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Application of Zeolite, Pumice, and Activated Carbon For Lowering Water Hardness and Total Dissolved Solids (TDS)

Retno Wulandari[1*], Ken Ima Damayanti[2], Shohifah Annur[3], Lusi Irawati[4], Ari Irmawan[5], Fikri Firman Syah[6]
[1]Universitas Bhayangkara Jakarta Raya, Jakarta, Indonesia, retno.wulandari@ubharajaya.ac.id
[2]Universitas Serang Raya, Serang, Indonesia, k3n.ima@gmail.com
[3]Universitas Serang Raya, Serang, Indonesia
[4]Universitas Serang Raya, Serang, Indonesia
[5]Universitas Serang Raya, Serang, Indonesia
[6]Universitas Serang Raya, Serang, Indonesia

Corresponding Author: retno.wulandari@ubharajaya.ac.id[1]

Abstract: Water is one of the most essential natural resources for living organisms. Tonjong Village is a residential, agricultural, and fish farming area. According to the test results from the Environmental Laboratory Unit of the Environmental Agency, the groundwater quality in Tonjong Village shows the following physical and chemical parameters: TDS 3352 mg/L, TSS 11 mg/L, pH 6.85, Hardness ($CaCO_3$) 1100 mg/L, COD 9.34 mg/L, and BOD 2.40 mg/L. This study aims to reduce TDS and water hardness using a multi-stage treatment method. The research consists of three stages: the preliminary stage, the equipment fabrication stage, and the testing stage. The results indicate a decrease in TDS from 3352 mg/L to 1380 mg/L and a reduction in hardness using material variation 2 from 1100 mg/L to 752.5 mg/L.

Keyword: Zeolite, Pumice, Activated Carbon, TDS, Hardness.

INTRODUCTION

Tonjong Village, Kramatwatu, Serang, Banten, is one of the densely populated areas in Banten Province, located in the Tonjong Baru District. Tonjong Village and its surroundings consist of residential, agricultural, and fish farming areas. Groundwater plays a crucial role in supporting agricultural activities and daily needs in this region (Gao et al., 2018). Over time, the demand for groundwater continues to rise (Danielopol et al., 2003). According to local residents, the groundwater used for daily activities such as bathing, washing, cooking, and other household needs is suspected to be contaminated, as it tends to have a brackish quality (Sepehr et al., 2013). Therefore, a study is needed to assess groundwater quality in Tonjong Village by analyzing several parameters, including pH, TDS, and hardness, to address groundwater contamination in the area.

The groundwater quality in the Tonjong Village area, based on tests conducted by the UPTD Environmental Laboratory of the Environmental Service, shows physical and chemical parameters with results of TDS 3352 (with the standard TDS value of 1000), TSS 11, pH 6.85 (within the pH standard of 6-9), hardness ($CaCO_3$) 1100 (with the standard hardness of 500), COD 9.34, and BOD 2.40. Previous research aimed at reducing TDS levels and hardness was carried out using a tiered method. This method has both advantages and disadvantages. The advantages include producing clear, odorless, non-acidic, and non-brackish water, with easily available materials and simple maintenance. However, the method's disadvantages are that the water cannot be continuously channeled, as it involves a certain amount of water, and this approach is not suitable for contaminated water (Santos et al., 2015). Based on the research mentioned above, a study will be conducted to reduce TDS levels and water hardness in Tonjong Village using the tiered method, with variations in the mass and contact time between water and materials (Lou et al., 2007).

Various materials can be used to lower the total dissolved solids (TDS) and water hardness, such as zeolite, pumice, and activated charcoal (Khoiriyah & Purnomo, 2024). Zeolite is a mineral group formed through hydrothermal processes in basic igneous rocks, characterized by its three-dimensional structure and pores capable of holding water molecules (Aragaw & Ayalew, 2019). Zeolites have a high adsorption capacity, which allows them to separate molecules according to their structure and size (Ackley et al., 2003). There are several possible adsorption mechanisms, such as hydrogen bonding, coordination complex formation, chemical adsorption (using electrostatic interactions), and physical adsorption (involving Van der Waals forces) (Foo & Hameed, 2010). According to (Çifçi & Meriç, 2016), activated pumice has a metal ion absorption capability of (66-99.5)%, while non-activated pumice absorbs at a rate of (55-89)%. Pumice, as an adsorbent (Syam & Beso, 2019), offers several benefits, including being environmentally friendly, cost-effective, and easy to apply in the field (Sud et al., 2008). Because it contains cellulose (23%-43%) and lignin (35%-45%), coir fiber is very promising as a sorbent for extracting heavy metals from water. Coir fiber functions as a biosorbent, which facilitates metal binding, due to its cellulose content, which contains carboxyl groups, and lignin, which contains phenolic acids. Biopolymers that aid in heavy metal removal include cellulose and lignin (Zia et al., 2020). Lime is also used in water treatment to reduce acidity, soften the water, and clarify drinking water (Ostovar & Amiri, 2013).

METHOD

The study utilizes various materials such as zeolite, quicklime, pumice, coconut husk, and activated charcoal. The research will proceed with the following phases:

Initial stage

Water samples for testing will be collected from wells in nearby residential areas.

Equipment fabrication stage

A purification device is constructed using a 3000 ml mineral bottle, with the bottom cut to allow the insertion of various materials such as Zeolite, quicklime, pumice, coconut husk, activated charcoal, and foam.

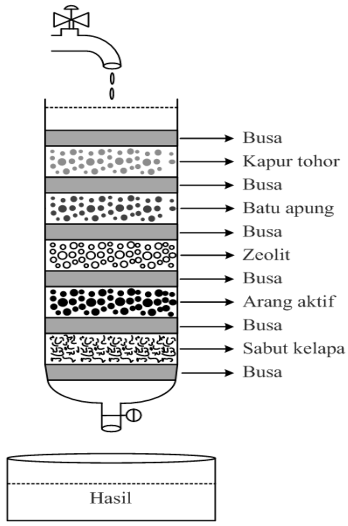
The device is built using two distinct material processes, one of which is:

a. **Variation 1**

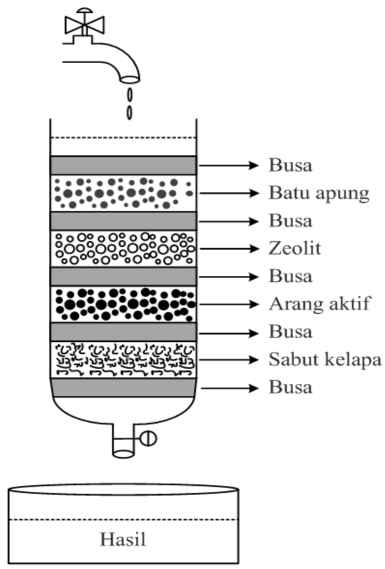
This process involves the combination of Zeolite, quicklime, pumice, coconut husk, activated charcoal, and foam, as shown in Figure 1.

b. **Variation 2**

In this process, the materials Zeolite, pumice, coconut husk, activated charcoal, and foam are combined, as illustrated in Figure2.



Source: Research Results
Figure 1. Variation 1



Source: Research Results
Figure 2. Variation 2

Testing phase

The testing process includes five different tests:

a. Stage 1 test (Physical and Chemical Analysis)
b. Stage 2 test (TDS Measurement)
c. Stage 3 test (Contact time and material mass comparison)
d. Stage 4 test (TDS Measurement)
e. Stage 5 test (Hardness Test)

RESULT AND DISCUSSION

The water in Tonjong Village plays a vital role in supporting agriculture and other activities, including daily use, that demand consistent water quality. To ensure these needs are met, it is essential to have a set of water quality criteria, where water quality is defined by specific measurements and tests based on certain parameters and methods, in line with current regulations.

In stage 1 of the testing, physical and chemical tests are performed on the water quality from Tonjong Village, as analyzed by the Serang District Environmental Agency laboratory.

Table 1. Outcomes of the laboratory-based physical and chemical testing conducted by the Environmental Office of Serang District

No	PARAMETERS	UNIT	RESULT	STANDARD PERMENKES RI NO. 32 TAHUN 2017
	Physic			
1	TSS	mg/L	11	(-)
2	TDS	mg/L	3352	1000
	Chemical			
1	pH	-	6,85	6-9
2	Hardness	mg/L	1100	500
3	COD	mg/L	9,34	(100)
4	BOD	mg/L	2,4	(50)

Source: Research data

The results from the first-stage testing, shown in Table 1 above, were obtained from the regional health laboratory and reflect the water quality in Tonjong Village. Among the physical and chemical parameters tested, some, like TSS, pH, COD, and BOD, have met the required standards set by the Ministry of Health Regulation of the Republic of Indonesia. However, other parameters, including TDS and Hardness, do not comply with these standards. Therefore, after reviewing the test results from the health laboratory, this study aims to focus on reducing the levels of TDS and Hardness to ensure they meet the required standards.

1. Optimum Mass and Contact Duration of CaO and Zeolite

The contact time between water and the mass is tested by placing the material in a container where it is in contact with the water raw material, and the results are then measured using a TDS meter.

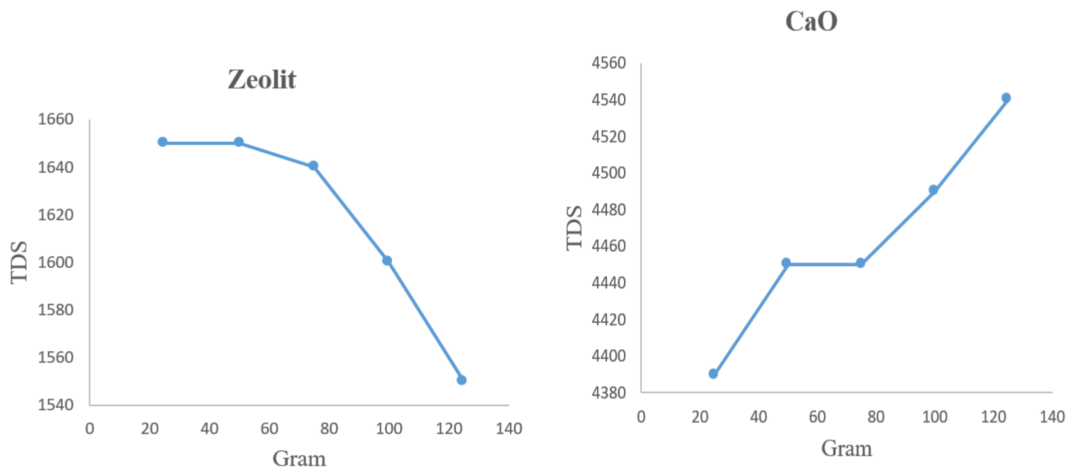
Tabel 2. Results of the TDS Physical Test Comparing Mass and Time with the Use of a TDS Meter

	25 g	50 g	75 g	100 g	125 g
Zeolit	1650	1650	1640	1600	1550
CaO	4390	4450	4450	4490	4540

Source: Research data

In this test, the materials used for contact with the raw material mass are CaO and Zeolite, with the mass of each material varying at 25 grams, 50 grams, 75 grams, 100 grams, and 125 grams. The contact time is set at 120 minutes, and the results are shown in the graph below.

The graph above shows that Zeolite, with mass amounts of 25 grams, 50 grams, 75 grams, 100 grams, and 125 grams, significantly reduced TDS. Zeolite acts as an ion exchange material using zeolite filters (Arrigo et al., 2007). When used for filtering groundwater, natural zeolite effectively reduces iron and manganese content (Asiva Noor Rachmayani, 2015). This is because the zeolite used had not been activated beforehand and was commonly found in communities. The findings suggest that unactivated zeolite can reduce TDS and prevent physical environmental pollution (Malekmohammadi et al., 2016). However, this method could increase surfactant levels, which may pose chemical risks. The surfactant levels in the water cannot be directly measured but could accumulate and harm both the environment and health. Therefore, activation and modification of zeolite are essential to improve its quality by enhancing the active core, which helps release trapped air in the zeolite crystals, increasing its surface area. Chemical activation using a base is done to clean the pores and remove exchangeable substances.



Source: Research Results

Figure 3. TDS Test with Time and Mass Variations, Material Composition Variation 2

For CaO, with mass amounts of 25 grams, 50 grams, 75 grams, 100 grams, and 125 grams, the TDS levels tended to increase. The rise in TDS in the tested water is due to lime containing dissolved solids, which accumulate in the water. The results indicate that adding lime significantly increases TDS. The increase in TDS is not just due to contaminants in the well water but also because lime contributes dissolved solids, leading to their accumulation. The test confirms the significant impact of adding lime on the increase in TDS.

2. Performance of Equipment Composition in Reducing TDS & Hardness

a. Material Composition Variation 1

In the first stage of testing, as shown in Table 1, the results from the regional health laboratory provide a representation of the water quality in Tonjong Village. The physical and chemical test results indicate that some parameters, including TSS, pH, COD, and BOD, meet the quality standards set by the Ministry of Health Regulation of the Republic of Indonesia. However, parameters such as TDS and Hardness do not meet the required standards. Consequently, after analyzing the results from the laboratory tests, this study focuses on lowering the levels of TDS and Hardness to meet the required standards. The first-stage test used the material composition shown in Figure 1, Variation 1, with the raw material results being checked using a TDS meter.

After determining that some parameters failed to meet the required quality standards, the second-stage test was carried out, as outlined in Table 2, using Variation 1, with the results displayed in the graph below.

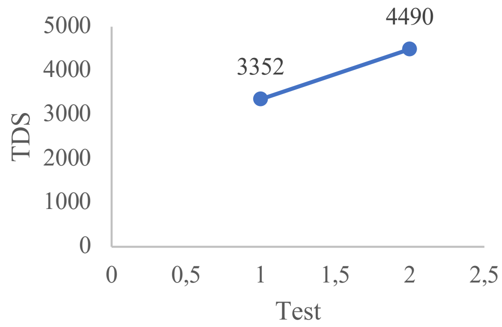
As shown in the graph above, after conducting the test with the material composition from Variation 1, the TDS levels increased. This suggests that the materials used in Variation 1 were not suitable for the tiered water purification method. Before continuing with additional experiments using a different material composition, a third-stage test was conducted. This test focused on the contact time between the raw materials and the mass ratio to determine which material caused the increase in TDS.

Table 3. The results of the TDS physical test using the TDS meter

No	PARAMETERS	UNIT	RESULT	STANDARD PERMENKES RI NO. 32 TAHUN 2017
	Physic			
1	TDS	mg/L	4490	1000

Source: Research data

The materials used in the contact time test consisted only of CaO and Zeolite, with mass ratios of 25 grams, 50 grams, 75 grams, 100 grams, and 125 grams, and a contact time of 120 minutes. The results of this test are presented in Subsection 4.1, which explains the test results for the mass of CaO and Zeolite with respect to time.



Source: Research Results
Figure 4. TDS Test with Variation 1

b. Material Composition Variation 2

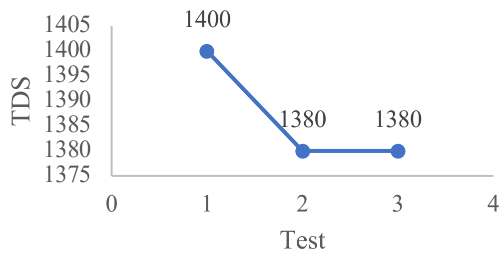
In stage 4 of the testing, the material composition from Figure 2, Variation 2, is utilized, and the raw material is analyzed using a TDS meter.

Table 4. The physical TDS test using the TDS meter.

No	PARAMETERS	UNIT	MINUTE	RESULT	STANDARD
A	Physic				
1	TDS	mg/L	45	1400	1000
			90	1380	
			135	1380	

Source: Research data

The study then progresses with further experiments involving TDS content testing for the second variation. The results of the TDS test, based on prior research, are displayed in Figure 5 below.



Source: Research Results
Figure 5. TDS Test with Variation 2

From the results above, it is clear that the TDS level decreased with the water purification tool using variation 2 at the 90-minute mark, while no decrease was observed at 135 minutes. One of the most crucial factors in determining whether water is safe for consumption is its TDS (Total Dissolved Solids) level. According to the Ministry of Health Regulation No. 492/Menkes/Per/IV/2010, the allowable TDS content in drinking water is 500 mg/L. Both activated carbon and zeolite have been effective in absorbing TDS in water, as they have been widely used in various industries and waste treatment. (Mohan et al., 2008) discussed the creation and properties of activated carbon made from coconut shells (*Cocos nucifera L.*), and activated carbon made from coconut shell charcoal has also been used as an adsorbent to reduce phenol content in wastewater, as reported by (Ahsan et al., 2001), achieving a removal efficiency of 99.745%. (Martínez et al., 2006) also reported that activated carbon from shells could be used to remove iron and organic substances, while (Al-Anber & Al-Anber, 2008) showed that zeolite could be used in ion-exchange filtration. (Guida et al., 2020) reported that natural zeolite effectively reduces iron and manganese levels in groundwater filtration.

This is because the activated carbon and zeolite used in the tests were available in the community without prior activation, indicating that unactivated zeolite can lower TDS levels and prevent physical environmental pollution (Kurniawan et al., 2006). However, this process can be hazardous chemically, as it increases surfactant levels, which can be harmful to the environment and health when accumulated over time. This is why activation and modification processes are crucial to improve zeolite’s effectiveness by increasing its surface area through activation, which removes trapped air from the zeolite's pores. Chemical activation is done using an alkaline solution to clean the pore surfaces and remove exchangeable materials. After observing the TDS reduction, the next step involves testing hardness reduction, as seen in the table below.

Table 5. Results of the chemical hardness tests before and after the water filtration process by Dinas Lingkungan Hidup Kabupaten Serang

	PARAMETERS	UNIT	RESULT	STANDARD
	Chemical			
Before	Hardness	mg/L	1100	500
After	Hardness	mg/L	752,5	500

Source: Research data

The results of the hardness test conducted using the water purification device with variation 2 show that there was a 31.6% reduction in hardness, comparing the initial water hardness before passing through the purification tool to the water after treatment. Hard water, which contains specific minerals—primarily calcium and magnesium ions in the form of carbonate salts—was initially recorded at 1100 mg/l of hardness, which then decreased to 752.5 mg/l after the process. During ion exchange, calcium and magnesium ions are swapped with sodium ions. This occurs when the hard water flows through a natural ion exchange medium, known as zeolite, and then synthetic ion-exchange zeolite is often used. Sodium cation exchange resin is used to soften or remove hardness from water. The calcium and magnesium ions in the hard water are exchanged for sodium ions in the zeolite as it passes through the column. This exchange process continues until the zeolite is saturated, meaning all sodium ions have been replaced with calcium and magnesium ions from the water.

CONCLUSION

The water purification tool's mass composition includes 25 grams, 50 grams, 75 grams, 100 grams, and 125 grams, with the optimal zeolite mass being 125 grams. Based on the composition of variation 2 (Zeolite, Pumice, Coconut husk, Activated charcoal, and Foam) used to lower TDS and hardness, it can be concluded that the water purification tool with variation 2 performs better than variation 1. This is because it reduces TDS from 3352 mg/L to 1390 mg/L and hardness from 1100 mg/L to 752.5 mg/L.

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