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Water Treatment Effectiveness at the Refilling Drinking Water Station in Ternate on Water Quality Based on Physical, Chemical, and Biological Parameters

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ABSTRACT

Safe drinking water is a primary necessity for life. This study aims to evaluate the effectiveness of water treatment at the Refilling Drinking Water Station in Ternate using the non-parametric Man Whitney technique to analyze the difference in water quality before and after treatment. The method used was quantitative descriptive, with data collected from 20 water samples (10 before and 10 after treatment), with parameters tested including physical, chemical, and biological aspects. The results showed that the physical parameters met quality standards. The chemical parameters indicated that Cr(VI) levels in well water exceeded the quality standard, while biological parameters recorded a significant decrease in coliform bacteria and E. coli after treatment. The conclusion of this study suggests that the water treatment at Drinking Water Refill Station Ternate is effective in improving water quality, making it safe for consumption, though more attention is needed regarding the Cr(VI) content, which remains high in some samples.

Keywords: Water, Drinking Water Refill Station, Biology, Physics, Chemistry

INTRODUCTION

Water is a fundamental necessity for life, and good water quality is essential for the sustainability of life (Djana, 2023). This is because drinking water is directly related to biological processes in the human body. Water is used in metabolic processes, nutrient transportation, waste disposal, body temperature regulation, and aids in digestion (Ahmad, 2023; Baiki et al., 2024; Wandrivel et al., 2012). Approximately 70 percent of the human body is water, and about 90 percent of biochemical processes in the body use water as their medium (Ahmad et al., 2023; Lily Mutmainnah et al., 2023). Therefore, water intended for consumption must be free from heavy metals, hazardous chemical compounds, and microorganisms that can cause diseases (Puspitarini & Ismawati, 2022).

The Minister of Health Regulation No. 32 of 2017 on environmental health standards stipulates that drinking water and clean water must meet biological, physical, and chemical parameters (Marhamah et al., 2020). These parameters are set so that biologically, water must be free from harmful microorganisms, such as pathogenic bacteria. Physically, clean water must be odorless, colorless, and tasteless. From a chemical standpoint, water must be free from hazardous chemicals like heavy metals. The importance of water treatment is to eliminate harmful chemicals and microorganisms, making it safe and healthy for consumption (Utami et al., 2020).

Previous research has focused mainly on pathogen detection in water. For example, Wasliyah in Ternate only analyzed the presence of coliform and E. coli bacteria as indicators of fecal contamination, concluding that most refilled drinking water samples still tested positive for these indicator bacteria, indicating contamination during the treatment or distribution process. However, this did not include a comprehensive analysis of the chemical and physical parameters of the water for pathogen detection (Washliyah & Sangadjisowohy, 2023).

Meanwhile, Anwar and Djumati revealed that 30.7% of 8 refilled drinking water Stations surveyed in Ternate were contaminated with coliform bacteria, including Enterobacter and Escherichia coli. Their findings showed that the operational duration of the Stations was not a determining factor for the presence of these bacteria (Anwar & Djumati, 2020). In some regions of Indonesia, such as the study on refilled drinking water from Gunung Salak, Bogor, conducted by Puspitaarini and Ismawati, the results were fairly good due to comprehensive testing on all physical, chemical, and biological parameters. However, there was no clear comparison with Indonesia's national drinking water standards, making it difficult to assess whether the water is truly safe for long-term consumption. Additionally, the study provided few concrete recommendations for improving water quality at refilled drinking water Stations (Puspitarini & Ismawati, 2022). A water quality test of gallon water in Papua conducted by Marhamah et al. on 6 refilled water Stations lacked specific details on which physical, chemical, and microbiological parameters were analyzed (Marhamah et al., 2020). Other studies mainly focused on microbiological parameters (Coliform and E. coli) (Rafika et al., 2022; Wandrivel et al., 2012).

There is a gap in research on the quality of refilled drinking water, especially in terms of the limited scope of parameters analyzed, which predominantly focuses on microbiological quality, a lack of comparison with standards and quality benchmarks, and unclear recommendations. To address these gaps, it is important to conduct comprehensive testing, including heavy metal analysis, by adding the analysis of heavy metals like Cr(VI). To date, this type of research has not been conducted in Ternate. Therefore, the research to determine the effectiveness of Drinking Water Refill Station's water treatment from various water quality parameters is new.

The aim of this study is to evaluate the effectiveness of water treatment at the Refilling Drinking Water Station in Ternate in improving water quality (physical, chemical, and biological parameters) by analyzing the difference in water quality before and after the treatment process using the non-parametric Man Whitney analysis approach. It also aims to identify the presence of Cr(VI) heavy metals in water samples and compare it with the established quality standards.

RESEARCH METHOD

This research is a quantitative descriptive study, which aims to describe the data on the effect of raw water sources on water quality before and after treatment at Drinking Water Refill Station in Ternate.

The sampling method used was purposive sampling, which deliberately selects specific Drinking Water Refill Station samples based on criteria using well water and Local Water Supply Company water from four sub-districts in Ternate City, where there are many gallon refilled water Stations. Water quality testing was conducted before and after treatment. The two water sources reviewed were well water and Local Water Supply Company water. A total of 20 samples were taken from 10 Drinking Water Refill Station, with each Station providing 10 samples - 5 samples before treatment and 5 samples after treatment.

Table 1 shows the equipment and materials used in the examination of the three parameters: physical, chemical, and biological.

Table 1.
Equipment and Materials for Examination and Measurement

Parameter	Equipment and Materials	Function
Physical Parameters	Colorimeter	Test for Color
	Thermometer	Measure temperature
	pH Meter	Measure pH
Chemical Parameters	Spectrophotometer (AAS)	Test for heavy metals (Cr(VI))
	TDS meter	Measure TDS
	Chemical Reagents (citric acid)	Sample preparation for AAS
Biological Parameters	Lactose Broth	Coliform growth medium
	Tergitol 7	Identify E. Coli bacteria
	Petri Dish	Agar medium for bacterial growth
	Microscope	Identify bacterial morphology
	Autoclave	Sterilize culture media
	Chemical Reagents	Biochemical testing

The method for analyzing water quality in this study involves a series of procedures to measure and evaluate the physical, chemical, and biological parameters of water samples. Physical parameters such as temperature, odor, and taste were measured using a colorimeter for color and a thermometer for temperature. Chemical parameters such as heavy metal concentration were measured using spectrophotometry, pH was measured using a pH meter, and TDS (Total Dissolved Solids) was measured using a digital TDS meter.

Biological parameters, such as the number of coliform and E. coli bacteria, were determined through microbiological culture methods using specific growth media and incubation at specific temperatures.

Data processing was performed using statistical approaches, specifically the non-parametric Mann-Whitney method. Data was collected through surveys at 10 Drinking Water Refill Station and experiments conducted at the Hydraulics Laboratory of Universitas Khairun and the Water Quality Laboratory of Institut Teknologi Bandung (ITB). The data analyzed includes chemical and biological parameters. Physical parameters were not analyzed as they generally met the quality standards.

RESULTS AND DISCUSSION

Physical Parameters

The testing of samples was conducted on physical parameters, including odor, taste, color, TDS (Total Dissolved Solids), and temperature. Physical parameter tests were only performed on 4 samples, consisting of 2 samples before treatment by Drinking Water Refill Station and 2 samples after water treatment at Drinking Water Refill Station. Of these 4 samples, 1 sample came from Local Water Supply Company water, and 1 sample came from well water. The results of the sample tests are presented in Table 2.

Table 2.
Results of Physical Parameter Testing

Parameter		Unit	Standard Quality	Local Water Supply Company Water	Well Water
Before Drinking Water Refill Station Processing	Color	TCU	Max. 10	3	5
	Odor	-	Odorless	Odorless	Odorless
	Taste	-	Tasteless	Tasteless	Tasteless
	Temperature	^{0}C	Room Temperature ± 3	24	23
	TDS	mg/L	<300	125	162
After Drinking Water Refill Station Processing	Color	TCU	Max. 50	3	4
	Odor	-	Odorless	Odorless	Odorless
	Taste	-	Tasteless	Tasteless	Tasteless
	Temperature	^{0}C	Room Temperature ± 3	23	22
	TDS	mg/L	<300	120	150

Table 2 indicate that the treated water at Drinking Water Refill Station meets the quality standards according to the Minister of Health Regulation No. 2 of 2023, with an average temperature of 23-24°C and TDS below 200 mg/L.

The average results of the physical tests on refilled water at the Station, specifically regarding odor, taste, and color, were consistent across all samples and in accordance with quality standards found in several studies conducted in Indonesia (Fatimura et al., 2021; Hanin & Pratiwi, 2017; Toalu et al., 2023). Temperature in several studies of Drinking Water Refill Station water ranged from 24-25°C, depending on the geographical conditions of the area, and TDS ranged from 5 to 30 mg/L. All values generally met the quality standards (Islam et al., 2010; Olofinlade et al., 2018; Ravikumar et al., 2013).

The absence of taste, odor, and color in the water indicates that it is free from contaminants such as iron, tannins, and humic acids, which can cause a yellowish color resembling urine (Moeinzadeh et al., 2023; Ronald & Warwuru, 2023). The lack of color also suggests the absence of plankton and humus, which serve as bioindicators of pollution (Kong et al., 2024). The neutral taste of the water suggests that it is free from harmful contaminants (Shomar & Hawari, 2017). TDS in well water is higher compared to Local Water Supply Company water because Local Water Supply Company water is treated beforehand. The higher TDS in well water indicates the presence of dissolved inorganic salts, such as Sodium (Na^{+}), Sulfate (SO_4^{2-}), Chloride (Cl^{-}), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), and some heavy metals (Markus et al., 2022). Additionally, the TDS levels suggest the presence of small amounts of organic substances, such as proteins. The higher TDS in well water is likely due to seawater intrusion, as the well is located near the sea (Idowu & Lasisi, 2020). Seawater intrusion affects soil composition and the concentration of dissolved particles in water, thus increasing TDS (Hossain et al., 2024). Meanwhile, the temperature was not high because the sample was taken in the morning when the ambient temperature was still within the quality standard range (Xu et al., 2008).

Chemical Parameters

The chemical testing of water samples included the examination of pH and hexavalent chromium (Cr(VI)). A total of 10 samples were taken before the treatment process at Drinking Water Refill Station and 10 samples after the treatment. Among these 10 samples, 5 samples were from well water and 5 samples were from Local Water Supply Company water. Table 3 shows the results of the chemical parameter tests.

Table 3.
Results of Chemical Parameter Testing

Water Source	Cr (VI)		pH	
	1*	2*	1*	2*
Well Water	0.02	0.001	6.1	7.3
	0.03	0.002	6.4	7.3
	0.04	0.001	6.3	7.2
	0.02	0.002	6.2	7.2
	0.04	0.001	6.1	6.9
Local Water Supply Company Water	0.001	0.0002	7.2	7.4
	0.001	0.0001	6.8	7.3
	0.002	0.0003	7.1	7.3
	0.001	0.0001	6.7	7.1
	0.001	0.0001	6.8	7.2

Note :
1* : Before processing by Drinking Water Refill Station
2* : After processing by Drinking Water Refill Station

Table 3 shows that the average pH of well water tends to be acidic, and the hexavalent chromium (Cr(VI)) concentration was higher before treatment. The examination of these two parameters in some well water samples exceeded the quality standards. The quality standard for pH is 6.5 – 8.5, and the maximum allowable concentration of Cr(VI) is 0.01 mg/L. In the well water samples, the pH was 6.3 in sample 3, 6.2 in sample 4, and 6.1 in sample 5. Water with a pH lower than 6.5 is considered corrosive and can be toxic if consumed.

The study results showed that the pH of treated drinking water was within the range of 7 to 7.3, whereas untreated Local Water Supply Company water had a pH ranging from 6.8 to 7.5, as it had already undergone treatment before distribution (Loganathan et al., 2013; Plappally & Lienhard V, 2012; Zhang & Lampe, 1999). Water with a pH lower than 6.5 can cause heavy metals to dissolve (Chowdhury et al., 2016).

The hexavalent chromium (Cr(VI)) concentrations in well water samples on average did not meet the quality standards. This was also observed in several other studies, where Cr(VI) concentrations in well water exceeded 0.01 mg/L (Astuti et al., 2021). A study of several wells in Manokwari, Papua, found Cr(VI) concentrations of 0.085 mg/L (Marhamah et al., 2020). The presence of chromium is influenced by anthropogenic activities such as industrial processes and household waste (Prasad et al., 2021). Cr(VI) formation is believed to be influenced by the ultra-low oxidation levels in minerals within aquifers, which generate high levels of Cr(VI) in water, compounded by anthropogenic activity from domestic waste spills (Charizopoulos et al., 2018).

Consuming well water with high concentrations of Cr(VI) can lead to irritation and cancer, as it is carcinogenic (Den Braver-Sewradj et al., 2021). Regular consumption of Cr(VI)-contaminated water can trigger various chronic diseases. This heavy metal can damage DNA and disrupt the function of body cells (Bertin & Averbeck, 2006). Cr(VI) can affect the reproductive system in both men and women, increasing the risk of infertility and birth defects (Shobana et al., 2017). In addition to harming human health, Cr(VI) contamination also threatens the survival of ecosystems. This heavy metal can accumulate in the soil and sediments, contaminate the food chain, and kill various aquatic organisms. Consequently, the quality of surface and groundwater around pollution sources will significantly degrade (Peralta-Videa et al., 2009).

Addressing Cr(VI) contamination in well water requires comprehensive and sustainable efforts (Djellabi et al., 2022). Some mitigation measures include routine testing of well water quality to monitor Cr(VI) levels and other contaminants. This is important to detect any increase in Cr(VI) levels early and take immediate action. If the concentration exceeds the safe limit, water treatment becomes a crucial step (Monga et al., 2022). Some treatment methods that can be used include adsorption with adsorbent materials like activated carbon to absorb Cr(VI) (Wang et al., 2020), precipitation techniques by adding specific chemicals to precipitate Cr(VI) from water (Xie et al., 2017), and ion exchange using ion-exchange resins to remove Cr(VI) ions from water. Additionally, membrane technologies such as reverse osmosis can be used to filter water (Kerur et al., 2021).

Another mitigation strategy is to prevent industrial waste containing Cr(VI) from entering the environment and work with local governments to develop stricter policies and regulations regarding the management of hazardous waste and the protection of water resources (Rada et al., 2021).

Biological Parameters

Microorganism testing was conducted on 20 water samples, comprising 10 samples before treatment and 10 samples after treatment by Drinking Water Refill Station. Each set consisted of 5 Local Water Supply Company water samples and 5 well water samples. The biological testing was carried out through coliform and E. coli examinations. The results of these tests are shown in Table 4.

Table 4

Results of Biological Parameter Testing

Water Source	No.	Coliform (MPN/100 mL)		EColi (MPN/100 mL)	
		Coliform 1*	Coliform 2*	Ecoli 1*	EColi 2*
Well Water	1	20	0	45	12
	2	27	23	35	16
	3	26	12	60	14
	4	29	20	26	18
	5	30	4	37	13
Local Water Supply Company Water	6	21	10	34	12
	7	18	0	25	9
	8	15	6	21	10
	9	18	5	25	11
	10	19	0	26	9

Note :
1* : Before processing by Drinking Water Refill Station
2* : After processing by Drinking Water Refill Station

Table 4 shows that the number of bacteria exceeds the quality standard. The quality standard for bacteria count should be 0 MPN/100 mL. In some Local Water Supply Company water samples, no coliform bacteria were found. Generally, the number of coliform and E. coli bacteria in well water is higher compared to the source water from Local Water Supply Company. The higher bacterial count in well water is due to the lack of initial treatment for well water. On the other hand, Local Water Supply Company water has undergone treatment processes like filtration, chlorination, disinfection, and sedimentation, which effectively remove most of the bacteria.

A 2020 study by the Ministry of Health revealed concerning figures: 74.4% of households in Indonesia rely on drinking water contaminated with Escherichia coli bacteria (Wirachandra et al., 2024). On average, coliform and E. coli bacteria found in well water were higher compared to Local Water Supply Company water. In well water, the average count was over 30 MPN/100 mL, while Local Water Supply Company water averaged below 20 MPN due to prior treatment (Marsono et al., 2022). A study in Maulafa Kupang found that the highest contamination of Escherichia coli and Enterobacter in well water was 6 MPN/100 mL, while the lowest was 4 MPN/100 mL (Pakpahan et al., 2015).

The high content of coliform and E. coli bacteria is believed to be due to some wells being located near septic tanks (Pang et al., 2004). The distance between the well and the septic tank also influences the number of coliform and E. coli bacteria found (Xiang et al., 2019a). The presence of E. coli and coliform bacteria in Drinking Water Refill Station equipment in Ternate is likely due to poor hygiene practices of the equipment. This is consistent with other research, which found that high levels of E. coli and coliform bacteria are commonly associated with equipment and water treatment tools that are not properly maintained or cleaned (Xiang et al., 2019b).

Analysis of the Impact of Drinking Water Refill Station

Statistical tests were performed to examine the influence or difference in water treatment at Drinking Water Refill Station on chemical and biological parameters. The test used to assess this impact was the Mann-Whitney analysis, as the data were categorical and non-parametric (Fagerland et al., 2011). The categorical data used in the Mann-Whitney analysis was based on the numeric value of 1 for water before being treated at Drinking Water Refill Station and 2 for water after being treated at Drinking Water Refill Station. These numbers served as the data to evaluate their impact on the chemical and biological parameters. Table 5 provides an example of the data for pH and the corresponding category:

Table 5.
pH Data and Categories

pH	Before/After Water Treatment
6.1	1
6.4	1
6.3	1
6.2	1
6.1	1
7.3	2
7.3	2
7.2	2
7.2	2
6.9	2

In addition to determining the effect of the water treatment process at Drinking Water Refill Station on the pH parameter, an impact test was also conducted on Cr(VI), coliform bacteria, and E. coli. The analysis was conducted to assess the effect before and after water treatment at Drinking Water Refill Station on the chemical parameters, namely pH and Cr (VI), as well as biological parameters (coliform and E. coli). A hypothesis approach is required in this case, where there are two hypotheses: first, H0, which assumes no effect, and second, H1, which suggests the presence of an effect of water treatment on the chemical and biological parameters. The results of this impact test, based on Mann Whitney analysis, are shown in Table 5:

Table5
Mann-Whitney Test Results

Parameter	Asymp. Significance	Conclusion
pH	0.001	H1 Accepted
Coliform	0.003	H1 Accepted
E-coli	0.001	H1 Accepted
Cr (VI)	0.007	H1 Accepted

Table 5 shows that the significance value (Asymp. Significance) for each parameter is below 0.05, so H0 is rejected and H1 is accepted. The result indicates that H0 is rejected. This shows a significant effect of the Drinking Water Refill Station water treatment process in Ternate on the quality of the resulting water. The water treatment used in some Drinking Water Refill Station facilities in Ternate combines reverse osmosis and ultrafiltration technologies, which affect the quality of the water produced.

This aligns with findings from previous studies that show this combination of membrane technology is capable of removing various contaminants, including bacteria, viruses, and suspended particles, with a high level of efficiency (Goswami & Pugazhenthi, 2020). The reverse osmosis process works by forcing water through a very tight semi-permeable membrane, allowing only pure water molecules to pass through (Qasim et al., 2019).

Meanwhile, ultrafiltration uses a membrane with larger pores to filter out larger particles, such as bacteria and viruses. The combination of these two technologies provides double protection against microbiological and chemical contamination (Alam et al., 2021). Several studies have shown that the combined system is not only effective in removing pathogenic microorganisms but also in reducing concentrations of harmful organic and inorganic compounds in water (Hlongwane et al., 2019). Furthermore, the synergistic application of reverse osmosis and ultrafiltration can increase the removal of heavy metals by up to 95% (Koli & Singh, 2023). Additionally, research has revealed that this combination is capable of producing water that meets the standards set by the WHO, making it a promising solution for providing clean water in areas affected by severe water pollution (Zamora-Ledezma et al., 2021). Therefore, integrating membrane technologies like these is not only important to ensure the availability of clean water but also contributes to environmental sustainability by minimizing the discharge of hazardous waste into water resources (Surchi, 2011). With further innovations in membrane design and materials, the efficiency and durability of these systems are expected to continue improving, providing a greater positive impact on global water resource management.

The results of this study also show that the water quality produced by Drinking Water Refill Station in Ternate varies depending on several factors, including the condition of the source water used for treatment, which significantly affects the final water quality (Delpla et al., 2009). Source water that has been contaminated with various pollutants will be more difficult to treat into drinking water that meets the standards (Van Der Bruggen & Vandecasteele, 2003).

Moreover, the maintenance of equipment, especially the membranes, is highly influenced by routine care and maintenance. Damage or clogging of the membranes can reduce treatment efficiency and cause a decline in water quality (Dong et al., 2022). The findings of this study have significant implications for efforts to improve drinking water quality in Ternate.

CONCLUSION

The conclusion of this study is that water treatment using reverse osmosis and UV technologies is effective in reducing coliform and E. coli levels in most samples, but the Cr(VI) parameter still requires further treatment. The analysis shows that after treatment, there was a significant reduction, indicating that the treatment process successfully reduced microbiological contamination and other pollutants. The water quality, as seen in the chemical and biological parameters of the source water from wells, mostly does not meet the standard, while water from Local Water Supply Company shows many samples meeting the standards. However, the Drinking Water Refill Station can reduce pollution levels in both the chemical and biological parameters of these two water sources, making the Drinking Water Refill Station in Ternate quite effective and efficient.

RECOMMENDATIONS

There needs to be tighter supervision of the drinking water quality produced by Drinking Water Refill Station in Ternate, including regular checks of physical, chemical, and microbiological parameters. Clear and detailed Standard Operating Procedures (SOP) should be developed for each stage of the water treatment process, from raw water collection to distribution to consumers. Further research is needed to identify other factors that can affect drinking water quality in Ternate and to evaluate the effectiveness of various water treatment technologies available. A limitation of this study is that not all chemical parameters were reviewed. This study only tested pH and the heavy metal Cr (VI), so future studies should include tests for mercury, arsenic, lead, cadmium, and nickel. Additionally, the small sample size in this study does not represent all Drinking Water Refill Station facilities across the city of Ternate. Future researchers should take more samples to better represent the quality of Drinking Water Refill Station in Ternate City.

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