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Research Article

Water Pollution Index: Measurement of Shallow Well Water Quality in Urban Areas

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Abstract: Determination of water quality status based on the pollution index method. Water said to polluted if it cannot use according to its standard designation. The purpose of this research is to identify and find out the level of pollution contained in shallow well water used by communities in urban areas. Water quality index measurements using the Storet Method. This study uses ten samples with techniques Purposive random sampling with well water sources used by people in Makassar, especially in Untia Sub-District, Makassar, South Sulawesi. The number of samples used was 15 water samples taken each week with a total of 10 shallow well water sample points. The parameters measured in the study are Iron (Fe), Manganese (Mn), Total Coliforms, Total Dissolved Solids (TDS). The results of the study showed that the condition of shallow well water quality classified in category D, which heavily polluted which means it not recommended to use before filtering. The increase in parameters that have exceeded the maximum quality standard comes from natural sources and high domestic waste from community activities. Water pollution is a condition in which a water reservoir changes due to human activity — the change caused by the entry of substances that should not be in the water.

Keywords: Fresh Water, Groundwater, Iron (Fe), Manganese, Total Coliforms, Total Dissolved Solids.

1. Introduction

Groundwater is the largest source of fresh water on planet Earth, accounting for approximately 30 percent of total freshwater or 10.5 million km cubic [1]. Groundwater is one of the primary sources of water supply in most countries [2]. Lately, the use of groundwater has increased rapidly, even in some places where exploitation has reached dangerous levels. Groundwater usually is taken, both for clean water sources and irrigation [3]. According to WHO [4], calculations in developed countries, each person needs water between 60-120 liters per day. Whereas in developing countries, including Indonesia, each person needs between 30-60 liters of water per day. Among the essential uses of water is the need to drink (including for cooking) water must have unique requirements so that the water does not cause disease to humans.

The main problems faced by water resources include the quantity of water that has been unable to meet the needs that continue to increase, and the quality of water for domestic needs is declining. Industrial, domestic, and other activities, harm water resources, including causing a decrease in water quality. This condition can cause disturbance, damage, and danger to all living things that depend on these water resources.

Groundwater is water that moves in the soil contained in the spaces between the grains of soil that form it and in rock cracks. Groundwater found in permeable geological formations, usually known as aquifers, which are water-binding formations that allow water to move through them in large enough quantities. The glacial sand and gravel deposits, alluvial fans of flood plains and sand delta

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deposits are all excellent sources of water. In an aquifer, groundwater occupies rock holes known as pores, fractures, or large holes [5].

As one of the natural resources which are the source of life for all living things on this earth, no one can deny that water is a crucial element in human life, not only for consumption, the need for water also supports many human activities. Water is a natural resource needed for the livelihoods of many people, even by all living things. Therefore, water resources must protect so that humans and other living things can adequately utilize them. The use of water for various purposes must do wisely, considering the interests of current and future generations.

In Indonesia, in general, around 50 percent of household water needs come from water. Groundwater is one of the vital needs in aspects of community life — groundwater sources used in meeting urban and rural needs. For rural areas, the fulfillment of water needs generally comes from springs or groundwater wells. Some areas in Indonesia still have poor groundwater quality. If cooking groundwater is enough to be a solution to eliminate contamination, then that is the wrong thing. Contamination will not disappear just by cooking it. Cooking will only remove bacteria and not contaminants in the groundwater [6]. If it boils, the pesticides, nitrates, and lead contained therein will still be there. Precisely when the water cooked, the volume of water will decrease and make the concentration of contaminants will be more concentrated [7].

Status as the provincial capital has a significant impact on population growth, causing a high demand for clean water consumption. This indicated by the increasing number of clean water customers, mainly by household customers [8]. At present, the number of customers of the Makassar City Water Supply Company reaches 170 thousand or covers 72 percent of all existing households. The results of research conducted by, some data show that there is an influence between the conditions of population density on the condition of groundwater quality [9]–[13]. The results of initial measurements of groundwater quality in Untia Sub-district classified as in poor groundwater conditions and areas with high population density classes.

In general, groundwater quality greatly influenced by human activities, including the disposal of domestic, agricultural, and industrial waste disposal [14]. The denser the occupancy of an area is usually the quality of groundwater reduced (less suitable for drinking water) because there is a higher chance of increasing sources of pollution that can pollute the quality of groundwater in the location [15], [16]. Locations with a high population density generally tend to have complex types of activities; this is one source of pollution for groundwater quality conditions in these locations. It feared that human activity waste can affect the condition of groundwater quality because every activity carried out by humans will generally produce waste, whether solid, liquid, or gas. Human activities can take the form of industry, workshops, transportation, shops, household activities, bathing washing latrines [17]. All these activities will produce waste, and the waste has the potential to damage groundwater quality [15].

Well, water is the primary source of clean water supply in Indonesia, both for residents living in rural and urban areas. Well, the water divided into shallow wells and deep wells. Shallow wells are the most abundant type of well in Indonesia. The source of water for this type of shallow well comes from rainwater infiltration, so this type of well very easily contaminated with dirty water from bathing-washing-latrines [18]. Water is an essential part of daily life. More than half of the composition of the human body consists of water. The body needs to consume enough fluids to get rid of impurities or waste from the body through sweat, urine, feces, and even moisture that comes out when we breathe [19]. The water we drink also serves to replace wasted body fluids [20]. Not only that, but water is also vital for kitchen activities, for bathing, cleaning the house, and many more. However, if groundwater has been contaminated, for example, by seawater, parasites, bacteria, chemicals, nitrates, mercury, lead, or feces, it can cause various health problems if it enters the body [21].

2. Research Methods

2.1. Approach and Location Study

This study is quasi-experimental; researchers do not have the flexibility to manipulate the subject, meaning that random groups usually used as a basis for establishing treatment and control groups. Experimental research usually recognized as the most scientific research of all types of research because researchers can manipulate treatments that cause something to happen. According to Consuelo [22], experimental research is the only research method that can test hypotheses regarding causal relations. The research design used in this study was the One Group Pre-test and Post-test Design, which is a research design that contained a pre-test before treated and post-test after treated. Therefore, it can be known more accurately because it can compare withheld before being given treatment [23].

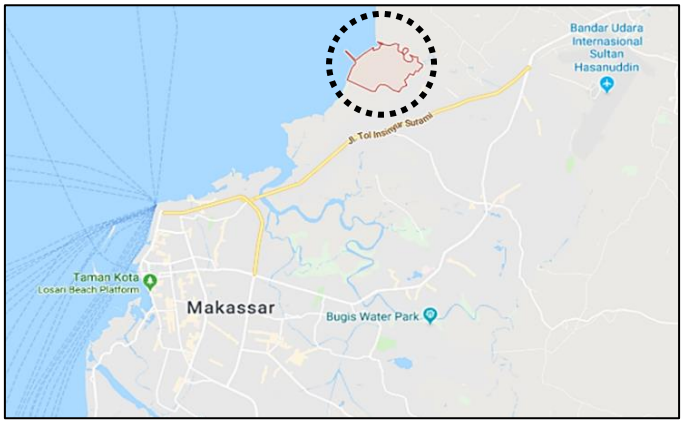

Figure 1. Location Study

This research conducted for the location in Untia Sub-District, Biringkanaya District Makassar City, South Sulawesi Province. The location was chosen because it is one of the areas with the clean water crisis in Makassar City and is a densely populated coastal area. Until the time of the study, the area was still an area with poor health quality, especially the clean water facilities used by the community.

2.2. Population and Sample

The population is a generalization area that consists of objects or subjects that have certain qualities and characteristics determined by researchers to studied and then drawn conclusions [24]. The population in this study is well water, which is located and used by the community for daily activities in Makassar City. The number of dug wells found in Untia Sub-district which are still in use, is 234 wells.

The sample is part of the number and characteristics possessed by the population [25]. If the population is significant, and researchers may not study everything in the population, for example, because of limited funds, workforce and time, then researchers can use samples taken from that population. Roscoe [26], provides a general reference for determining sample sizes:

- Most studies use between 30 and 50 samples as an appropriate number of samples.
- If the sample fragmented down into subsamples (male/female, junior/senior.), a minimum sample size of 30 for each category is appropriate.
- In multivariate studies (including multiple regression analysis), the sample size should be 10x more massive than the number of variables in the study.
- For simple experimental studies with tight experimental control, sample sizes recommended between 10 and 20 for a minimum of research samples.

Then according to [27], for correlational research, the minimum number of samples to obtain good results is 30, whereas in experimental studies, the minimum number of samples is 15 from each group and for survey research, the minimum sample size is 100. This study uses ten samples with techniques Purposive random sampling with well water sources used by the people in Makassar, especially in Untia Sub-District.

2.3. Variable

The variable used is anything in the form of whatever is determined by the researcher to studied to obtain information about it, then conclusions are drawn. The independent variable is the variable that affects, while the dependent variable is the variable that affected. The variables in this study, such as independent variables, include the color of water, turbidity, iron (Fe), manganese (mg), total coliform and E-coli as well as the dependent variable includes a water filter. To avoid misinterpretation in this study, the following operational definitions will be presented. The operational definitions in this study are as follows:

- For colors measured on a TCU (True Color Unit) scale, maximum: 50 TCU clean water, 5 TCU drinking water. Turbidity measured by the NTU (Nephelometric Turbidity Unit) scale, maximum: 25 NTU clean water, 5 NTU drinking water. With the naked eye, these two scales are indistinguishable at all. 50 TCU and 5 TCU both look colorless. 5 NTU and 25 NTU both look clear. Furthermore, dozens of other chemical parameters such as nitrate, ammonia, heavy metals, pesticides also tend to be almost the same value. In other words, almost all the parameters do not make the two-look different.
- Iron (Fe) content in water can cause odor and color in drinking water, and colloidal color in water. The instrument used to measure iron (Fe) is a TDS meter that describes the number of dissolved substances in Part Per Million (PPM) or equal to milligrams per Liter (mg/L). This measurement uses the Electrical Conductivity method, where two probes connected to the solution to measured, then the signal processing circuit expected to produce an output that shows the conductivity of the solution.
- High levels of manganese can increase water corrosivity, which results in the natural rusting of metal-made equipment. The instrument used to determine levels of manganese is a Chlorine Meter, or Chlorine Meter is a tool to measure the amount of manganese contained in liquids with units of PPM or equal to milligrams per Liter (mg/L).
- Indicators of microbial pollution of drinking water are total coliforms and Escherichia coli (E. coli). Total coliform is a group of bacteria that used as an indicator of the pollution of impurities. Coliform bacteria can use as an indicator because the density is directly proportional to the level of water pollution [28]. The total coliform in food or drink indicates the possibility of enteropathogenic and toxigenic microbes that are harmful to health. Total coliform divided into two groups [28], namely fecal coliforms, such as E. coli, which comes from human feces, warm-blooded animals, and non-fecal coliforms, such as Aerobacter and Klebsiella which are not from human feces but derived from animals or plants that already died.

2.4. Data Analysis

From the results of water quality measurements, then analyzed by the Storet Method. The Storet method is one of the methods for determining the status of water quality that commonly used. With the Storet method, parameters can find that have met or exceeded the water quality standard. Storet is an acronym for Storage and Retrieval developed by the Environmental Protection Agency (EPA-USA) as a database of water, biological and physical quality for use by various institutions [29]. In principle, the Storet

method is to compare water quality data with water quality standards adjusted for their designation to determine water quality status. The way to determine the status of water quality is to use the value system of the "US-EPA (Environmental Protection Agency)" by classifying water quality into four classes, namely:

Table 1. Storet Method Water Quality Classification

Class	Score	Water Quality Status
A	0	Safe (No Polluted)
B	-1 to -10	Lightly Polluted
C	-11 to -30	Medium Polluted
D	≥-30	Heavy Polluted

Initially, the Storet Method developed to assess water quality for a specific use, for example, the designation of drinking water. Nevertheless, lately, the method can also use to assess the overall use of air. Determination of water quality status using time series data. Determination of water quality status using the method Storet done with the following steps:

1) Perform data collection on water quality and water discharge periodically to form data from time to time (time series data).
2) Compare the measurement data from each water parameters with a standard quality value following the class of water.
3) If the measurement results meet the water quality standard value (measurement results < quality standard) then it gave a score of 0.
4) If the measurement results do not meet the water quality standard value (measurement results > quality standard), then the score is given as follows (Table 2).
5) The negative number of all parameters calculated and Quality status determined from the total score obtained using the value system.

Table 2. Determination of a value system for determining water quality status [30].

Number of Examples*	Value	Parameter		
		Physics	Chemistry	Biology
<10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
≥10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-6	-12	-18

Note: *) number of parameters used for determining water quality status.

3. Results and Discussions

In calculations using the Storet method, the data must be in the form of time series. Time series used to do data analysis that considers the influence of time. Data collected periodically based on time can be in hours, days, weeks, months, quarters, and years. In this study, sample data were taken in time series every day for one week. The data can then analyze by the laboratory and calculated.

Table 3. Water Quality Status.

Sample Point	Score	Class	Status
Point 1	-35	D	Heavy Polluted
Point 2	-35	D	Heavy Polluted
Point 3	-35	D	Heavy Polluted
Point 4	-35	D	Heavy Polluted
Point 5	-35	D	Heavy Polluted
Point 6	-35	D	Heavy Polluted
Point 7	-35	D	Heavy Polluted
Point 8	-35	D	Heavy Polluted
Point 9	-35	D	Heavy Polluted
Point 10	-35	D	Heavy Polluted

From the results of the analysis obtained pollution index included in category D, which means that the water sample tested in heavily polluted conditions. Pollution of groundwater quality that occurs starts from the absorption of waste or the content of the elements in the trash into the soil and carried by the water until it mixed with groundwater. As a result, groundwater in these locations will be contaminated with elements in the form of toxins resulting from human activity waste. The potential for pollution that can affect the quality of groundwater in the study area, namely the City of Makassar, the researchers concluded that it is necessary to conduct groundwater quality research in the area so that it can be known and studied together about how the condition of groundwater quality that will be used by the community as a source of clean water to meet their daily needs, especially drinking water.

In the most recent national report, water quality in the United States, 45% of river miles valued, 47% of lake lakes valued, and 32% of bays graded and square mile estuaries classified as polluted [31]. Water pollution is a major global problem that requires evaluation and revision of water resource policies at all levels (from the international level to private water sources and wells). It has said that water pollution is the world's leading cause of death and disease and recorded for the deaths of more than 14,000 people every day [32], [33]. An estimated 700 million Indians do not have access to toilets, and 1,000 Indian children die of diarrhea every day [34]. About 90% of Chinese cities suffer water pollution to some degree [35], and nearly 500 million people do not have access to safe drinking water [36]. Water pollution is an acute problem in developing countries, industrialized/developed countries are still struggling with the problem of pollution as well.

The threshold for acceptable aesthetic criteria for human drinking water is 500 mg/L; there is no general concern over odors, tastes, and colors at levels much lower

than those required for danger. Numerous studies have conducted and show a variety of species reactions ranging from intolerant to direct toxicity due to high Total Dissolved Solids. Several results must consistently interpret, as the result of actual toxicity will be related to specific chemical constituents. However, some numerical information is a useful guide to genetic risks in exposing aquatic organisms or terrestrial animals to high levels of Total Dissolved Solids. Most aquatic ecosystems involving mixed fish fauna can tolerate TDS levels of 1000 mg/L.

Total Dissolved Solids (TDS) is a measure of the combined content of all inorganic and organic substances present in a liquid as molecules, ionized or micro-shaped granules (sol colloids) trapped. In general, the operational definition is that solids must be small enough to escape filtering through a 2 µm (micrometer) filter. Total Dissolved Solids can be used to estimate the quality of drinking water because it represents the number of ions in the water. Water with high Total Dissolved Solids often has a bad taste and high-water hardness and can have a laxative effect. High Total Dissolved Solids generally indicate hard water, which can cause scale in pipes, valves and filters, reduce performance and increase system maintenance costs. This effect can see in aquariums, SPA, swimming pools, and "reverse osmosis" water treatment systems. Typically, in such applications, total dissolved solids are often tested, and membrane filtration must be checked to prevent adverse effects.

The concentration of manganese in natural water systems is generally less than 0.1 mg/L, and if the concentration exceeds 1 mg/L, then it is challenging by conventional treatment to reduce the concentration to the degree permitted as drinking water. Therefore, we need unique processing methods. In 1961 the WHO set a maximum concentration of manganese in drinking water in Europe of 0.1 mg/L but subsequently renewed to 0.05 mg/L. In the United States (U.S. EPA) from the beginning, determine the maximum concentration of manganese in drinking water 0.05 mg/L. Japan sets the total concentration of iron and manganese in drinking water a maximum of 0.3 mg/L. Indonesia, based on Minister of Health Decree No. 907 of 2002, established iron levels in drinking water a maximum of 0.3 and a maximum Manganese of 0.1 mg/L [37].

In the human body, small amounts of manganese do not cause health problems, but in large amounts can be buried in the liver and kidneys. There are various opinions about health problems due to the poisoning of manganese compounds, but generally in chronic conditions cause interference with the nervous system and display symptoms such as Parkinson's disease. Based on experiments conducted on rabbits, manganese poisoning causes interference with bone growth. Both iron and manganese in water usually dissolved in the form of compounds or bicarbonate salts, sulfate salts, hydroxides and in the form of colloids or in conditions of joining organic compounds. Therefore, the way of processing must also be adjusted to the form of iron and manganese compounds in the water to treated. In the removal of iron and manganese, the principle is the oxidation process, which is to increase the oxidation level by an oxidizer to change the form of dissolved iron to the form of insoluble iron (sediment). The precipitate formed removed by sedimentation and filtration processes.

Water pollution caused by fecal contamination is a severe problem due to the potential for disease transmission by pathogens (disease-causing organisms). Often the concentration of pathogens from contamination of toilet waste can be found in relatively small amounts. However, there is a high likelihood that other pathogens will be present at the time of contamination. This causes the pathogen testing in every water sample taken to be impractical and inefficient. Practically observing the presence of pathogens can be done by testing the presence of pollution indicator organisms such as Coliform bacteria. These bacteria come from the same source as pathogenic organisms. Coliform bacteria quite easily identified and are generally present in more numbers than the more dangerous pathogens. Besides, the characteristics of how to handle coliform bacteria in the environment, sewage treatment plants and water treatment plants have many similarities with many pathogens. Therefore, testing the presence of coliform bacteria is a rational method as an indication of the presence of other pathogenic bacteria in the environment [38].

Iron content in groundwater, especially in well water is common. Groundwater which generally has a high concentration of carbon dioxide, can cause anaerobic conditions. This condition causes the concentration of insoluble iron form (Fe^{3+}) reduced to iron which dissolves in the form of two-dimensional ions (Fe^{2+}). The concentration of iron in groundwater varies from 0.01 mg/L - 25 mg/L [39]. Iron (Fe) is a component of various enzymes that affect all-important chemical reactions in the body even though it is difficult to absorb (10-15%). Iron is also a component of hemoglobin which allows red blood cells to carry oxygen and deliver it to body tissues [40].

4. Conclusions

Pollution of water sources at the study site is already very high and very improper to use for daily activities by the community. To avoid water pollution, communal septic tanks should construct, then dug well water treatment at a household scale with chlorination according to dosage and in-depth research on water pollution analysis based on complete chemical, physical, and biological parameters. Water pollution can overcome by recognizing the source of pollution first, the nature and character of the pollutants, then making decisions to address pollution. Pollution control needs to done to protect water sources by

organizing spatial planning that is environmentally sound and protected by applicable laws.

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