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Research Article

Escherichia Coli and Total Coliform Contamination in Various Raw Water Sources in Ende Regency, Nusa Tenggara Timur Province, Indonesia

Yohanes Erik Kurniawan Nggae[1], Intan Supraba[2*], Radianta Triatmadja[3], Chen-Yi Sun[4]

[1]Graduate Student, Civil and Environmental Engineering Department, Faculty of Engineering, Universitas Gadjah Mada, Indonesia
[2]Associate Professor, Civil and Environmental Engineering Department, Faculty of Engineering, Universitas Gadjah Mada, Indonesia
[3]Professor, Civil and Environmental Engineering Department, Faculty of Engineering, Universitas Gadjah Mada, Indonesia
[4]Professor, Department of Land Economics, College of Social Sciences, National Chengchi University, Taiwan
*correspondence e-mail: intan.supraba@ugm.ac.id

Abstract

Global demand for clean water, emphasized by the sixth Sustainable Development Goals (SDGs), seeks universal access to safe, affordable drinking water through Goal 6.1. This research aims to assess the quality of some raw water sources and treated water distributed to customers by Perumda Tirta Kelimutu at Ende Regency in Nusa Tenggara Timur Province. The research method is quantitative and qualitative approaches to explain the presence of bacteria in water. The raw water samples including six samples collected from various water sources, six samples obtained from end consumers, and five samples collected from locations where wells and spring water can be freely accessed as it is outside the responsibility of Perumda Tirta Kelimutu. In addition, additional data sets from 2019 to 2022 provided by Perumda Tirta Kelimutu were also included in the analysis. The water quality data was then compared with the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023, which regulates raw water requirements for clean and potable water. The results reveal that all water quality samples are contaminated by Escherichia coli (E. coli) and total coliform. Several factors contribute to potential water contamination, including human activities in proximity to water sources, the absence of protection for raw water, the presence of debris in the water, leakages, the lack of water treatment plants in the water supply system, insufficient chlorination in water treatment plants, and residences located too close to water sources such as wells.

Keywords: *clean water, E. coli, total coliform*

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1. Introduction

According to the report published by UNESCO, the global urban population facing water scarcity is projected to double from 930 million in 2016 to 1.7–2.4 billion people in 2050. As articulated in the Sustainable Development Goals (SDGs), a fundamental human right is the attainment of universal access to safe and affordable drinking water services (United Nations, 2018). It is also essential to emphasize the importance of water quality (Gusti Ngurah Agung Suryaputra et al., 2021). Prioritizing the quality of water used or consumed aligns with concerns related to human health, as well as broader environmental and ecological considerations (Al-Barwary et al., 2018; Batool, 2018; Daghara et al., 2019; Luvhimbi et al., 2022).

Typically, water source is surface water from rivers, lakes, and reservoirs, or groundwater (U.S. Geological Survey (usgs.gov), 2018). Surface and groundwater constitute indispensable resources for clean water provision (Triatmadja, 2021). Drinking water companies are responsible to distribute safe water that fulfill drinking water quality standard. Nevertheless, the utilization of raw water from surface and groundwater poses challenges, encompassing issues related to both quantity and quality of water (Batool, 2018).

Various physical parameters, chemical parameters, and biological parameters reflect the quality of water. Physical parameters including odor, taste, color, turbidity, temperature, and total dissolved solids (TDS). Chemical parameters such as pH, salinity chloride, sulfate, nitrogen, fluoride, iron, and manganese, and hardness. Moreover, biological parameters such as bacteria, algae, viruses, and protozoa play a pivotal role in assessing water quality. The World Health Organization (WHO) designates total coliforms and Escherichia coli (E.coli) as crucial microbial indicators for drinking water quality (WHO, 2017). These two facial indicators bacteria should not detectable on 100 mL water sample (Luvhimbi et al., 2022). Water with these kinds of bacteria is unsafe and unhealthy to be consumed and used. Some factors influence the quality of the raw water. The main factors are location and environmental factors such as the type of rock, aquifer, and water temperature (Hafiz et al., 2023). Additionally, anthropogenic factors, agriculture, and urbanization have some effects on water pollution (Al-Khashman et al., 2017; Daghara et al., 2019; Gusti Ngurah Agung Suryaputra et al., 2021; Luvhimbi et al., 2022).

Consuming water from unprotected wells and springs without awareness of its pollution poses significant health risks (Colín Carreño et al., 2023). Such practices can lead to various diseases, including cholera, dysentery, diarrhea, and other severe illnesses detrimental to human health. Consequently, ensuring safe and adequate water through a reliable water supply system becomes imperative for regional drinking water companies. Rigorous analysis of water quality is essential to guarantee the safety of the water distributed to the public.

This research investigates the water quality of some raw water in Ende Regency. Samples were obtained from springs and rivers, and treated water was distributed to customers by Perumda Tirta Kelimutu, one of the water utilities in Ende, East Nusa Tenggara, Indonesia. Additionally, raw water samples were gathered from sites where community members rely on water for drinking and hygienic purposes, notably from unregulated wells and springs not overseen by Perumda Tirta Kelimutu. The principal emphasis of this study lies in examining microbial indicators present in the sampled water.

2. Methodology

Samples of raw water from the water supply system were collected from various sources, including Ae Pana Spring Water, Ae Kipa Spring Water, Woloare Spring Water, Tiwu Kipi Spring Water, and the Wolowona River having two intakes in Km. 10 and Km. 6. Additionally, water sample from consumers were obtained from six different locations: Jalan Ahmad Yani which distributed from Ae Pana Spring Water, Pupui area from Ae Kipa Spring Water, Jalan Woloare from Woloare Spring Water, Subdistrict Rukuramba, Kojadewa from Tiwu Kipi Spring Water, Area in Dolog from Wolowona River in Km.10, as well as Jalan Undana from Wolowona River in Km.6. These data were complemented by several water quality records from Perumda Tirta Kelimutu, spanning from the year of 2018 to 2022. Water quality data has yet to be available for 2020 because of the Covid-19 pandemic.

Samples were also gathered from locations that utilize well and spring water outside the responsibility of Perumda Tirta Kelimutu. These samples were specifically obtained from house connection system from Ae Bhoko Spring Water in Roworena Barat Subdistrict, a well in Tanjung Subdistrict, a well in the PLTD area of Mautapaga Subdistrict, a well in Kota Ratu Subdistrict, and a well in the Ipi area of Tetandara Subdistrict. The geographical distribution of these water sample collection points is illustrated in Figure 1.

The water quality data is assessed based on the standards outlined in the Minister of Health of the Republic of Indonesia Regulation No. 2 of 2023. This regulation comprehensively addresses the quality standards for drinking water, clean water for hygiene and sanitation purposes, water for pools, spas, and water for public baths. The comparison of the collected data with the standards stipulated in this regulation, as depicted in Table 1, will ascertain whether the water quality is deemed safe or unsafe for consumption by customers.

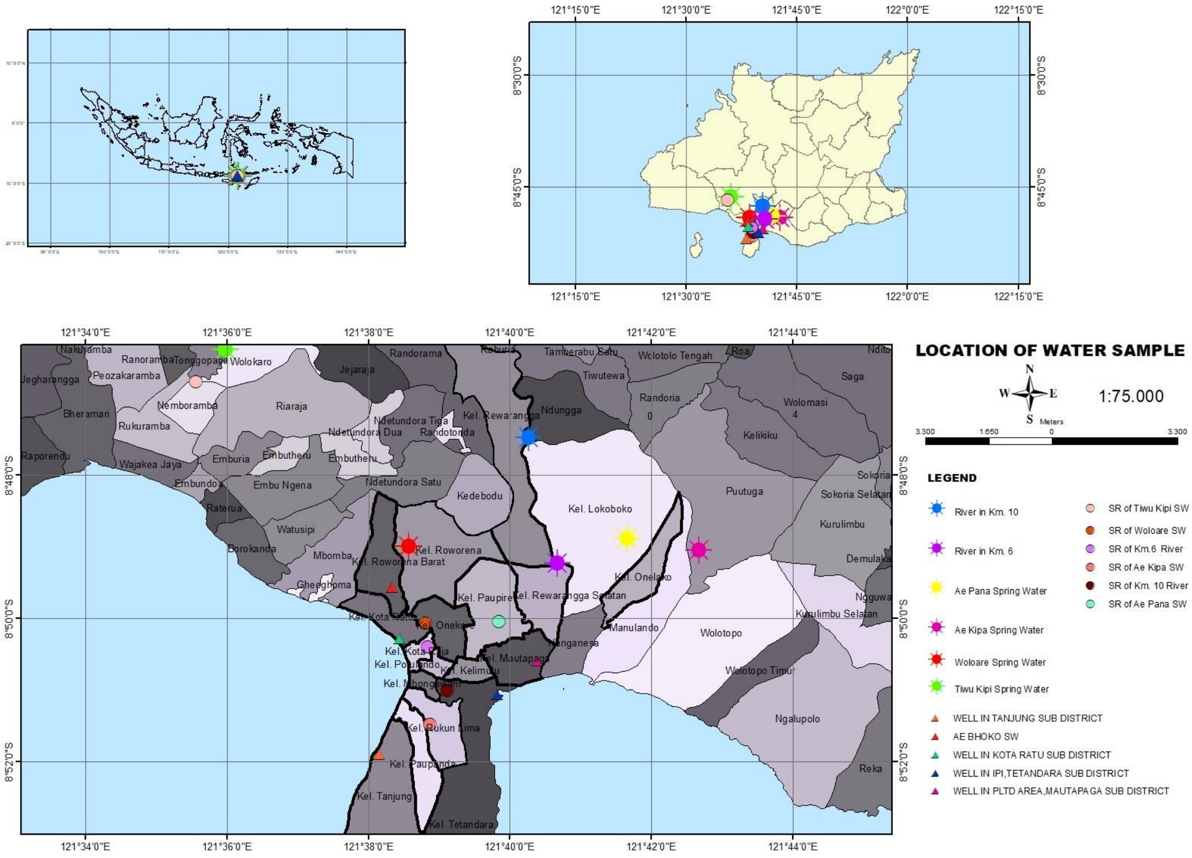


Figure 1. Map of Study Area

Source: modified from /www.indonesia-geospasial.com/2020/01/shp-rbi-provinsi-nusa-tenggara-timur.html

Table 1. Water Quality Standard of Clean Water for Hygiene and Sanitation Purpose Base on Minister of Health of Republic Indonesia Regulation No.2 of 2023

No	Parameters	Unit	Recommended
Physical			
1	Odor	-	Odorless
2	Taste	-	Tasteless
3	Colour	TCU	10
4	Turbidity	NTU	<3
5	Temperature	^0C	Air Temperature ± 3^0C
6	Total Dissolved Solid (TDS)	mg/L	<300
Chemical			
7	pH	-	6,5-8,5
8	Salinity	$^0/_{00}$	0
Microbiology			
9	E.Coli	CFU/100 mL	0
10	Total Coliform	CFU/100 mL	0

3. Results

The results of microbial parameters from seventeen water samples are shown in Table 2. The data reveals that all water samples collected from raw water resources, including springs and rivers, and water from consumers and wells fail to meet the required microbial parameters. All samples show the presence of microbial pathogens, including total coliform and E. coli.

Table 2. Microbial Parameters on Water Samples

No	Year	Date	Location		Location Description	Parameters	
			Latitude	Longitude		Total Coliform (CFU/100 ml)	E. coli (CFU/100 ml)
1	2023	11-Sep-23	-8,81739060	121,7112240	Aekipa Spring Water	460	20
2	2023	11-Sep-23	-8,8580317	121,6479198	SR in Pupui Area	150	39
3	2023	11-Sep-23	-8,8147575	121,6944304	Aepana Spring Water	> 2400	1100
4	2023	11-Sep-23	-8,833969	121,664072	SR in Jalan Ahmad Yani	39	150
5	2023	13-Sep-23	-8,8165581	121,6428702	Woloare Spring Water	150	23
6	2023	13-Sep-23	-8,8344642	121,6467192	SR in Jalan Woloare A	43	15
7	2023	11-Sep-23	-8,791159	121,6711415	Wolowona River in KM. 10	150	150
8	2023	11-Sep-23	-8,8501488	121,6520112	SR in Area in Dolog	1100	1100
9	2023	11-Sep-23	-8,8204845	121,6778022	Wolowona River in KM. 6	1100	28
10	2023	11-Sep-23	-8,8399433	121,6473401	SR in Jalan Undana	93	93
11	2023	21-Sep-23	-8,7706796	121,5995915	Tiwu Kipi Spring Water	460	21
12	2023	21-Sep-23	-8,7780635	121,5926679	SR in Subdistrict Rukuramba, Kojadewa	150	15
13	2023	11-Sep-23	-8,8262290	121,6388485	SR Ae Bhoko Spring Water	120	120
14	2023	13-Sep-23	-8,865172	121,635879	Well, in Tanjung Subdistrict	120	75
15	2023	13-Sep-23	-8,843362	121,6732217	Well in PLTD Area, Mautapaga Subdistrict	> 2400	> 2400
16	2023	08-Nov-23	-8,8382236	121,6407508	Well, in the Kota Ratu Subdistrict	93	240
17	2023	08-Nov-23	-8,8511628	121,6638234	Well, in Ipi, Tetandara Subdistrict	> 2400	240

The water quality data from Perumda Tirta Kelimutu, spanning from 2018 to 2022, is presented in Table 3. Total coliforms and E. coli were not tested in 2020 during the COVID-19 pandemic. Samples were collected from various reservoirs and houses utilizing water from Perumda Tirta Kelimutu. The data reveals that all samples exhibit detectable levels of microbial total coliform and E. coli. Implementation and determination of test parameters are based on a request from Perumda Tirta Kelimutu and the availability of tools and materials from the Regional Health Laboratory in Ende Regency.

Table 3. Water Quality Data from Perumda Tirta Kelimutu

No	Year	Date	Location	Total Coliform (CFU/100 ml)	E. coli (CFU/100 ml)
1	2022	18-Feb	IKK Puubetho	-	27
2		18-Feb	PDAM office in Nangaba	-	96
3		29-Jun	Reservoir in Pos Office	-	5
4		13-Oct	PDAM Kran Proses Awal	43	-
5		13-Oct	Reservoir in Boanawa	64	-
6		13-Oct	Woloare Spring Water	43	-
7		13-Oct	Reservoir in Woloare	64	-
8		24-Oct	SR Pu'uwaru	64	-
9		24-Oct	SR Nanganesa	240	-
10		24-Oct	Aekipa Spring Water	240	-
11		24-Oct	Radaara Spring Water	240	-
12	2021	1-Sep	WTP Outlet KM.8	-	27
13		1-Sep	WTP Inlet	-	96
14		1-Sep	WTP Outlet	-	0
15		15-Sep	Reservoir in Boanawa	-	96
16		15-Sep	SR Boanawa 1	-	96
17		15-Sep	SR Boanawa 2	-	96
18		15-Sep	SR Jalan Ahmad Yani 1	-	240
19		15-Sep	SR Jalan Ahmad Yani 2	-	240
20		15-Sep	SR Jalan Katedral 1	-	96
21		16-Sep	SR Jalan Katedral 2	-	96
22	2019	11-Jun	SR Jalan Woloare	-	21
23		11-Jun	SR Jalan Marilonga	-	96
24		11-Jun	SR Jalan Hayam Wuruk 1	-	64
25		11-Jun	SR Jalan Hayam Wuruk 2	-	43
26		11-Jun	SR Jalan Nangka 1	-	43
27		11-Jun	SR Jalan Nangka 2	-	21
28		11-Jun	SR Jalan Masjid Raya 1	-	21
29		11-Jun	SR Jalan Masjid Raya 2	-	96
30		11-Jun	SR Jalan Kelimutu 1	-	21
31		11-Jun	SR Jalan Kelimutu 2	-	96
32		11-Jun	SR Jalan Garuda 1	-	96
33		11-Jun	SR Jalan Garuda 2	-	97

No	Year	Date	Location	Total Coliform (CFU/100 ml)	E. coli (CFU/100 ml)
34		11-Jun	Reservoir Boanawa	-	96
35		11-Jun	Reservoir Woloare	-	96
36		17-Jun	SR Ndona	-	96
37		17-Jun	SR Lokoboko	-	96
38		17-Jun	WTP PDAM	-	240
39		17-Jun	Reservoir in PDAM	-	240
40		17-Jun	SR Jalan DI. Panjaitan 1	-	240
41		17-Jun	SR Jalan DI. Panjaitan 2	-	96
42		17-Jun	SR Jalan Perumnas 1	-	240
43		17-Jun	SR Jalan Perumnas 2	-	96
44		17-Jun	SR Jalan Durian 1	-	12
45		17-Jun	SR Jalan Durian 2	-	96
46		17-Jun	SR Jalan Melati 1	-	240
47		17-Jun	SR Jalan Melati 2	-	42
48		31-Jul	WTP PDAM	-	96
49		31-Jul	Reservoir PDAM	-	96
50		31-Jul	Reservoir Boanawa	-	96
51		31-Jul	Reservoir Woloare	-	96
52	2019	31-Jul	SR Jalan Samratulangi 1	-	96
53		31-Jul	SR Jalan Samratulangi 2	-	240
54		31-Jul	SR Jalan Eltari 1	-	240
55		31-Jul	SR Jalan Eltari 2	-	240
56		31-Jul	SR Jalan Basuki Rahmat 1	-	96
57		31-Jul	SR Jalan Basuki Rahmat 2	-	96
58		31-Jul	SR Jalan Wirajaya 1	-	96
59		31-Jul	SR Jalan Wirajaya 2	-	96
60		31-Jul	SR Jalan Nenas 1	-	240
61		31-Jul	SR Jalan Nenas 2	-	96
62		31-Jul	SR Jalan Anggrek 1	-	96
63		31-Jul	SR Jalan Anggrek 2	-	240
64		31-Jul	SR Jalan Gatot Subroto 1	-	96
65		31-Jul	SR Jalan Gatot Subroto 2	-	240
66		31-Jul	SR Jalan Wolowona 1	-	96
67		31-Jul	SR Jalan Wolowona 2	-	240
68		31-Jul	SR Jalan Woloweku 1	-	96
69		31-Jul	SR Jalan Woloweku 2	-	240
70		2-Oct	Reservoir Woloare	-	8,8
71		2-Oct	SR Jalan Woloare A	-	8,8

No	Year	Date	Location	Total Coliform (CFU/100 ml)	E. coli (CFU/100 ml)
72		2-Oct	SR Jalan Woloare B 1	-	10
73		2-Oct	SR Jalan Woloare B 2	-	8,8
74		2-Oct	SR Jalan Udayana 1	-	38
75		2-Oct	SR Jalan Udayana 2	-	38
76		2-Oct	SR Jalan Marilonga 1	-	38
77		2-Oct	SR Jalan Marilonga 2	-	240
78		2-Oct	SR Jalan Durian 1	-	240
79		2-Oct	SR Jalan Durian 2	-	240
80		2-Oct	SR Jalan Kokos Raya 1	-	96
81	2019	2-Oct	SR Jalan Kokos Raya 2	-	96
82		2-Oct	SR Jalan Undana 1	-	96
83		2-Oct	SR Jalan Undana 2	-	96
84		2-Oct	Reservoir Boanawa	-	240
85		2-Oct	SR Jalan Katedral	-	240
86		2-Oct	SR Jalan Sudirman	-	240
87		2-Oct	SR Jalan Boanawa 1	-	240
88		2-Oct	SR Jalan Boanawa 2	-	240
89		2-Oct	SR Jalan DI. Panjaitan 1	-	240
90		2-Oct	SR Jalan DI. Panjaitan 2	-	240
91		2-Oct	SR Jalan Melati 1	-	240
92		2-Oct	SR Jalan Melati 2	-	240
93		15-Oct	WTP PDAM	-	240
94		15-Oct	Reservoir PDAM	-	240
95		15-Oct	SR Jalan Boanawa 1	-	96
96		15-Oct	SR Jalan Boanawa 2	-	96
97		10-Dec	SR Jalan Anggrek	-	96
98		10-Dec	SR Jalan Gatot Subroto	-	96

SR: House Connection System, WTP: Water Treatment Plant, IKK: District Installation

3. Discussions

Escherichia coli (E. coli) is a gram-negative, facultative anaerobic, rod-shaped, coliform bacterium of the genus *Escherichia* that is commonly found in the lower intestine of warm-blooded organism. It can survive in challenging environments and thrive in various conditions, including fresh water, seawater, and soil. However, it is essential to note that not all strains of E. coli found in water are pathogenic; most are non-pathogenic. Nonetheless, there are instances where pathogenic strains, such as enterotoxigenic and enterohemorrhagic E. coli, which produce Shiga toxin, can be detected (Winiati P. Rahayu, Siti Nurjanah, 2018). Pathogenic E. coli is known to cause several diseases, including diarrhea, urinary infections, and neonatal meningitis. At the same time, total coliform is an indicator that signals the presence of microorganisms in water, including bacteria like E. coli etc (Arsyina et al., 2019). Total coliform can be attributed to sources such as human or animal feces and natural occurrences in water.

During field surveys, we observed that the catchment areas of Ae Kipa, Ae Pana, and Tiwu Kipi Spring Water are open spaces where various types of debris can enter the water. Additionally, the springs are surrounded by biodegradable leaves that can contribute to water pollution as they decompose through microbial activity. Previous research states that E. coli can also live and attach to the surface of leaves depending on the topography, temperature, and nutrients available (Doan et al., 2020). Ae Pana Spring Water is situated in an area far from residential zones but close to an old village, posing a potential risk of contamination from remnants of human activities near the catchment area. Furthermore, there is a likelihood that these three springs are contaminated by fecal matter from animals such as monkeys, dogs, and birds, introducing E. coli and total coliform into the water (Ercumen et al., 2017). A reservoir protects water from Woloare Spring Water. However, its proximity to residential areas raises concerns, as human activities can directly contribute to water contamination. Water from rivers in Km 10 and Km. 6 can be contaminated by total coliform and E. coli because of rubbish and human activities in rivers. People wash, bathe, and throw rubbish in the river. Locations of raw water in the water supply system of Perumda Tirta Kelimutu are shown in Figure 2.

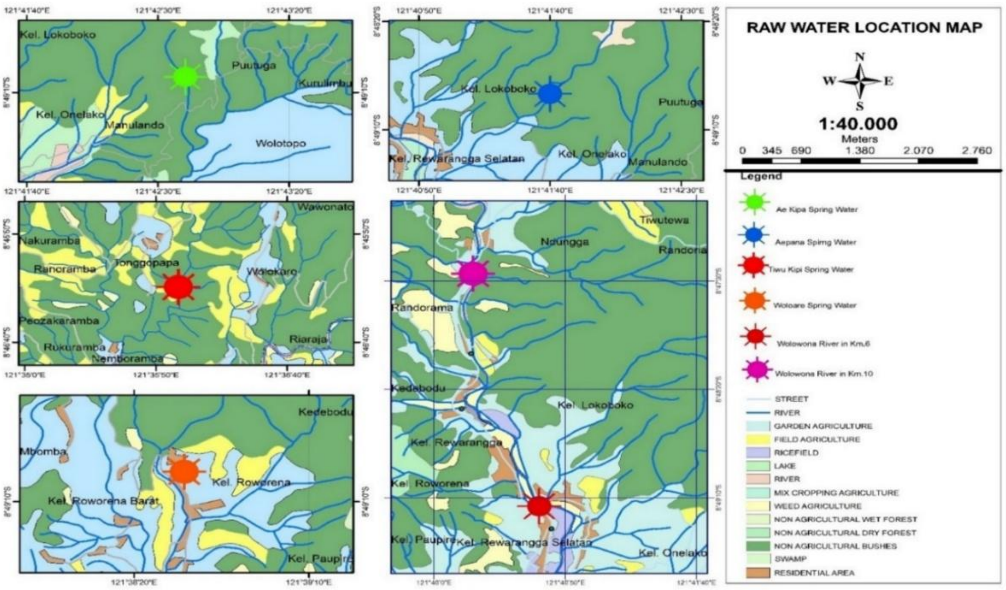
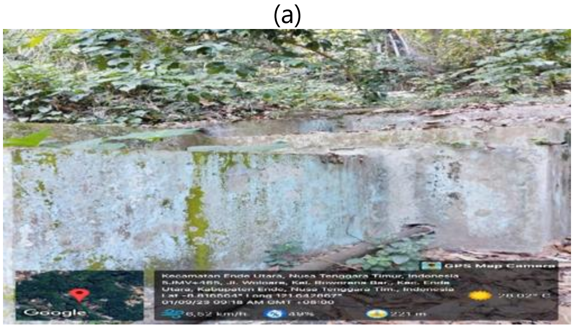


Figure 2. Raw Water Location Map is Overlaid to Land Use Map
Source: modified from /www.indonesia-geospasial.com/2020/01/shp-rbi-provinsi-nusa-tenggara-timur.html

(a)

(b)



(c)

(d)

(e) (f)

Figure 3. Current Condition of Raw Water of Water Supply System of Perumda Tirta Kelimutu (a) Ae Kipa Spring Water, (b) Ae Pana Spring Water, (c) Woloare Spring Water, (d) Tiwu Kipi Spring Water, (e) River In Km.10, and (f) River In Km. 6

Samples from various wells and Ae Bhoko Spring Water house connection systems have been collected to assess and compare their water quality with the distributed water from Perumda Tirta Kelimutu. All collected samples show a high presence of total coliform and E. coli. The wells in the sampling area are located within residential zones where each house has its well, and residents do not rely on water from Perumda Tirta Kelimutu. Samples of Ae Bhoko Spring Water is situated in Roworena Barat Subdistrict. These wells are susceptible to contamination by total coliform and E. coli due to nearby defecation activities (Naily et al., 2023), while the samples from Ae Bhoko Spring Water might be polluted due to the contamination from the sources. Current conditions of wells of water samplings in Ende are shown in Figure 4 and Location of water sample is overlaid to land use map can be seen in Figure 5.

(a) (b) (c) (d)

Figure 4. Wells of Water Sampling (a) Well in Ipi, (b) Well In Kota Ratu, (c) Well in Tanjung, and (d) Well in Lorong PLTD

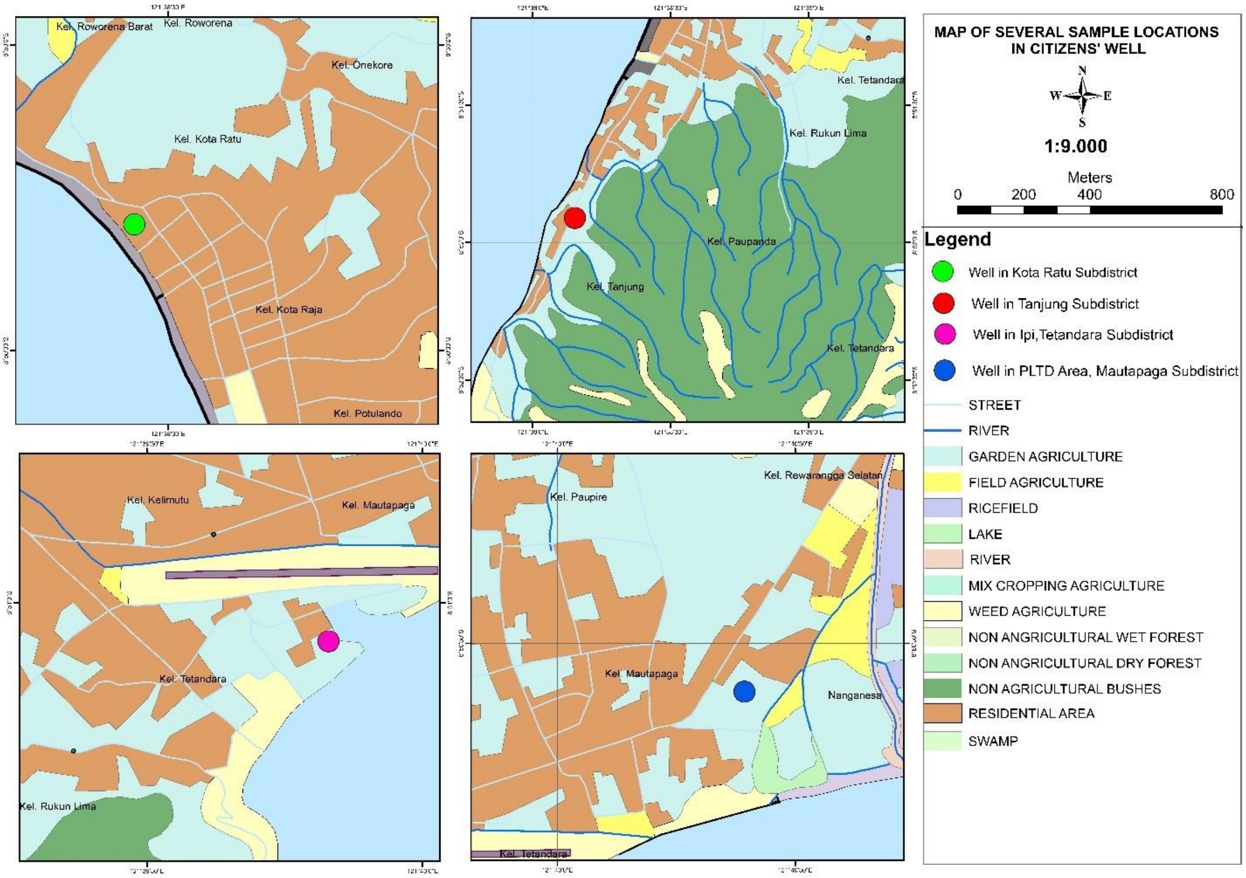


Figure 5. Map of Several Sample Locations in Citizens' Well is Overlaid to Land Use Map
Source: modified from /www.indonesia-geospasial.com/2020/01/shp-rbi-provinsi-nusa-tenggara-timur.html

The data set from Perumda Tirta Kelimutu shows no change in water quality from 2019 to 2022. This suggests that routine water quality testing has yet to yield improvements in the water supply system. In response to these findings, Perumda Tirta Kelimutu must formulate water safety plans to minimize contamination and to ensure the distribution of safe and healthy water to consumers. These water safety plans should encompass risk management strategies within the water utility, including developing a risk register and implementing controls to prevent the occurrence of identified risks (Effendi, 2013; Li et al., 2020; PRAGA & S DJ, 2020; Roeger & Tavares, 2018).

4. Conclusion

None of the water samples meet the microbial parameters, including total coliform and E. coli, as stipulated by the Minister of Health of the Republic of Indonesia Regulation No. 2 of 2023, which defines water quality standards. Several factors contribute to potential water contamination, including human activities in proximity to water sources, the absence of protection for raw water, the presence of debris in the water, leakages, the lack of water treatment plants in the water supply system, insufficient chlorination in water treatment plants, and residences located too close to water sources such as wells. Therefore, Perumda Tirta Kelimutu has to ensure the availability of water treatment plant in each water supply system and develop comprehensive water safety plans to mitigate all potential risks of water contamination. Furthermore, community education and counseling programs on safe water consumption should be implemented to raise awareness and ensure public adherence to safe water practices.

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