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Chemicals Analysis of Drilled Ground Waters in Moa Island, Maluku, Indonesia

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Abstract—Moa Island is one of the remote Indonesian Islands that face the difficulty in accessing clean water, especially during the dry season. One way to get clean water is by drilling for groundwater. The drilled groundwater in Kaiwatu Village on Moa Island, Southwest Maluku Regency, Maluku Province, was analyzed for its content to obtain primary data. Primary data related to the quality of drilled groundwater sources includes chemical, physical, and microbiological parameters. The results of chemical parameters obtained from the test results were <0.01 mg/L fluoride, total chromium, nitrite, nitrate, iron, manganese, zinc, cyanide, lead, <0.001 mg/L cadmium, 17.9 mg/L hardness, sulfate 147.55 mg/L, pH 7.50, and organic substances 2.8 mg/L. The physical parameter analysis showed a turbidity level of 3.71 NTU, a temperature of 26.8 °C, and a color of 5 TCU. The microbiological parameters obtained by the analysis were 0/100 mL. Primary data was then compared with secondary data, namely environmental health quality standards and air health requirements from Minister of Health Regulation No. 32 of 2017 for chemical and physical parameters, as well as water quality requirements and monitoring from Minister of Health Regulation 416/MENKES/IX/1990 for microbiological parameters. The analysis results using a comparison of primary and secondary data showed that all parameters contained in the primary data had values below the safe limits set by the requirements in the secondary data.

Keywords— *Chemical parameters, Drilled ground water, Microbiological parameters, Physical parameters.*

1. INTRODUCTION

Clean water is an essential element for life. Every human being has the right to access clean and safe water for various purposes, such as household, industrial, sanitation, irrigation, etc. [1]. Sources of clean water come from the earth's surface (rivers, lakes, and seas), the ground, and the air [2]. The need for clean water increases annually and is triggered by increasing population growth [3].

Moa Island is a remote island located in the Southwest Maluku Regency, Maluku Province, Indonesia. Like other areas, the population on Moa Island also increases annually, namely 16.294 people in 2020. Most of the people of Moa Island access clean water from retention basins, wells, refill water, tap water, and naturally drilled groundwater. However, population growth is not in line with the availability of water sources. The number of accessible wells on Moa Island has decreased, from 8 wells in 2014 to 3 wells in 2020 [4].

The people of Moa Island are also struggling with a long dry season from April to October. The long dry season causes the dryness on Moa Island. Therefore, clean water is difficult to access during the dry season [5]. The long dry season affects not only humans but also the agricultural sector on Moa Island. It is reported that during the dry season of 2022, thousands of buffalo cattle on Moa Island died. It is such an irony because the buffalo cattle of Moa Island are the indigenous livestock of Moa Island [6].

A local drinking water company draws water from locally drilled groundwater to provide clean water, but the water is only enough to meet the community's

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needs. Water requirements for livestock and agriculture are obtained usually by collecting rainwater in natural reservoirs. The prolonged dry season makes the natural reservoirs dry, so many livestock die because they do not get enough water [6].

Several attempts have been made by local and national institutions to drill wells searching for groundwater on Moa Island. However, the water obtained is brackish, so residents cannot use it. Before drilling a well, the geoelectrical method is conducted to determine the potential groundwater location, including the prediction of the water debit. The geoelectric method is a geophysical method for estimating subsurface geological conditions, especially the types and properties of rocks based on the electrical properties of rocks. From the data on the electrical properties of rocks in the form of resistivity, each is submitted and processed by also considering existing data on local geological conditions. Measuring the magnitude of the resistivity of rocks below the ground surface using the Schlumberger Vertical Electrical Sounding (VES) method aims to determine variations in the arrangement of underground rock layers vertically, namely by providing an electric current into the ground and recording the potential difference [7].

Table 1. Chemical, physical, and microbiological parameters of water sample analysis

No		Parameters	Method
1	Chemicals	Fluoride	Alizarin
2		Total Chromium	IKM/5.3/BLKKAK-Promal
3		Cadmium	IKM/5.4/BLKKAK-Promal
4		Nitrite	IKM/5.5/BLKKAK-Promal
5		Nitrate	Brusin
6		Cyanide	Calorimetry
7		Iron	IKM/5.6/BLKKAK-Promal
8		Hardness	IKM/5.7/BLKKAK-Promal
9		Manganase	IKM/5.8/BLKKAK-Promal
10		pH	IKM/5.9/BLKKAK-Promal
11		Zinc	IKM/5.10/BLKKAK-Promal
12		Sulfate	IKM/5.11/BLKKAK-Promal
13		Lead	IKM/5.12/BLKKAK-Promal
14		Organic Compound	Titrimetry
1	Physics	Turbidity	IKM/5.1/BLKKAK Promal
2		Temperature	Expansion with a thermometer
3		Color	Spectrophotometry
1	Micro-biology	Total Coliforms	IKM/5.19/BLKKAK-Promal

The geoelectric method generally uses subsurface electric potential fields as the main observation object (including measurements of potential, currents, and electromagnetic fields), which occur either naturally or as a result of current injection into the earth, and the geoelectric method is a simple method for determining groundwater. Based on geoelectrical analysis, several points have the potential to have groundwater sources. One of them is in Kaiwatu Village. Kaiwatu Village is a densely populated area on Moa Island, close to hilly areas and livestock grazing areas. This point is a top priority in drilling because the water obtained is not only used for the community but can also be used for livestock.

Before being distributed to the people, dried well water is sent to the laboratory to check the water quality. The chemical, physical, and microbiological parameters of the water sample analysis was presented in **Table 1.** The water quality is crucial because it is very essential for life. The water quality analysis parameters are divided into three groups, namely chemical parameters (pH, electrical conductivity, nitrate, sulfate, potassium, chlorineide, sodium, magnesium, and calcium), physical parameters (color, total dissolved solids (TDS) and turbidity), and microbiological parameters [7]. According to the regulation of the Republic of Indonesia's Minister of Health No. 429/Menkes/per/IV/2010, regarding requirements and supervision of water quality, good water has no taste, no color, and no smell, in terms of chemical and physical parameters [9, 10].

2. EXPERIMENTAL SECTION

2.1. Instrumentations

Digital Water Quality Measuring Instrument pH ORP TDS EC Temp 5 in 1, bottle, lucifer, Atomic Absorption Spectrophotometer in the Laboratory Analysis was carried out at the Health Service, Maluku Provincial Health Laboratory.

2.2. Sampling and Data Collection

The research was conducted at a groundwater drilling location in Kaiwatu Village, Moa Island, Southwest Maluku Regency, Maluku Province. Before carrying out the drilling process, the drilled groundwater point was determined using a geoelectric survey that applied the Schlumberger Vertical Electrical Sounding (VES) method. After the source of the drilled groundwater was identified, a drilling process was carried out 50 m deep underground. Laboratory analysis was carried out at the Health Service, Maluku Provincial Health Laboratory, and the Medical Equipment Calibration Center, and sample collection was carried out on January 18, 2023.

Data collected for research includes primary and secondary data. Primary data related to the quality of drilled groundwater sources, which is the focus of the research are chemical parameters, including fluoride, total chromium, nitrite, nitrate, iron, cyanide manganese, zinc, lead, cadmium, hardness, sulfate, organic substances, and pH. Meanwhile, data support includes physical parameters, including turbidity, color, and temperature, as well as microbiological parameters, namely total coliforms.

Water sample analysis used several methods according to the analysis purpose, including chemical, physical, and microbiological parameters. The methods used are shown in **Table 1**.

Primary data was obtained through several stages, including the field observation process, sampling at groundwater drilling locations, and laboratory analysis. Secondary data was obtained through literature studies on environmental health quality standards and water health requirements from Minister of Health Regulation No. 32 of 2017 and Requirements and Water Quality Monitoring from Minister of Health Regulation 416/MENKES/IX/1990.

3. RESULT AND DISCUSSION

Clean water quality analysis aims to evaluate the suitability of water to quality standards determined based on its class. Natural drilled groundwater sources are categorized as class I, indicating a very high water purity level. Water quality analysis was conducted at drilling drilled groundwater in the Kaiwatu Village, Southwest Maluku, covering several physical, chemical, and microbiological parameters. The chemical parameters observed include fluoride, total chromium, cadmium, nitrite, nitrate, cyanide, iron, hardness, manganase, zinc, sulfate, lead, organic substances, and pH. The physical parameters observed include turbidity, temperature, and color. Meanwhile, the microbiological parameter observed was total coliform.

Data obtained from the analysis of physical and chemical parameters was compared with the quality standards regulated in Minister of Health Regulation No. 32 of 2017. This standard shows the maximum limits groundwater must meet regarding physical and chemical parameters. Meanwhile, microbiological parameters were compared with Minister of Health Regulation No.416/Menkes/Per/IX/1990. This standard relates to the level of contamination by microorganisms in water and is a reference in assessing the safety of water for consumption by living creatures.

The analysis results produce an overview of the water sources in Kaiwatu Village in meeting the established water quality standards. Analysis results that meet standards were then classified as safe and of good quality for use in everyday life.

3.1. Chemical Parameter

The results of research and monitoring of drilling groundwater chemical parameters on Moa Island are shown in Table 2.

Table 2. Results of chemical quality analysis of Moa island drilled groundwater sources

No	Parameters	Units	Allowable levels	Results
1	Fluoride	mg/L	1.5	< 0.01
2	Total Chromium	mg/L	0.05	< 0.01
3	Cadmium	mg/L	0.005	< 0.001
4	Nitrite	mg/L	1	< 0.01
5	Nitrate	mg/L	10	< 0.01
6	Cyanide	mg/L	0.1	< 0.01
7	Iron	mg/L	1	< 0.01
8	Hardness	mg/L	500	77.9
9	Manganase	mg/L	0.5	< 0.01
10	Zinc	mg/L	15	< 0.01
11	Sulfate	mg/L	400	147.55
12	Lead	mg/L	0.05	< 0.01
13	Organic Compound	mg/L	10	2.8
14	pH	-	6.5-8.5	7.5

Based on **Table 2**, the chemical quality of the drilled groundwater from drilling results on Moa Island shows that the water samples meet environmental health requirements based on Minister of Health Regulation No. 32 of 2017. The chemical parameters, namely fluoride, total chromium, nitrite, nitrate, iron, manganese, zinc, sulfate, chloride, and lead, have very small or close to undetectable levels. However, several chemical parameters exceed the previous parameters, such as hardness, sulphate, organic compounds, and pH. This is the concern and topic of discussion that will be discussed in the chemical parameters sub-chapter. The data resulting from the chemical parameter analysis is then presented in diagram form, aiming to make it easier to analyze the data.

The resulting diagram (**Fig. 1**) shows comparative data from the water sample analysis results with class I water quality standards based on Permankes No. 32 of 2017. A comparison of these data shows that the water condition meets the standards for various chemical parameters, namely hardness, sulfate, organic substances, and pH that are below the water quality standards according to their intended use.

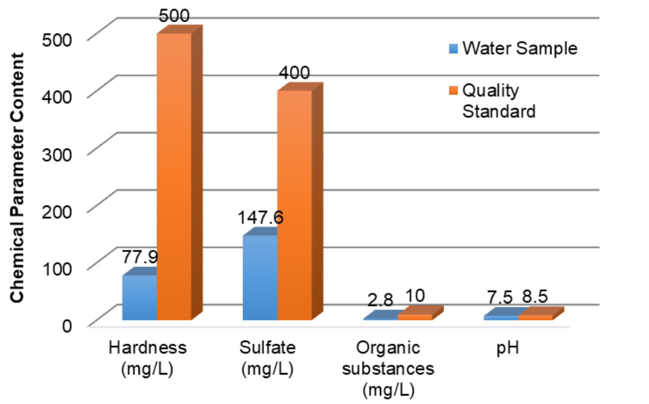

Fig. 1 Chemical parameter monitoring result

The results of the hardness analysis show data of 17.9 mg/L, which is still within the water quality standards. Data shows that the mineral content of calcium (Ca) and magnesium (Mg) in drilled groundwater sources are minerals that can influence the level of hardness in drilled groundwater sources. The drilling process carried out in the Kaiwatu Village did not significantly affect the cation mineral content in the soil. Hardness does not directly impact health but can cause problems in the economic sector. This is indicated by a high hardness, making it difficult for detergent to dissolve in water [11].

$$CaCl_{2(aq)} + 2NH_4OH_{(aq)} \rightarrow Ca(OH)_{2(aq)} + 2NH_4Cl_{(aq)} \quad (1)$$

Meanwhile, if calcium is reacted with dilute sulfuric acid (H_2SO_4), it produces a white $CaSO_4$ precipitate. The precipitate formed is difficult to dissolve in acidic conditions. However, when it interacts with water it dissolves more easily. The reaction is shown in eq (2).

$$CaCl_{2(aq)} + H_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + 2HCl_{(aq)} \quad (2)$$

In addition to calcium, a mineral that influences water hardness conditions is magnesium. Magnesium has almost the same tendency when reacting with a chemical compound such as water. When magnesium reacts with sodium hydroxide (NaOH), a white precipitate will form. The white precipitate factor is formed because magnesium forms bivalent cation (Mg^{2+}) hydroxide oxide. The reaction is shown in eq. (3).

$$Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \rightleftarrows Mg(OH)_{2\,(s)} \quad (3)$$

The high level of hardness in air sources is affected by many factors, one of which is that air sources can be contaminated by outer space air or surface air trapped in the ground. This water source carries various types of metals that can increase the hardness level, namely calcium and magnesium. The content of metal elements pollutes the air in the soil, causing the air from the soil to contain high amounts of calcium. [12].

Sulfate is one of the chemical parameters analyzed from drilled groundwater sources. The sulfate analysis method is that the sulfate ions formed are precipitated with $BaCl_2$ under acidic conditions to produce a white precipitate in the form of $BaSO_4$ crystals, as shown in eq. (4).

$$SO_4^{2-}{}_{(aq)} + BaCl_{2\,(aq)} \rightarrow BaSO_{4(s)} + 2Cl^-_{(aq)} \quad (4)$$

The sulfate content in the analyzed drilled groundwater showed results below standard quality standards. Thus, this indicates the water source is suitable for consumption. The sulfate content above the quality standard can change the physical properties of the water, such as the taste of the water becoming bitter, and can cause side effects. Higher sulfate levels in water can cause laxative disease or diarrhea [12].

In addition, another chemical parameter is pH. The data obtained from the pH analysis results was 7.5. This result indicates that this parameter meets water quality standards. A pH value that does not comply with standards can affect the taste of water; it can also impact health. The analysis of organic substances parameter showed that the parameter was within the quality standard range. $KMnO_4$ is a chemical compound that can oxidize organic substances in air sources by heating in an acidic atmosphere. Excess oxalic acid is used as a way to reduce residual $KMnO_4$, and $KMnO_4$ is used as a titration medium to overcome excess oxalic acid [14]. The reaction is shown in eq. (5).

$$MnO_4^-{}_{(aq)} + 8H^+_{(aq)} + 5e \rightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)} \quad (5)$$

Excessive organic substance content can affect the physical condition of water, such as changes in color, smell, and taste, as well as severe impacts caused by toxic water content [15].

The results of chemical parameter measurements showed that fluoride, total chromium, chloride nitrite, nitrate, iron, manganese, zinc, cyanide, lead, hardness, sulfate, pH, and organic compounds were below the safe limits set by the Indonesian Minister of Health Regulation No. 32 of 2017. These results indicate that the water analyzed with the observed parameters is not harmful to the environment and does not cause side effects when consumed by living creatures. The results of chemical parameter measurements showed that the values for fluoride, total chromium, chloride nitrite, nitrate, iron, manganese, zinc, cyanide, lead, hardness, sulfate, pH, and organic compounds were below the safe limits set by the Indonesian Minister of Health Regulation No. 32 of 2017.

3.2. Physical Parameter

The results of research and monitoring of the physical parameters of the drilled groundwater sources were observed to show a turbidity level of 3.71 NTU, a temperature of 26.8 °C, and a color of 5 TCU, then the data obtained was compared with the applicable regulations. According to Minister of Health Regulation No. 32 of 2017, the safe limits for physical parameters (turbidity, temperature, and color) for each parameter are 25 NTU, 30 °C, and 50 TCU.

Comparison of the results of water sample analysis with class I water quality standards based on Permankes No. 32 of 2017 (**Fig. 2**) shows that the condition of the water that comes from it meets quality standards, indicated by the diagrams produced for various physical parameters: temperature, turbidity, and color, which are below the required quality standards. Physical parameters are essential in assessing the quality of clean water that can be consumed, and physical parameter testing can be carried out visually and using analysis in the laboratory.

The results of the turbidity parameter analysis showed a value of 3.71 NTU. This value is below the standard quality standard. Turbidity parameters can be observed using visual methods because light absorption affects the quality of clarity. The quality of clarity is influenced by the number of physical or chemical particles in the water and causes light dispersion. The turbidity of the water analyzed is affected by other factors, namely perfectly suspended organic or inorganic compounds. High turbidity levels can indicate the presence of unwanted particles in the water, such as mud, sediment, organic particles, or dissolved materials [16].

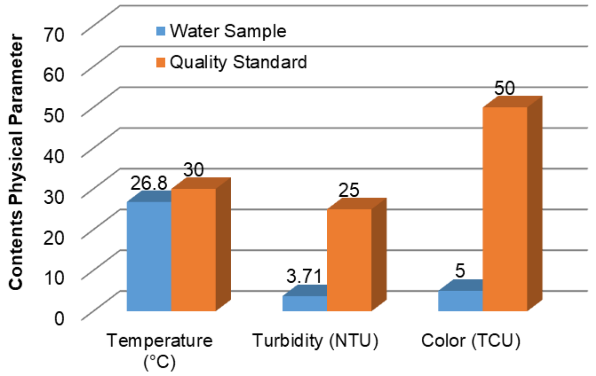

Fig. 2 Physical parameter monitoring result

Physical parameters, namely color, were measured using the TCU (True Color Unit) scale. These results obtained from the analysis were 5 TCU. This results indicate that the water quality meets quality standards. Color is a parameter that can be measured using various methods, including visual and laboratory analysis methods. In this case, the visual method is the initial approach in evaluating the color of the water, then reinforced with laboratory analysis results [17,18].

The measurement results show that the value is below the safe limit set by the Indonesian Minister of Health Regulation No. 32 of 2017. Thus, the drilled groundwater in the Kaiwatu Village has a quality that meets standards for physical parameters. The analysis results show that the water is clear (low turbidity), the temperature is within normal limits, and the color follows established standards. Therefore, it is safe for various purposes, including consumption by living creatures.

3.3. Microbiological Parameters

Microbiological parameters are one of the parameters that serve as a reference in determining water quality. The microbiological parameter commonly analyzed is total coliform, where the total coliform measured comes from drilled groundwater in the Kaiwatu Village due to drilling.

Comparison of the water sample analysis results with class I quality standards based on Minister of Health Regulation 416/MENKES/IX/1990 (**Fig. 3**) shows the results of water sample analysis on microbiological parameters, resulting in total coliform data of 0/100 mL. The analysis results show that the total coliform content in the water samples is below the maximum limit regulated in the relevant regulations. Based on applicable quality standards, the maximum limit for total coliform content in clean water is 50 total coliforms per 100 mL of water. The results showed that no total coliforms were detected in the water samples.

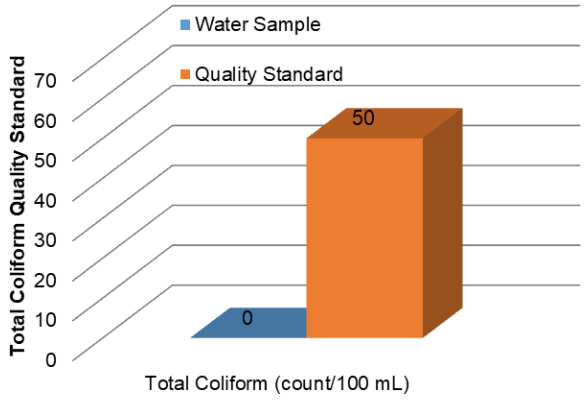

Fig. 3 Microbiological parameter monitoring result

Water samples were obtained from drilled groundwater originating from the ground. The samples studied have an advantage because they tend to be purer and avoid factors that can increase the total coliform content. Environmental conditions surrounding sampling, which are accessible from factories or livestock sites and are close to forests, also contribute to the high level of water purity. The analysis results of the total absence of coliforms in the water sample indicate that the water meets safety standards following applicable regulations.

Total coliform is a group of gram-negative bacteria that indicate dirt pollution and poor water conditions. It is initially from fecal origin, and some are isolated from the environment. The presence of coliform bacteria in the water indicates that the water has been contaminated with enteropathogenic or toxigenic microbes that are harmful to health [19,20].

CONCLUSION

Based on the compared test results for the content of physical, chemical, and microbiological parameters in drilled groundwater in the Kaiwatu Village, Moa Island, Southwest Maluku Regency, Maluku Province, with applicable regulations, it can be concluded that the quality of water samples included chemical parameters, namely fluoride, total chromium, chloride nitrite, nitrate, iron, manganese, zinc, cyanide, lead, hardness, sulfate, pH, and organic substances, which meet the quality standard requirements according to the Minister of Health Regulation No. 32 of 2017. The quality of water samples included physical parameters, namely temperature, turbidity, and color meeting the quality standard requirements according to the Minister of Health Regulation No. 32 of 2017. The quality of water samples through microbiological parameters, namely total coliforms, met the quality standard requirements according to the Minister of Health Regulation 416/MENKES/Per/IX/1990. From the result, the drilled ground waters meet water health requirements for sanitation hygiene purposes.

SUPPORTING INFORMATION

There is no supporting information of this paper. The data that support the findings of this research are available on request from the corresponding author (MSNP).

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CONFLICT OF INTEREST

All authors have no conflicts of interest to declare regarding this research.

AUTHOR CONTRIBUTIONS

MSNP & APS were conducted the experiment. MSNP & NSPH were wrote and revised the manuscript. All authors agreed to the final version of this manuscript.

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