**Journal of Progressive Science Education**
Volume 1, Number 1, 2025 pp. 52-59
Open Access: https://journal.kopialinea.com/index.php/JPSE

# Analysis of Water Hardness in Lapindo Mud Sources: Identification of $Ca^{2+}$ and $Mg^{2+}$ using the EDTA Method as a Science Learning Medium

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**ARTICLE INFO**

**Article History:**

| | |
|---|---|
| Submitted | : September 15, 2025 |
| Final Revised | : November 20, 2025 |
| Accepted | : November 24, 2025 |
| Published | : November 25, 2025 |

***Keywords:***
*Hard water, EDTA, Lapindo mudflow*



***ABSTRACT***
*Water hardness refers to water that has a high calcium and magnesium ion content, which affects water quality. Hard water can cause several side effects, one of which is health problems that can trigger kidney stones. This study was conducted with the aim of determining the level of hardness contained in Lapindo mud water, as well as providing information on the methods used to accurately test water hardness levels. The method used was a laboratory experiment conducted by changing the independent variable to see its impact on the dependent variable. This research was conducted on 14 August 2025 at the Household Chemistry Laboratory of the Science Education Study Programme at Trunojoyo University, Madura, which produced a total hardness of 379.4 mg/L in the sample. The results obtained show that the method used is very effective in identifying the level of water hardness and provides valid data to support the treatment of water to make it suitable for consumption.*

## 1. INTRODUCTION

Water quality issues are a serious concern in many regions, especially for communities that depend on groundwater and springs (Haikal et al., 2025a). One of the problems often encountered in the use of groundwater and springs is water hardness, which is the high content of calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$) ions that cause water to become hard (Bouamer, et al. 2024). These ions can make it difficult for water to lather when used with soap, cause scaling on equipment, and potentially lead to health problems such as kidney stones. High mineral content in hard water can precipitate in the urinary tract, especially if the body does not get enough fluids or if consumption patterns are unbalanced (Kumar, 2024).

In the context of science education, the issue of water hardness can be a relevant learning material because it relates to basic chemistry concepts such as ions, elements, compounds, mixtures, and interactions between substances in solutions. Through water hardness analysis activities, students not only learn how the EDTA titration method works, but also understand how the properties of $Ca^{2+}$ and $Mg^{2+}$ ions affect water characteristics. This approach helps students see that the concepts they learn are strongly related to environmental and public health issues. Thus, water hardness analysis practicals can serve as an instructional tool to foster scientific literacy, critical thinking skills, and awareness of how water quality intersects with social behavior, local environmental constraints, and community decision-making in managing water resources, an aspect highlighted in recent studies on urban water management (Haikal et al., 2025b).

In science education, contextual and environment-based laboratory activities such as water hardness testing have been shown to support students' conceptual understanding and engagement by linking abstract scientific ideas to authentic problems (Firdaus et al., 2025a). Experimental tasks that require students to design procedures, interpret data, and justify conclusions are also in line with research showing that well-structured learning environments can strengthen critical thinking disposition and self-regulated learning (Firdaus et al., 2025b). Moreover, in the era of Artificial Intelligence, maintaining direct hands-on laboratory experiences is essential to preserve academic integrity and prevent students from relying solely on AI-generated answers without developing their analytical reasoning (Firdaus, 2025).

This research is important because it aims to determine the level of hardness contained in the sample (Lapindo mudflow). The Lapindo mudflow in Sidoarjo is a unique and important case because it originated from a hot mudflow that has been ongoing since 2006 and has had a major impact on the environment and the lives of the surrounding community. So far, research on Lapindo mudflow has focused more on its geological and social impacts, while studies on the potential quality of the water as a source of consumption are still limited. This gap is an important basis for this study to fill an unexplored scientific space. In addition, this research can also provide information on methods that can be used to accurately test water hardness levels, so that the results of this research can be used as a reference in monitoring water quality and water treatment efforts to make it suitable for use.

## 2. METHOD

The laboratory experiment method is a form of research in which researchers deliberately alter independent variables to observe their impact on dependent variables. During this process, external factors that could potentially influence the results are strictly controlled or maintained in a regulated and standardised environment, whether conducted in a laboratory or another location where the environment can be controlled (Rosdin, et l. 2022).

The place and date of the research was 14 August 2025 at the Household Chemistry Laboratory of the Science Education Study Programme, Trunojoyo University, Madura. This study examined the hardness of Lapindo mudflow water originating from Sidoarjo, East Java. The hardness of the Lapindo mudflow water was tested using several solutions, such as 0.01 M $Na_2EDTA$ solution, pH 10 buffer solution, EBT indicator, distilled water, 0.1 N NaOH solution, and Murexide indicator.

The use of laboratory experiments in this study aims to obtain accurate results, as variable conditions can be optimally controlled. External factors such as pH, temperature, and solution concentration can be standardised so that data quality is more assured. In addition, research on the hardness of Lapindo mud requires measurements with a high degree of accuracy.

The use of standard solutions including Na, EDTA 0.01 M, pH 10 buffer, EBT indicator, and murexide indicator enables careful analysis and scientifically accountable results. This makes laboratory experiments the right choice because they not only produce precise data but also strengthen the validity of research conclusions (Amelia, et al., 2023). Laboratory-based tasks such as EDTA complexometric titration are essential in science education because they provide concrete experiences that strengthen the linkage between conceptual knowledge and practical skills, a connection emphasized in contemporary science learning research (Firdaus, 2022).

The flow chart for this study is as follows:

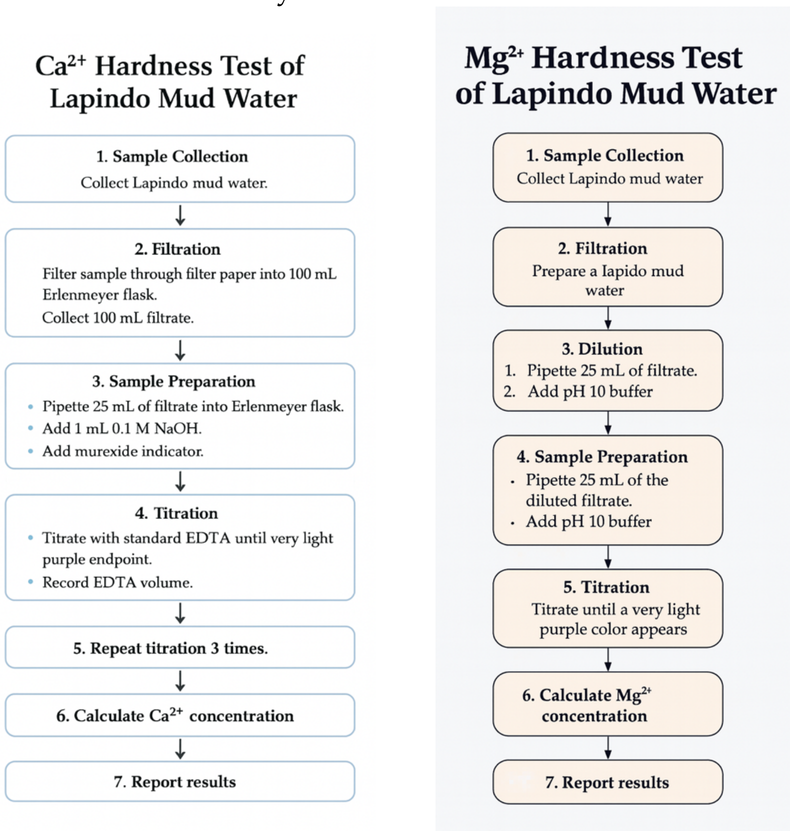


**Figure 1.** flow chart $Ca^{2+}$ and $Mg^{2+}$ Hardness Test

## 3. RESULT AND DISCUSSION

**Table 1.** Results of hard water testing using $Ca^{2+}$

| No. | Sample | Colour Change | | Volume |
|---|---|---|---|---|
| | | **Beginning** | **End** | |
| 1. | Lapindo mudflow | colourless | Very young purple | 3,5 ml |
| 2. | Lapindo mudflow | colourless | Very young purple | 2 ml |
| 3. | Lapindo mudflow | colourless | Very young purple | 3 ml |
| | | Average | | 104 mg/L |

**Table 2.** Results of hard water testing using $Mg^{2+}$

| No. | Sample | Colour Change | | Volume |
|---|---|---|---|---|
| | | Beginning | End | |
| 1. | Lapindo mudflow | colourless | deep blue | 3,5 ml |
| 2. | Lapindo mudflow | colourless | deep blue | 3 ml |
| 3. | Lapindo mudflow | colourless | Purplish blue | 2 ml |
| | | Average | | 275,4 mg/L |

1. Hardness Test Ion $Ca^{2+}$
   - Experiment 1

     $$Ca^{2+} = \frac{V_{EDTA} \times EDTA \times ArCa \times 1000}{V_{sampel}}$$

     $$Ca^{2+} = \frac{3{,}5\ ml \times 0{,}01\ M \times 40 \times 1000}{25}$$

     $$Ca^{2+} = 56\ mg/L$$

   - Experiment 2

     $$Ca^{2+} = \frac{V_{EDTA} \times EDTA \times ArCa \times 1000}{V_{sampel}}$$

     $$Ca^{2+} = \frac{2\ ml \times 0{,}01\ M \times 40 \times 1000}{25\ ml}$$

     $$Ca^{2+} = 32\ mg/L$$

   - Experiment 3

     $$Ca^{2+} = \frac{V_{EDTA} \times EDTA \times ArCa \times 1000}{V_{sampel}}$$

     $$Ca^{2+} = \frac{3\ ml \times 0{,}01\ M \times 40 \times 1000}{25\ ml}$$

     $$Ca^{2+} = 48\ mg/L$$

   - Average level $Ca^{2+}$

     $$= \frac{56 + 32 + 48}{3}$$

     $$= 104\ mg/L$$

2. Hardness Test Ion $Mg^{2+}$
   - Experiment 1

     $$Mg^{2+} = \frac{\text{VEDTA x EDTA x ArMg x 1000}}{V\ sampel} x\ 10$$

     $$Mg^{2+} = \frac{3{,}5\ ml\ x\ 0{,}01\ M\ x\ 24{,}3\ x\ 1000}{25\ ml}\ x\ 10$$

     $$Mg^{2+} = 34{,}02 \times 10$$

     $$Mg^{2+} = 340{,}2\ mg/L$$

   - Experiment 2

     $$Mg^{2+} = \frac{\text{VEDTA x EDTA x ArMg x 1000}}{V\ sampel}\ x10$$

     $$Mg^{2+} = \frac{3\ ml\ x\ 0{,}01\ M\ x\ 24{,}3\ x\ 1000}{25\ ml}\ x\ 10$$

     $$Mg^{2+} = 29{,}16 \times 10$$

     $$Mg^{2+} = 291{,}6\ mg/L$$

   - Experiment 3

     $$Mg^{2+} = \frac{\text{VEDTA x EDTA x ArMg x 1000}}{V\ sampel}\ x10$$

     $$Mg^{2+} = \frac{2\ ml\ x\ 0{,}01\ M\ x\ 24{,}3\ x\ 1000}{25\ ml}\ x\ 10$$

     $$Mg^{2+} = 19{,}44 \times 10$$

     $$Mg^{2+} = 194{,}4\ mg/L$$

   - Average level $Mg^{2+}$

     $$= \frac{340{,}2+291{,}6+194{,}4}{3}$$

= 275,4 mg/L

So, the hardness = $Ca^{2+} + Mg^{2+}$

= 104 mg/L + 275,4 mg/L

= 379,4 mg/L.

Image of Titration Result

**Figure 2.** Titration result 1

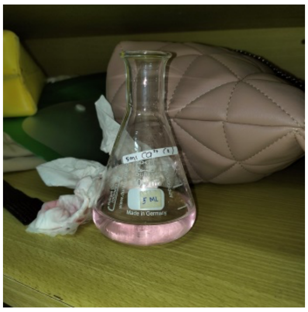

**Figure 3.** Titration result 2

**Figure 4.** Titration result 3

The results of the study show that Lapindo mud water has a total hardness level of 379.4 mg/L, which comes from a combination of $Ca^{2+}$ and $Mg^{2+}$ ion concentrations. Based on the titration data, the largest contribution comes from magnesium ions, namely 275.4 mg/L, while calcium ions only contribute 45.3 mg/L. This condition is in line with the hardness theory which states that the total hardness of a water sample is determined by the presence of divalent ions such as $Ca^{2+}$ and $Mg^{2+}$, and in certain water sources, $Mg^{2+}$ can dominate due to the dissolution of dolomite and serpentinite minerals from the surrounding geological structure. Interpreting variations in $Ca^{2+}$ and $Mg^{2+}$ concentrations requires evaluating evidence, comparing datasets, and drawing conclusions, all of which align with students' critical thinking disposition development as previously emphasized in science learning research (Firdaus et al., 2025c).

This finding is reinforced by literature explaining that areas with high volcanic activity or mineral sedimentation tend to produce water with a higher $Mg^{2+}$ content than $Ca^{2+}$ (Kitessa et al., 2024). The geochemical characteristics of the Lapindo environment provide the scientific basis for why magnesium dominates the hardness in this study. Furthermore, these findings demonstrate that water hardness analysis is not only scientifically accurate but also pedagogically meaningful, reinforcing students' procedural skills, analytical reasoning, and capacity to interpret environmental data skills that are identified as central to modern science education (Firdaus et al., 2024)

This level of hardness can be categorised as hard water, even approaching the very hard category. Based on the Sawyer & McCarty classification, water with a hardness of more than 300 mg/L is classified as very hard, which is synonymous with water that has a low ability to form soap suds, has the potential to cause scaling in pipes and metal equipment, and requires additional energy in the heating process. High $Ca^{2+}$ and $Mg^{2+}$ ion content can trigger the formation of $CaCO_3$ or $MgCO_3$ deposits on kitchen appliances and industrial installations (Santos et al., 2023). The high total hardness (TH) in this study indicates that the direct use of Lapindo mud water without treatment has the potential to cause technical and health problems.

From a public health perspective, high hardness levels are often associated with the risk of kidney stone formation, especially calcium oxalate-based stones. The relationship between hardness and health is not always linear. According to Hanna et al. (2022), high consumption of $Ca^{2+}$ in drinking water can increase urinary calcium excretion, thereby increasing the likelihood of kidney stones. Other studies have found that high magnesium levels in water can actually inhibit kidney stone formation through ionic competition with calcium in the crystallisation process (Suryantoro et al., 2025). The relative composition of $Ca^{2+}$ and $Mg^{2+}$ determines the health impact, not just the total hardness value. In this study, $Mg^{2+}$ dominates, so the impact on kidney stone risk cannot be immediately determined to be negative; further toxicological testing is required to confirm its effects on health.

Hardness of 379.4 mg/L is still below the maximum limit set by Indonesian Minister of Health Regulation No. 492/Menkes/Per/IV/2010, which is 500 mg/L as $CaCO_3$. This figure far exceeds the standard range recommended by the WHO, which is 100–300 mg/L, where values above 300 mg/L are categorised as very hard and not recommended for long-term consumption. This study shows that the hardness of Lapindo mud water is still within the limits permitted by national regulations, but scientifically and practically, the water remains risky for consumption without treatment because it exceeds the WHO comfort and safety limits. The importance of water softening before use by the community is clear from these conditions.

Methodologically, this study proves that the complexometric titration method using murexide as an indicator for $Ca^{2+}$ and EBT for $Mg^{2+}$ is an effective technique for accurately determining water hardness. EDTA titration is known to have a high level of selectivity towards divalent ions and has been used as a standard for water hardness analysis in analytical chemistry (Dhoka, 2025). The success of this study reinforces the evidence that the titration procedure used is capable of producing valid, consistent, and replicable data, as seen from the consistency of the results in three repetitions. This indicates that this method can be recommended as a standard procedure for measuring water hardness in academic and basic laboratory settings.

Overall, the results of this study provide important scientific and practical insights into the quality of Lapindo mudflow water. The high hardness not only indicates the rich mineral composition of the area, but also provides an indication of the potential risks and the need for further treatment before the water can be utilised. The conclusion that can be drawn is that Lapindo mud water is not suitable for direct use without a softening process, even though it is still within safe limits according to national regulations. With this data, further research can be directed towards exploring methods.

## 4. CONCLUSION

Research shows that Lapindo mud water has a total hardness of 379.4 mg/L, with $Mg^{2+}$ ions dominating over $Ca^{2+}$ ions. This value places the sample in the very hard water category, so it is not recommended for direct use without a softening process. The complexometric titration method using EDTA has been proven to provide accurate and consistent results, making it suitable as a standard procedure in water quality analysis. This research contributes to science by providing a clearer understanding of the relationship between water mineral content and hardness levels, as well as the importance of geochemical characteristics in determining water quality. The educational implications of this research are evident in the potential use of the research results and procedures as a medium for contextual science practicums, thereby helping students understand the concepts of analytical chemistry, water quality, and their impact on health and the environment.

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