good waste management, especially in rural areas. In addition, local governments can support the construction of more efficient household and agricultural waste treatment facilities. Finally, a policy of regular monitoring and inspection of dug wells, as well as incentivising communities that practice sustainable sanitation, would go a long way in preventing groundwater contamination and protecting public health.

AUTHOR’S CONTRIBUTION STATEMENT

Herawati developed the design and implementation of the research, collecting data, analyzing and interpreting data, writing and revising draft article, final approval of the version to be published. Maria Kanan, Ramli Bidullah, Sandy N. Sakati, and Dwi Wahyu Balebu contributed to the data analysis and interpretation.

CONFLICTS OF INTEREST

The authors have stated that they do not have any conflicts of interest, including personal relationship or finacial matters, that could potentially influence the results of this study.

SOURCE OF FUNDING STATEMENTS

The authors received no funding for this study.

ACKNOWLEDGMENTS

We extend our gratitude to the Faculty of Public Health at Tompotika Luwuk University for their support in conducting the research, as well as to DRTPM Kemenristekdikti for the technical guidance offered.

BIBLIOGRAPHY

1. Kementerian Koordinator Bidang Perekonomian Republik Indonesia. Kembangkan Ketangguhan Sektor Pertanian, Indonesia Raih Penghargaan dari International Rice Research Institute - Kementerian Koordinator Bidang Perekonomian Republik Indonesia. EkonGoId [Internet]. 2022;2021–2. Available from: https://www.ekon.go.id/publikasi/detail/4443/kembangkan-ketangguhan-sektor-pertanian-indonesia-raih-penghargaan-dari-international-rice-research-institute
2. Gowda YHK. Hydrochemical analysis of ground water quality in Anchepalya industrial area Kunigal taluk Tumkur district. Mater Today Proc [Internet]. 2023;89:19–23. Available from: https://api.elsevier.com/content/article/eid/1-s2.0-S2214785323018199
3. Izzati T. Further study of ground water quality in industrial area of Bekasi and residential area of Depok, West Java, Indonesia. IOP Conf Ser Mater Sci Eng [Internet]. 2018;453(1). Available from: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85058059824&origin=inward
4. Kneese A V. Rationalizing Decisions in the Quality Management of Water Supply in Urban-Industrial Areas.

Public Econ Urban Communities [Internet]. 2016;170–91. Available from: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85127679517&origin=inward

5. Dash PC. Water Quality Index of surface water in rural area around Angul - Talcher Industrial Zone, Orissa. Pollut Res [Internet]. 2011;30(2):267–71. Available from: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=80052845155&origin=inward
6. Li P. Drinking Water Quality and Public Health. Expo Heal [Internet]. 2019;11(2):73–9. Available from: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85061036535&origin=inward
7. Zhang Q. Groundwater Quality Assessment Using Improved Water Quality Index (WQI) and Human Health Risk (HHR) Evaluation in a Semi-arid Region of Northwest China. Expo Heal [Internet]. 2020;12(3):487–500. Available from: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85078334453&origin=inward
8. Ji Y. Seasonal Variation of Drinking Water Quality and Human Health Risk Assessment in Hancheng City of Guanzhong Plain, China. Expo Heal [Internet]. 2020;12(3):469–85. Available from: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85083455015&origin=inward
9. Wang Z. Distribution of antibiotic resistance genes in an agriculturally disturbed lake in China: Their links with microbial communities, antibiotics, and water quality. J Hazard Mater [Internet]. 2020;393. Available from: https://api.elsevier.com/content/article/eid/1-s2.0-S0304389420304155
10. Egbueri JC. A multi-criteria water quality evaluation for human consumption, irrigation and industrial purposes in Umunya area, southeastern Nigeria. Int J Environ Anal Chem [Internet]. 2023;103(14):3351–75. Available from: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85104245805&origin=inward
11. Sakati SN, Mallongi A, Ibrahim E, Budimawan, Stang, Palutturi S, et al. Utilization of Rainwater as Consumable Water with Rainwater Harvesting Methods: A Literature Review. Pharmacogn J. 2023;15(6):1254–7.
12. Safitri W, Pujiati RS, Ningrum P. Kandungan Nitrat Pada Air Tanah Di Sekitar Lahan Pertanian Padi, Palawija, Dan Tembakau (Studi Di Desa Tanjungrejo Kecamatan Wuluhan Kabuapten Jember). Digit Repos Univ Jember. 2014;3(3):69–70.
13. Sari DR, Febrion C, Novia F, Studi P, Lingkungan T, Kebangsaan U, et al. PENGARUH SISTEM SANITASI TERHADAP KUALITAS AIR TANAH DI KECAMATAN LENGKONG , KOTA BANDUNG. 2024;7(1).
14. Energi D, Daya S, Tengah PJ. Kebijakan Provinsi Jawa Tengah Dalam Pengendalian Pemanfaatan Air Tanah. 2022;(September):12–3.
15. Altenburger R. Future water quality monitoring: improving the balance between exposure and toxicity assessments of real-world pollutant mixtures. Environ Sci Eur [Internet]. 2019;31(1). Available from: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85061815105&origin=inward
16. Marouane B, Belhsain K, Jahdi M, El Hajjaji S, Dahchour A, Dousset S, et al. Impact of agricultural practices on groundwater quality: Case of Gharb region-Morocco. J Mater Environ Sci. 2014;5:2151–5.
17. Herawati, Syahrir M, Yusuf, Sakati SN, Balebu DW. Assessing Groundwater Quality in Rural Communities: A Detailed Study of Physical, Chemical, and Microbial Contaminant. Int J Med Toxicol Leg Med. 2024;27(1):180–8.
18. Profil Puskesmas Tangeban [Internet]. Banggai; Available from: https://pkmbabakansaribdg.com/profil-puskesmas/
19. Prakoso AD. Analisis spasio-temporal tingkat pencemaran danau ebony dan danau crown golf, pantai indah kapuk, jakarta utara agus danu prakoso. 2019;
20. Tarigan R. Dinamika kualitas air dan tingkat pencemaran di sekitar rencana intake air baku di bagian hilir Sungai Cisadane. 2021;
21. Unemployment Y. HAPSc Policy Briefs Series. 2021;2(2):63–9.
22. Bochynska S, Duszewska A, Maciejewska-Jeske M, Wrona M, Szeliga A, Budzik M, et al. The impact of water pollution on the health of older people. Vol. 185, Maturitas. Elsevier Ireland Ltd; 2024.
23. Smith I. Water Pollution and Cancer: An Updated Review. Sci Insights. 2023;43(4):1079–86.
24. Mustafa BM, Hassan NE. Water Contamination and Its Effects on Human Health: A Review. J Geogr Environ

Earth Sci Int. 2024 Jan 15;28(1):38–49.

25. Levin R, Villanueva CM, Beene D, Cradock AL, Donat-Vargas C, Lewis J, et al. US drinking water quality: exposure risk profiles for seven legacy and emerging contaminants. J Expo Sci Environ Epidemiol. 2024;34(1):3–22.
26. Hou S, Zhao X, Liu Y, Tillotson MR, Weng S, Wang H, et al. Spatial analysis connects excess water pollution discharge, industrial production, and consumption at the sectoral level. npj Clean Water. 2022;5(1).
27. Barua S. Water Pollution Effects on Human Health : A Global View Water Pollution Effects on Human Health : A Global View. 2023;(September).
28. Akhtar MM, Tang Z, Mohamadi B. Contamination potential assessment of potable groundwater in Lahore, Pakistan. Polish J Environ Stud. 2014;23(6):1905–16.
29. Hara K. International Review for Environmental Strategies Special Feature on Groundwater Management and Policy Groundwater Contamination and Quality Management Policy in Asia. 2006;6(2):291–306.
30. Li P, Karunanidhi D, Subramani T, Srinivasamoorthy K. Sources and Consequences of Groundwater Contamination. Arch Environ Contam Toxicol [Internet]. 2021;80(1):1–10. Available from: https://doi.org/10.1007/s00244-020-00805-z
31. Farouq AU, Suru HU, Uwerevu EO, Ikpesu JE. Effects of Septic Tank on the Quality of Groundwater from Hand-Dug Wells in Effurun. Int Res J Adv Eng Sci [Internet]. 2018;3(1):137–41. Available from: www.water.usgs.gov/edu/bacteria.html