Household Groundwater Contamination Of Heavy Metal In Pulomerak District, Cilegon City

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Abstract. The pollution of household groundwater with heavy metals is one of the public health problems in Indonesia. This is due to the toxicity of the heavy metal, which leads to negative effects on physical health. It is possible that trash from both industrial and home sources has led to the deterioration of the ecosystem and the polluting of water. This research was conducted with the purpose of determining the concentration of heavy metals in the groundwater of the Pulomerak house in Cilegon City. A cross-sectional design was used for this investigation, which is a descriptive study. Using a method known as purposive sampling, the 36 borehole samples were collected. The results of the heavy metals groundwater study were compared to the criteria for water quality that are utilized in Indonesia while conducting the analysis. The results of the study indicate that the quantity of total dissolved solids (TDS), fluoride, manganese, and lead in groundwater exceeds the acceptable levels according to the regulations for water quality in Indonesia. The findings of the study may serve as a guide for the activities that the community and the local government do in order to guarantee that the region under investigation is equipped with a healthy and dependable supply of drinking water.

Keywords: Heavy Metal concentration, Household, Groundwater

1 Introduction

Groundwater serves as a crucial water resource for human lives [1]. Groundwater is already the preferred source of drinking water in rural and urban areas of developing countries [2]. An average of 66% of households in urban areas and 60% of households in rural areas in eleven Southeast Asian and Pacific countries assessed depend on groundwater for drinking [3]. More than 90% of domestic family needs are still met in Indonesia, both in urban and rural regions, making it more dependent on groundwater than other Southeast Asian nations [3].

The swift expansion of cities experiencing high population growth and industrialization has heightened their reliance on groundwater resources in developing nations [4]. Safe drinking water is a basic need of human health, and well-being [5]. According to the SKAMRT survey in 2020, it was found that 11.9% of people have access to safe drinking water. Of those, 15% live in urban areas, while 8% live in rural regions. In the meantime, 31% of Indonesian

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households utilize replenished water, 15.9% use wells that have been dug safely, and 14.1% use boreholes [6].

In recent years, high population growth rates and rapid industrialization in Cilegon City, have led to diverse serious environment problems among residents living in the industrial areas due to metal pollution [7]. Previous study showed that manganese levels range of 0.002-0.4 mg/L (below permisible limit 0.1 mg/L), in well water residential areas around the Bagendung landfill [8]. According to [9], Heavy metal samples were found to not meet the standards for safe drinking water, including parameters of pH, TDS, color, taste, odor, turbidity, manganese, chloride, and hardness levels of $CaCO_3$ in Suralaya village. Other studies have shown that the water's Pb concentration was high off Merak Kecil Island, Cilegon City [10].

The Cilegon City is geographically located at the western end of the island of Java, and is the main gateway that connects the island of Java with the island of Sumatra and separated by the Sunda Strait, home of Krakatoa volcano with a total coastline of approximately 185 km^2 [11]. In coastal regions, a lot of industrial and urban growth has happened, which has changed how land is used and made natural resources and the water environment worse [12]. One of the areas in Cilegon City is the Pulomerak District, which has many industrial activities like power plants, steel mills, iron and aluminum production, chemical plants, and cement factories. These industries are suspected of releasing fluoride and manganese into the environment, causing pollution and being a major source of human exposure to these harmful substances [13]. Overusing groundwater and polluting it with chemicals can greatly affect the water quality that people in the community will eventually consume [14].

Fluoride and manganese are known as neurotoxic elements, but they are also essential micronutrients required in trace amounts for human health. It has severe human health implications if fluoride levels exceed 1.5 mg/L and magnese (> 0.1 mg/L) in drinking water.The public health concerns caused by high fluoride content are dental caries and skeletal fluorosis [15]. Mn in water has only been considered as an aesthetic problem at the regulatory level. Mn in water supplies may cause an undesirable taste and discoloration in drinking water [16]. However, increasing evidence has emerged that Mn derived from drinking water could be a health risk, especially for children. A Canadian study [17], found a strong correlation between lower intelligence quotient (IQ) scores among schoolchildren aged 6-13 years and higher levels of Mn in tap water. Their tap water had a median Mn content of 34 µg/l. Potential carcinogenic effects of Pb on public health with levels exceeding (> 0.01 mg/L) in community water supplies [18]. The persistence of heavy metal issues in Cilegon City indicates the complex nature of the problem, requiring further attention and interventions. The evaluation of heavy metal concentrations should ultimately create the groundwork for sustainable water quality management by safeguarding the environment from pollution and people from illness brought on by drinking water tainted with heavy metal effect.

2 Methods

2.1 Research Design

This research is a quantitative study with a cross-sectional design (one time approach). This type of research is descriptive observational research because the data obtained will only be described and without any intervention.

2.2 Research Location

This study took place in the Pulomerak district of Cilegon City, in Banten Province, Indonesia. Groundwater samples were collected from Mekarsari village (point A) as the main site, Tamansari village (point B), and Lebak Gede village (point C) as the comparison site. The selection of Mekarsari villages as the main location was situated near a coastal areas (port of Merak), shipyard companies, and much industrial activity.

2.3 Population and Sample

The population of groundwater (boreholes) studied came from the Pulomerak district through points A, B, and C. Purposive sampling was used to collect the sample. A total of 36 samples (Point A = 14, Point B = 12, Point C = 10) were collected from various boreholes (depths of approximately 20–60 m). The sample consists of residents of the Pulomerak district who reside in three villages with boreholes from points A, B, and C.

2.4 Data Collection

We conducted our field survey in October 2024. The water samples from the borehole were put into polyethylene bottles that had been soaked in a 10% HCl solution. The bottles were then washed and rinsed three times with well water in the field before the sample was collected. The sample bottles were labeled S1 through S36 to show which area they came from. Then, the samples were sent to the PT. Unilab Perdana Laboratory in a cold storage box and stored in a freezer at 4 degrees Celsius until they were tested.

2.5 Data Analysis

The univariate analysis to find the minimum, maximum, and average of pH, TDS, fluoride, manganese and Pb concentration. Indonesian water quality standards (Permenkes No. 2/2022) were used to compare the findings of PT. Unilab Perdana Laboratory's groundwater analysis.

3 Results

The groundwater concentration of pH was 6.7-8.8 at point A, higher than points B (6.3-8.3) and point C (6.8-6.9) in the Pulomerak district of Cilegon City.The TDS concentration above 300 mg/L have been reported from point A (340.5 mg/L), point B (393.9 mg/L), and point C (458.6 mg/L). The concentration of TDS is not allowed based on the Indonesia Health Minister Regulation (300 mg/L). Fluoride (F) concentrations with point A having the highest average concentration (1.25 mg/L), followed by point B (1.20 mg/L) and point C (1.133 mg/L). The highest F value in point A, ranging from 1.517 to 1.624 mg/L, surpasses recommended limits (1.5 mg/L). Manganese average concentrations was 0.14 mg/L at Point A, followed by point B (0.125 mg/L) , point C (0.01 mg/L). The highest Mn value is in point A, ranging from 1.517 to 1.624 mg/L, and point B (0.018- 0.249 mg/L). Groundwater manganese concentration is below permissible limits (0.1 mg/L). A Plumbum (Pb) water sample was detected at point A (1 mg/L) exceeding the levels recommended by the Ministry of Health's drinking water standard (0.01 mg/L) (Table 1).

Table 1. Heavy metal groundwater analysis in the study area

Location	Minimum	Maximum	Average	Standards
Mekarsari				
pH	6.7	8.8	7.8	pH = 6.5-8.8
TDS (mg/L)	121.2	696.0	340.5	TDS = < 300 mg/L
F (mg/L)	0.590	1.624	1.25	F = 1.5 mg/L
Mn (mg/L)	0.009	0.388	0.14	Mn = 0.1 mg/L
Pb (mg/L)	Undetected	1	-	Pb = 0.01 mg/L

Taman Sari			
pH	6.3	8.3	7.5
TDS (mg/L)	119.2	720.0	393.9
F (mg/L)	0.753	1.453	1.20
Mn (mg/L)	0.018	0.249	0.125
Pb (mg/L)	Undetected	Undetected	-
Lebak Gede			
pH	6.8	6.9	6.8
TDS (mg/L)	443.0	480.0	458.6
F (mg/L)	0.811	1.299	1.133
Mn (mg/L)	0.007	0.022	0.01
Pb (mg/L)	Undetected	Undetected	-

Source: Laboratory test (2024)

4 Discussions

pH is a measurement parameter often used for most water sources, as it affects biological and chemical reactions [19]. The concentration of pH in boreholes at Point A, B and C was found to average of 7.8, 7.5 and 6.8. Groundwater pH standard according to Indonesia Health Minister Regulation was 6.5-8.5. When the pH is within advised bounds, it is rather alkaline, similar to the aquifer. This might be because of the local geology and the fact that water in tropical regions rarely has a pH higher than 7 due to weathering rock dissolution [20]. Changes in the pH of water can cause changes in taste, and odor of drinking water [21]. In order to prevent heavy metals from dissolving and the drinking water distribution network from corroding, drinking water should be neutral, not acidic or alkaline.

The TDS in groundwater shows directly how rocks, minerals dissolve interact with water, and how evaporation affects the groundwater system [22].The average TDS concentration above 300 mg/L have been reported from point A (340.5 mg/L), point B (393.9 mg/L), and point C (458.6 mg/L).The concentration of TDS surpasses recommended limits. In a similar kind of study of how domestic and industrial waste affects the quality of groundwater in Magelang City and it was observed that the concentration of TDS was in the range of 190 to 337 mg/L [23]. A test of the groundwater quality in Semarang City showed that the amount of dissolved solids in the water was higher than normal, ranging between 370 and 1,680 mg/L, with an average of 787.5 mg/L [24]. Another study found similar results in Wonokerto, Pekalongan District, and the TDS concentration was reported to be between 217 and 769 mg/L [25]. The high salt content in the water comes from both natural reasons and human actions, like waste from homes and factories. If a well is near the ocean or an industrial zone and has a lot of salt (>1000 mg/L), it could be because a small amount of saltwater is mixing with the water, or salt from the air is getting into the water, or salt is being washed out of old river deposits in that area [26]. Groundwater becomes salty when it contains a high amount of total dissolved solids. Having too much TDS in water can cause issues for farming and growing crops [27].

The concentration of fuoride sampled water in points A, B, and C was found in the average of 1.25 mg/L, 1.20 mg/L, and 1.133 mg/L. The highest F value in four (4) sampling sites in point A, ranging from 1.517 to 1.624 mg/L, which were situated near a port of Merak, shipyard companies, and manufacturing of steel mills, respectively. The result showed that the fluoride level was higher than normal, going beyond the allowed limit set by the Health Minister's regulation, which is 1.5 mg/L. Similar study of the fluoride ion levels in industrial area showed the results of fluoride ion analysis of 12 samples of groundwater and piped water showed positive results overall, with levels between 0.0459 to 0.7800 mg/L [28]. Fluoride is often spread into the environment through different industrial processes, such as operating power plants, and making steel, iron, aluminum, chemical fertilizers, cement, and hydrofluoric acid. This causes pollution from industrial fluoride [29]. Even though fluoride can be good for your health in some ways, drinking water that has a lot of fluoride can cause health issues, and all of these problems are known as fluorosis [30]

The concentration of manganese in point A and B was found in the average of 0.14 mg/L, 0.125 mg/L. The highest Mn value in five (5) sampling sites in point A, ranging from 0.215 to 0.388 mg/L. Out of 0.20-0.249 mg/L highest manganese value in point B at two (2) sampling sites. The results showed that the level of manganese was higher than usual, going beyond the Indonesia groundwater quality standard limit of 0.1 mg/L. In a similar study, elevated levels of manganese in groundwater were found in some areas of the Candi Industrial Estate in Semarang City, with manganese concentrations ranging between 0.1 and 0.2 mg/L [31]. Manganese levels in groundwater depended on rainfall chemistry, the dissolving of minerals from bedrock, leaching by water percolating through soil, and how long the water stays in the ground [32]. Mn are present in chemicals derived from both natural sources, such as soil and rock, and human activities, such as industrial wastewater and the overexploitation of groundwater, and can eventually pollute groundwater [33]. At the regulatory level, Mn in water has only been regarded as an aesthetic issue. Drinking water may become discolored and taste unfavorable due to Mn in water supply [16]. Nonetheless, there is mounting evidence that Mn from drinking water may pose a health risk, particularly to young people. According to a Canadian study [17], there is a direct link between greater levels of Mn in tap water and poorer IQ scores among schoolchildren aged 6 to 13.

Pb water sample was detected in point A (1 mg/L). The prior investigation also discovered that Merak Kecil Island, Cilegon City, had a high lead concentration [10]. It was indicated potential Pb contamination in Cilegon City. Pb levels in community water sources surpassing (> 0.01 mg/L) may have carcinogenic impacts on public health [18]. Furthermore, studies have shown that high salinity is also the cause of metal dissolution and that coastal groundwater is susceptible to salinization [34]. Based on the distribution of the electrical conductivity of deep groundwater and shallow groundwater (> 2.000 micromhos/cm), residential and industrial areas in the northern part of Pulomerak District are seawater intrusion areas [35]. This study is in line with other research about harmful chemicals in groundwater, likely because minerals from rocks dissolve and saltwater mixes with the groundwater, making the water not as clean [9]. The primary cause of these problems is the disruption of hydrogeological conditions brought on by human activity.

5 Conclusion

The study showed that heavy metal parameters investigated exceeded the levels recommended by the Ministry of Health's drinking water standard for residents (Regulation Number 2-2023). The study's findings might offer crucial details about the state of the water quality and lay the groundwork for long-term, sustainable water quality management in Cilegon City. The strategies for wastewater treatment plans and enhancing the role of the government, Cilegon Industrial Area, and the community are needed. Finally, community education and the creation of reliable, affordable, and sustainable water treatment technologies are used to prevent the harmful effects of heavy metals in drinking water, particularly for low-income communities.

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