Jurnal Aisyah: Jurnal Ilmu Kesehatan

Volume 7, Issue 3, September 2022, p. 921–930
ISSN 2502-4825 (print), ISSN 2502-9495 (online)

Filtration Method with Three Media Combinations to Improve Rainwater Quality as A Drinking Water

Qori Nur Annisa [1], Prayudhy Yushananta [2*], Bambang Murwanto [3]

[1] Politeknik Kesehatan Kementerian Kesehatan Tanjung Karang
[2] Politeknik Kesehatan Kementerian Kesehatan Tanjung Karang
[3] Politeknik Kesehatan Kementerian Kesehatan Tanjung Karang

ARTICLE INFO

Article history:

Received 11 April 2022
Accepted 21 July 2022
Published 10 September 2022

Keyword:

Rain water harvesting; filtration
Pollution
Silica
Zeolit
activated carbon

ABSTRACT

The high rate of population growth and industrialization impact increasing the need for clean water. Meanwhile, the quantity and quality of water are decreasing due to the exploitation of groundwater and industrial and domestic pollution. The utilization of rainwater is an alternative to sustainable water resources, but pollutants greatly influence its quality in the air. This study aims to improve the quality of rainwater as a source of drinking water by using the filtration method. The study used a completely randomized design with two replications. Three media were used (silica, zeolite, and activated carbon), and three thickness levels for each medium. Raw water is rainwater collected from the roofs of people's houses in industrial areas located by the sea, with the characteristics of dense population and heavy traffic. The water quality parameters observed were hardness, nitrite, nitrate, and sulfate. Water quality measurements were carried out before and after the experiment. The research has significantly proven that the combination of three media (silica, zeolite, and activated carbon) can improve the quality of rainwater on the parameters of hardness, nitrite, nitrate, and sulfate. The combination of the three media can reduce the value of hardness (37.9%), nitrite (73.18%), nitrate (61.32%), and sulfate (54.65%). The combination of thickness that is effective in reducing the values of the four parameters is 20 cm (silica), 40 cm (zeolite), and 40 cm (activated carbon). Overall, the parameters are in accordance with regulations. The filtration method with a combination of silica, zeolite, and activated carbon media effectively improve the chemical quality of rainwater so that it is suitable for consumption. However, the disinfection process needs to be carried out to eliminate microorganisms. Further research is needed to determine the saturation level of the filter media.

Kata kunci:

Pemanfaatan air hujan
penyaringan; polusi
silika
zeolit
karbon aktif

**) corresponding author*

Prayudhy Yushananta

Politeknik Kesehatan Kementerian
Kesehatan Tanjung Karang
Jalan Soekarno-Hatta No 6, Bandar
Lampung, Lampung-Indonesia

Email: prayudhyyushananta@gmail.com

ABSTRAK

Tingginya laju pertumbuhan penduduk dan industrialisasi berdampak pada meningkatnya kebutuhan akan air bersih. Sementara itu, kuantitas dan kualitas air semakin menurun akibat eksploitasi air tanah dan pencemaran industri dan domestik. Pemanfaatan air hujan merupakan salah satu alternatif sumber daya air yang berkelanjutan, namun kualitasnya sangat dipengaruhi polutan di udara. Penelitian ini bertujuan untuk meningkatkan kualitas air hujan sebagai sumber air minum dengan menggunakan metode filtrasi. Penelitian menggunakan rancangan acak lengkap faktorial dengan dua ulangan. Tiga media yang digunakan (silika, zeolit, dan karbon aktif), dan tiga tingkat ketebalan untuk setiap media. Air baku adalah air hujan yang ditampung dari atap rumah-rumah penduduk di kawasan industri yang terletak di tepi laut, dengan karakteristik padat penduduk dan padat

DOI: 10.30604/jika.v7i3.1235

lalu lintas. Parameter kualitas air yang diamati adalah kesadahan, nitrit, nitrat, dan sulfat. Pengukuran kualitas air dilakukan sebelum dan sesudah percobaan. Penelitian telah membuktikan bahwa kombinasi tiga media (silika, zeolit, dan karbon aktif) dapat meningkatkan kualitas air hujan pada parameter kesadahan, nitrit, nitrat, dan sulfat. Kombinasi ketiga media tersebut dapat menurunkan nilai kesadahan (37,9%), nitrit (73,18%), nitrat (61,32%), dan sulfat (54,65%). Kombinasi ketebalan yang efektif menurunkan nilai keempat parameter tersebut adalah 20 cm (silika), 40 cm (zeolit), dan 40 cm (karbon aktif). Secara keseluruhan, nilai parameter sesuai dengan regulasi. Metode filtrasi dengan kombinasi media silika, zeolit, dan karbon aktif efektif meningkatkan kualitas kimiawi air hujan sehingga layak untuk dikonsumsi. Namun, proses desinfeksi perlu dilakukan untuk menghilangkan mikroorganisme. Diperlukan penelitian lebih lanjut untuk mengetahui tingkat kejenuhan media filter.

INTRODUCTION

Health services carried out by the government and the The population growth rate and industrialization will impact increasing the fulfillment of clean water needs (Yushananta, 2021; Yushananta and Ahyanti, 2022a, 2022b). It is estimated that by 2050 the world's water supply will increase to meet the needs of 9.7 billion people (UN, 2020). According to (Nair-Bedouelle, 2022), more than 2 billion people live in water-stressed areas, and about 3.4 billion people (45% of the global population) do not have access to safe water and sanitation.

In Indonesia, the need for clean water in 2045 is estimated to be around 11.64 GM3/year (Yushananta and Ahyanti, 2022a, 2022b). The demand for clean water will increase 1.33 times, inversely proportional to the number of people who lack clean water (Utami and Handayani, 2017). Currently, the achievement of access to clean water has only reached 64.54% (BAPENAS, 2019).

The main problems related to water resources are the reduced quantity of water to meet the increasing demand and the decreasing quality of water for domestic purposes (Sasongko et al., 2014; Utami and Handayani, 2017). The decline in water quality is caused by industrial and domestic pollution (Yushananta, 2021; Yushananta and Ahyanti, 2022a, 2022b), both liquid and solid waste (Sasongko et al., 2014). As a result, people consume unsafe water, so they risk digestive diseases and heavy metals such as Cu, Pb, Cd, Zn, and Hg ((Kristianto, 2017; Yushananta and Bakri, 2021). It is estimated that more than 2 million children under five die from unhealthy or polluted (Taiwo et al., 2020; Yushananta, 2021).

The challenge of meeting water has promoted the search for new strategies to diversify the use of sustainable water, including reusing non-latrine household wastewater (greywater), waste utilization, and seawater desalination. However, it requires high investment and maintenance costs (García Soler et al., 2018; Sánchez et al., 2015). One solution to the challenge of increasing water demand at a low cost is rainwater harvesting. Besides reducing the pressure of water demand, the use of rainwater can reduce the run-off effect of rainfall (Jamali et al., 2020; Kisakye and Van der Bruggen, 2018; Semaan et al., 2020; Wurthmann, 2019). The rainwater harvesting has succeeded in suppressing 12.4 -35% of rainwater supply in several cities in various regions (Anie Yulistyorini, 2011).

The main challenge in using rainwater is water quality (Lee et al., 2012; Leong et al., 2017; Nalwanga et al., 2018; Zhu, J. jun et al., 2019). Several research reports state that the results of checking the quality of tank water from rainwater harvesting in several large cities show chemical and microbiological concentrations exceeding drinking water limits (Bae et al., 2019; García Soler et al., 2018; Hamilton et al., 2016; Nalwanga et al., 2018; Sánchez et al., 2015). Rainwater quality is strongly influenced by air quality (Sánchez et al., 2015).

According to Sánchez et al. (2015), pollutants are gases, dust, or particles containing heavy metals, polycyclic aromatic hydrocarbons, dioxins, furans, sulfates, nitrates, and others. The amount of pollutants in the air depends on the number of industries and traffic density and is influenced by meteorological factors (wind speed, temperature, relative humidity) and particle characteristics (size and shape) (Garcia-Montoya et al., 2015; Helmreich and Horn, 2009; Macomber, 2001; Zhu, K. et al., 2004). The presence of pollutants in the atmosphere will be carried away by rainwater and subsequently become a source of pollutants in water tanks (Sánchez et al., 2015). In addition, water quality is also affected by contamination from catchments, pipes, and reservoirs (Yushananta, 2021).

The research aims to improve the quality of rainwater by becoming a source of drinking water by filtration method with silica, zeolite, and activated carbon. The selection of the filtration method is based on considerations of cost and technological convenience so that the community can apply it.

METHODE

Study design and setting

This study is an experimental study with a factorial completely randomized design (CRD). Three factors (filter media) and three levels of each factor were used in this study, namely silica (0 cm, 10 cm, 20 cm); zeolite (0 cm, 20 cm, 40 cm); and activated carbon (0 cm, 20 cm, 40 cm) with a contact time of 5 minutes. The research was replicated twice so that 54 data were obtained for each parameter measurement. The water quality parameters assessed were hardness, nitrate, nitrite, and sulfate. Table 1 describes the treatment combination scheme in the study.

Table 1.
Treatments combination

$S_0.Z_0.AC_0$	$S_0.Z_1.AC_0$	$S_0.Z_2.AC_0$	$S_1.Z_0.AC_0$	$S_1.Z_1.AC_0$	$S_1.Z_2.AC_2$	$S_2.Z_0.AC_0$	$S_2.Z_1.AC_0$	$S_2.Z_2.AC_0$
$S_0.Z_0.AC_1$	$S_0.Z_1.AC_1$	$S_0.Z_2.AC_1$	$S_1.Z_0.AC_1$	$S_1.Z_1.AC_1$	$S_1.Z_2.AC_2$	$S_2.Z_0.AC_1$	$S_2.Z_1.AC_1$	$S_2.Z_2.AC_1$
$S_0.Z_0.AC_2$	$S_0.Z_1.AC_2$	$S_0.Z_2.AC_2$	$S_1.Z_0.AC_2$	$S_1.Z_1.AC_2$	$S_1.Z_2.AC_2$	$S_2.Z_0.AC_2$	$S_2.Z_1.AC_2$	$S_2.Z_2.AC_2$

S = silica, S_0= silica 0 cm, S_1= silica 10 cm, S_2= silica 20 cm. Z = zeolite, Z_0= zeolite 0 cm, Z_1= zeolite 20 cm, Z_2= zeolite 40 cm. AC = activated carbon, AC_0= activated carbon 0 cm, AC_1= activated carbon 20 cm, AC_2= activated carbon 40 cm.

Rainwater samples were taken from the roofs of residents' houses in Panjang Utara Village, Panjang District, Bandar Lampung City. Kelurahan Panjang is a densely populated area located in an industrial area with high traffic density. In addition, in Kelurahan Panjang there is also an international port (Port of Panjang), one of Indonesia's major ports with passenger, goods, and container ship services.

Materials and experimental

The materials used in this research are silica, zeolite, and activated carbon, obtained from the market. Chemicals, whether used directly or in a mixture, such as $CaCl_2$, buffer solution, EBT, sulfanilamide acid, n-Naphthyl solution, brusin solution, H_2SO_4, $BaCl_2$, and others were obtained from Sigma-Aldright. Preparation of the mixed solution was carried out with distilled water. Glassware using Pyrex products, such as a dropper, measuring pipette, volume pipette, Erlenmeyer, measuring cup, funnel, burette, and measuring flask. Meanwhile, a spectrophotometer from DLab (Model SP-UV1100) was used for parameter analysis.

The experimental reactor (Figure 1) consisted of a raw water reservoir and a filter tube. The reactor was made using simple materials such as plastic containers, PVC-pipe, 2L plastic water bottles, faucets, and hoses.

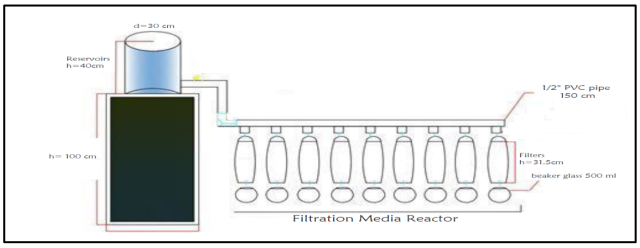

Figure 1. The experimental reactor

The filter media are arranged in a filtration tube, according to the design in Table 1. Raw water (rainwater) is put into a holding tank, then flowed into a filtration tube. The flow speed setting is done so that the contact time on each filtration tube is five minutes. The treated water was collected into a sample bottle and then analyzed to determine the hardness, nitrite, nitrate, and sulfate value. Measurements were also carried out on raw water to determine the parameter content before treatment.

Data analysis

Data analysis was carried out in stages with SPSS 24.0. Descriptive analysis to describe of each research variable using the mean and standard deviation (SD). The single and combined effect of variables (silica, zeolite, and activated carbon) on the decrease in parameter values was calculated using two-way ANOVA. Overall analysis was carried out at the 95% confidence level.

RESULTS AND DISCUSSION

The study's results (Table 2) show that all test parameters in raw water have decreased after processing with a simple filtration method. The hardness value decreased by 37.90%, from 70 mg/L to 43.47 mg/L. The nitrite content in raw water was 0.10 mg/L, which decreased to 0.03 mg/L (73.18%).

The amount of nitrate, which was initially 2.80 mg/L in raw water, after processing became 1.08 mg/L, or decreased by 61.32%. Similarly, sulfate, from 2.39 mg/L to 1.10 mg/L, decreased by 54.65%.

Table 2.
Water quality before and after treatment

Parameters	Before	After	SD	Reduction (%)
Hardness (mg/L)	70.00	43.47	15.19	37.90 %
Nitrite (mg/L)	0.10	0.03	0.03	73.18 %
Nitrate (mg/L)	2.80	1.08	0.93	61.32%
Sulfate (mg/L)	2.39	1.10	0.76	54.65%

Figure 2 shows the decreased average hardness and nitrite parameters based on the filter. In silica (Figure 2a), the hardness decreased from 70 mg/L to 54.53 mg/L, 45.87 mg/L, and 30.47 mg/L at media thicknesses of 0 cm, 10 cm, 20 cm. In zeolite (Figure 2b), it decreased to 58.75 mg/L, 45.83 mg/L, and 40.00 mg/L, at media thicknesses of 0 cm, 20 cm, and 40 cm. While on activated carbon (Figure 2c), the hardness decreased to 59.16 mg/L, 40.00 mg/L, and 31.25 mg/L at media thicknesses of 0 cm, 10 cm, and 20 cm. These results indicate that the best decreasing effect is on silica with a thickness of 20 cm (30.47 mg/L).

The nitrite decrease shows the same trend as the decrease in hardness. In silica (Fig. 2d), the nitrite decreased from 0.10 mg/L to 0.06 mg/L, 0.01 mg/L, and 0.03 mg/L, respectively, at a media thickness of 0 cm, 10cm, 20cm. In zeolite (Figure 2e), it decreased to 0.07 mg/L, 0.03 mg/L, and 0.01 mg/L, at media thicknesses of 0 cm, 20 cm, 40 cm. While on activated carbon (Figure 2f), nitrite levels decreased to 0.05 mg/L, 0.04 mg/L, and 0.02 mg/L, at media thicknesses of

0 cm, 10 cm, 20 cm. These results also showed that the best decreasing effect was on silica with a thickness of 20 cm (0.003 mg/L).

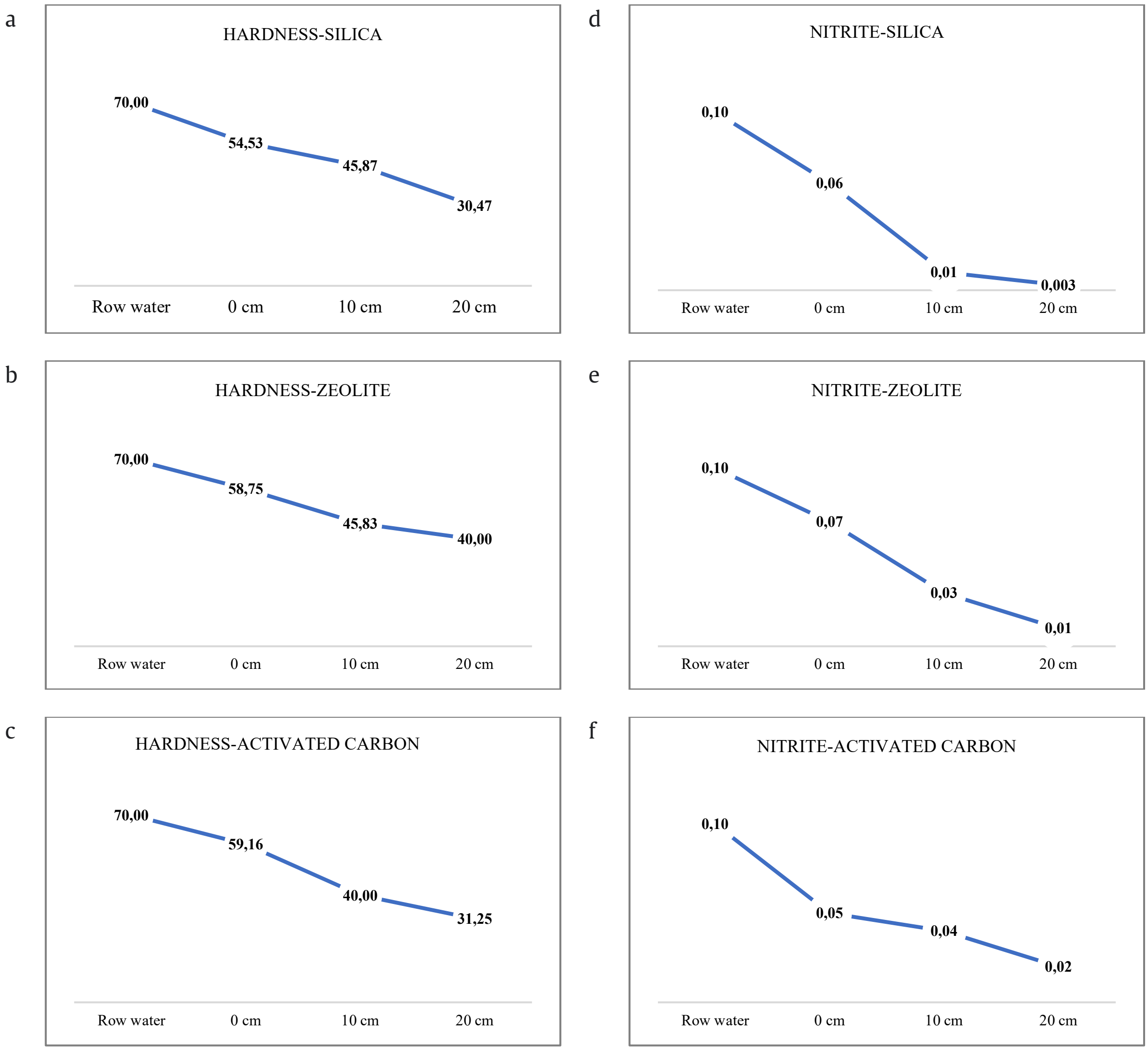

Figure 2. Decrease of hardness (a, b, c), nitrite (d, e, f) based on silica (a-d), zeolite (b-e), activated carbon (c-f).

The trend of nitrate and sulfate by type of filter media is shown in Figure 3. In silica (Figure 2a), the nitrate decreased from 2.80 mg/L to 2.03 mg/L, 0.87 mg/L. and 0.46 mg/L, at media thicknesses of 0 cm, 10 cm, and 20 cm. In zeolite (Figure 2b), it decreased to 2.33 mg/L, 0.64 mg/L, and 0.79 mg/L, at media thicknesses of 0 cm, 20 cm, and 40 cm. Meanwhile, activated carbon (Figure 2c) decreased to 1.28 mg/L, 1.36 mg/L, and 1.12 mg/L at media thicknesses of 0 cm, 10 cm, and 20 cm. These results indicate the best decreasing effect on silica with a thickness of 20 cm (0.46 mg/L).

The trend of sulfate value using silica (Figure 2d), from 2.39 mg/L to 1.49 mg/L, 1.09 mg/L, and 0.78 mg/L, at a media thickness of 0 cm, 10 cm, and 20 cm. In zeolite (Figure 2e), it decreased to 2.01 mg/L, 1.50 mg/L, and 1.51 mg/L, at media thicknesses of 0 cm, 20 cm, 40 cm. Meanwhile, activated carbon (Figure 2f) decreased to 2.06 mg/L, 1.71 mg/L, and 1.28 mg/L at media thicknesses of 0 cm, 10 cm, and 20 cm. These results also showed that the best decreasing effect was on silica with a thickness of 20 cm (0.78 mg/L).

The statistical analysis (Table 3) found that each filter media had a significant effect (p-value<0.05) on the reduction of all water quality parameters (hardness, nitrite, nitrate, and sulfate). The combination of silica and zeolite only gave the effect of decreasing the nitrate value (p-value = 0.025). Meanwhile, the other three parameters (hardness, nitrite, and sulfate) did not show a significant effect.

Table 3 also shows that filtration with a combination of silica and activated carbon has a significant effect on decreasing the hardness (p-value = 0.016), nitrate (p-value = 0.001), and sulfate (0.016). Meanwhile, the combination of zeolite and activated carbon decreased the nitrite (p-value=0.047) and nitrate (p-value=0.023).

The effect of three media is also shown in Table 3. The analysis showed a significant effect on the decrease in the four parameters, namely hardness (p-value = 0.014), nitrite (p-value = 0.027), nitrate (p-value = 0.004), and sulfate (p-value=0.014).

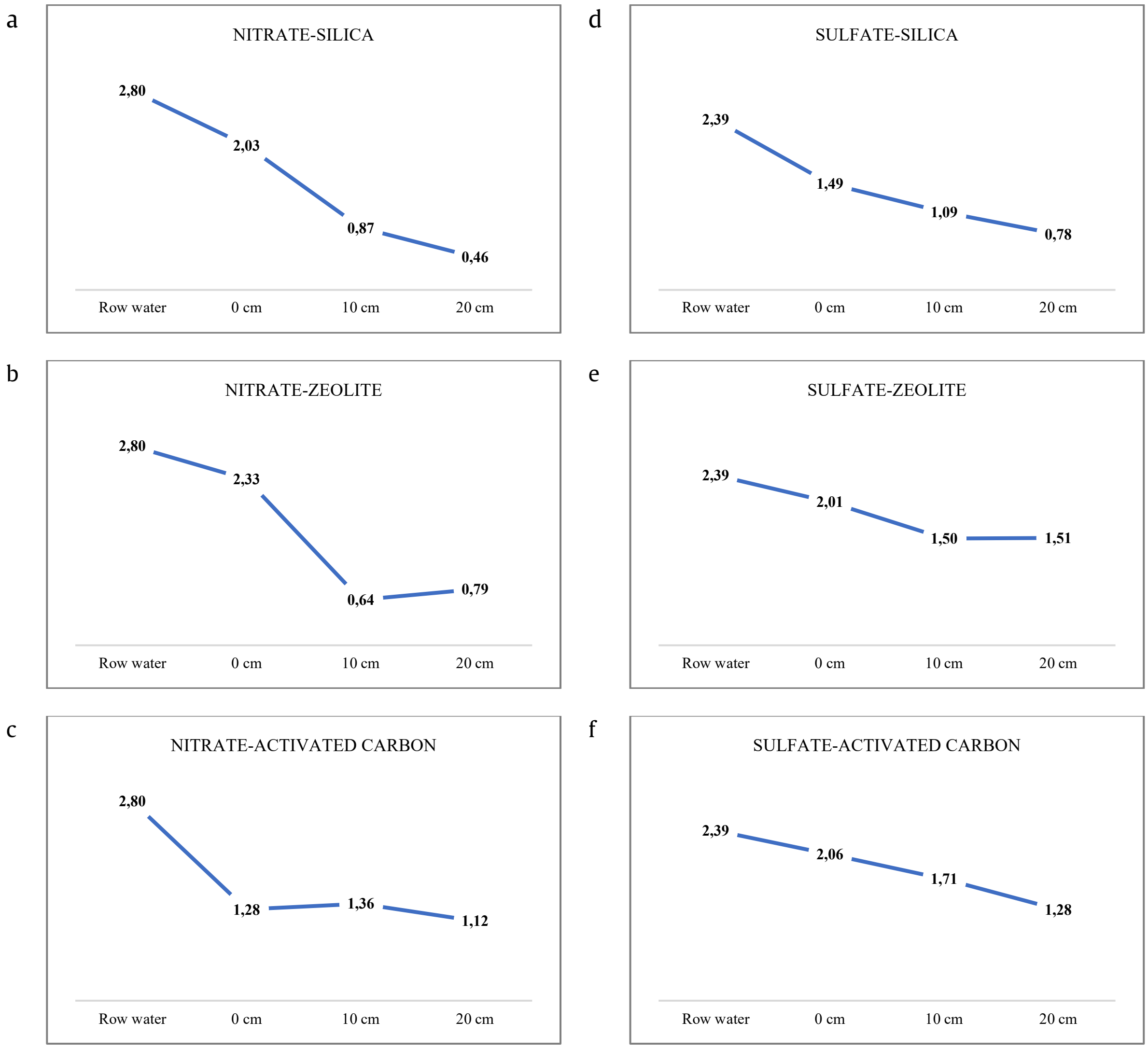

Figure 3. Decrease of nitrate (a, b, c) and sulfat (d, e, f) based on silica (a-d), zeolite (b-e), activated carbon (c-f).

Table 3.
Two-way ANOVA test results

Media	Hardness p-value	Nitrite p-value	Nitrate p-value	Sulfate p-value
Silica	0.000*	0.000*	0.000*	0.000*
Zeolite	0.000*	0.000*	0.001*	0.000*
Activated carbon	0.000*	0.000*	0.000*	0.000*
Silica * Zeolite	0.210	0.368	0.025*	0.210
Silica * Activated carbon	0.016*	0.735	0.001*	0.016*
Zeolit * Activated carbon	0.646	0.047*	0.023*	0.646
Silika * Zeolite * Activated carbon	0.014*	0.027*	0.004*	0.014*

* Signifikan (p-value <0,05)

Table 4 shows the highest percentage of decrease in each parameter based on the type and thickness of the media. In the hardness, the highest percentage (82%) used silica (20 cm), zeolite (40 cm), and activated carbon (40 cm). In the nitrate, the largest percentage was obtained in the medium of silica (20 cm), zeolite (40 cm), and activated carbon (40 cm). Meanwhile, for sulfate, the best reduction (99%) was on silica (10 cm), zeolite (20 cm), and activated carbon (40 cm), as well as on silica (20 cm), zeolite (40 cm), and carbon active (40 cm).

Generally, the study results indicate that the thicker the media used, the greater the percentage decrease in parameter values. Overall, the thickness of the media that gave the best reducing effect was silica (20 cm), zeolite (40 cm), and activated carbon (40 cm).

Table 4.
Percentage of decrease in parameter by type and thickness of filter media

Parameters		S_0			S_1			S_2		
		Z_0	Z_1	Z_2	Z_0	Z_1	Z_2	Z_0	Z_1	Z_2
Hardness	AC_0	0	11	34	5	27	29	13	34	48
	AC_1	13	29	63	27	23	38	29	43	55
	AC_2	30	43	55	32	54	79	54	73	82
Nitrite	AC_1	0	17.5	40	15	97.4	50	10.5	55	75
	AC_2	60	43	96.8	63	96	93.5	86	99.8	99.9
	AC_3	67	95	90.5	100	100	100	100	100	100
Nitrate	AC_1	0	16.4	19.1	7	68	6.4	7.1	66.8	80.4
	AC_2	74.5	89	68.6	7.7	79.8	59.5	78.7	85.4	76.1
	AC_3	74.5	89.5	92.7	78.6	92.5	93.6	84.8	90	95.5
Sulfate	AC_1	0	12.8	27.8	11.1	43.1	50	12.6	87.6	91
	AC_2	17.1	34.9	58.6	92.7	47.7	55.6	39.3	66.7	87.2
	AC_3	18.8	37.2	53.5	25.9	97.7	99	77	98.1	99

S = silica, S_0= silica 0 cm, S_1= silica 10 cm, S_2= silica 20 cm. Z = zeolit, Z_0= zeolit 0 cm, Z_1= zeolit 20 cm, Z_2= zeolit 40 cm. AC = activated carbon, AC_0= activated carbon 0 cm, AC_1= activated carbon 20 cm, AC_2= activated carbon 40 cm.

DISCUSSION

This study uses three types of media (silica, zeolite, and activated carbon) with a filtration method to improve the quality of rainwater as a source of drinking water, especially in water-scarce and coastal areas where groundwater quality is affected by seawater intrusion. Rainwater harvesting is the best solution to meet the increasing water demand because it is cheap and simple technology (García Soler et al., 2018; Jamali et al., 2020; Kisakye and Van der Bruggen, 2018; Naddeo et al., 2013; Semaan et al., 2020; Vialle et al., 2015; Wurthmann, 2019).

Generally, rainwater harvesting includes collecting from the catchment area and storing it in a reservoir (Yushananta, 2021). However, the main challenge is water quality (Leong et al., 2017; Nalwanga et al., 2018; Yushananta, 2021; Zhu, J. jun et al., 2019). Chemical content in rainwater is caused by pollutant contamination in the air which is influenced by the industries and traffic density, meteorological factors, and particle size and shape (Garcia-Montoya et al., 2015; Helmreich and Horn, 2009; Macomber, 2001; Zhu, K. et al., 2004).

The results showed that all test parameters could be derived by a filtration method using silica, zeolite, and activated carbon. Sequentially there was a decrease of 37.90%, 73.18%, 61.32%, and 54.65% for hardness, nitrite, nitrate, and sulfate (Table 2). The study has proven that a filtration method can improve rainwater quality. The most crucial improvement in rainwater quality is the reduction of suspended solids because it is related to the content of chemical compounds, hydrocarbons, heavy metals, and microorganisms (Yushananta, 2021).

Water treatment with the filtration method separates solids from solution to remove suspended particles (Asmadi et al., 2011; Jannah, 2019). According to Helmreich and Horn (2009); Zhao et al. (2019), the filtration method is a simple method that can be used to reduce pollutants in rainwater (such as bacteria, color, taste, odor, hardness, iron, aluminum, organic matter, nitrite, nitrate, sulfate, chloride, and zinc), in order to obtain water that meets health standards.

The results (Table 2) show that the use of silica can reduce the overall test parameters (p-value <0.05). In Figures 2 and 3 it can be seen that silica can reduce hardness (70.00 mg/l to 30.47 mg/l), nitrite (0.10 mg/l to 0.003 mg/l), nitrate (2.80 mg/l). l to 0.46 mg/l), and sulfate (2.39 to 0.78 mg/l). The decrease in all parameters is directly proportional to the thickness of the media. The thicker the media, the greater the effect of decreasing the parameters.

Silica is a mineral consisting of crystalline silica (SIO_2) and contains impurities during the deposition process (Kusnaedi, 2010). Silica is generally used in the early stages and is effective in water filters (Jannah, 2019).

The zeolite showed a significant effect (p-value <0.05) on the decrease in all parameters (Table 3). Figure 2 shows the decrease in hardness (70.00 mg/l to 40.00 mg/l), nitrite (0.10 mg/l to 0.01 mg/l), nitrate (2.8 mg/l to 0.79 mg/l), and sulfates (2.39 mg/l to 1.51 mg/l). The pattern of relationships also looks positive.

According to Kusnaedi (2010); Untari and Kusnadi (2015), zeolites are hydrated alumino-silicate compounds with sodium, potassium, and abrime cations. Zeolites have a unique molecular structure, namely silicon atoms surrounded by four oxygen atoms to form a kind of network with a regular pattern. In some places (in this network), silicon atoms are replaced with aluminum atoms which only have a 3^+ charge, while silicon itself has a 4^+ charge. The presence of this aluminum atom as a whole will cause the zeolite to have a negative charge so that it can bind cations such as iron (Fe), aluminum (Al), or magnesium (Mg). In addition, zeolite also easily releases cations and is replaced with other cations (for example, releasing sodium and being replaced by binding calcium or magnesium) (Marsidi, 2001; Retno et al., 2012; Sirait et al., 2014), Hence, it functions as an ion exchanger and adsorbent in water treatment.

The statistical analysis (Table 3) shows that activated carbon has a significant effect on the decrease in the four parameters (p-vale <0.05). Fig. 2 and Fig. 3 show the decrease in hardness (70 mg/l to 31.25 mg/l), nitrite (0.1 mg/l to 0.02 mg/l), nitrate (2.80 mg/l to 1.12 mg/l), and sulfates (2.39 mg/l to 1.28 mg/l). The pattern of relationships also looks positive.

Activated carbon is an amorphous carbon material with a surface area between 300-2000 m2/gram due to the pore structure. It can adsorb gases, vapors, or materials that are dissolved in liquids (Pitulima, 2018). The adsorbent is a solid substance that can absorb specific components from a fluid phase. Adsorbents usually have microscopic pores, so the adsorption process occurs in these pores (Carolin et al., 2017; Senthil Kumar et al., 2019).

Adsorption is the event of absorption of solutes, ions, or particles that are dispersed in the bulk phase on the solid surface of the adsorbent as a result of the attractive force between the adsorbed substance and the adsorbent surface (Pitulima, 2018; Senthil Kumar et al., 2019; Syauqiah et al., 2011). The atoms and molecules on the interior surface are evenly dispersed, resulting in a uniform attraction force on the entire surface of the adsorbent. This attractive force can be carried out by the molecules in the gas or liquid phase and then joined to the surface of the adsorbent (Pitulima, 2018).

The adoption of activated carbon is highly dependent on its surface area and surface characteristics. The porosity of the adsorbent is essential so that the adsorbent has a large adsorption capacity. The adsorption driving force is highly dependent on the affinity of the adsorbate to the solvent and the affinity of the adsorbate to the adsorbent (Pitulima, 2018; Syauqiah et al., 2011).

According to Wigmans (1986), activated carbon can adsorb gas molecules or dissolved molecules so that they are bound to the pore surface and hold them with weak bonds. The internal structure of the pores influences the adsorption capacity of activated carbon. On the surface of activated carbon, there is a carbon ring arranged in a hexagonal lattice that has carboxyl (-COOH), hydroxyl (-OH), and carbonyl (=O) functional groups. These functional groups can bind to ions, gas molecules, and solutes in liquids.

The surface of activated carbon is positively charged because it gives up electrons. Therefore, the activated carbon surface can adsorb negatively charged anions (an electrochemical mechanism). Electrical phenomena can occur at the interface layer due to an electrolyte solution and the potential difference between charged particles while still in the boundary distance phase (Pitulima, 2018).

The adsorption event on activated carbon occurs due to the intermolecular attraction between the solid molecules and the adsorbed solute being more significant than the solid surface (Syauqiah et al., 2011). Activated carbon also produces a large amount of positive charge so that it can react with negatively charged nitrite and nitrate (Harnowo et al., 2019; Rambe, 2009).

The combination of the three media (silica, zeolite, and activated carbon) showed a better reduction effect than the reduction in each medium (Table 4). According to Naddeo et al. (2013), combining filtration and adsorption methods can improve the quality of rainwater contaminated with air pollutants and reduce turbidity. However, chlorination and periodic cleaning of catchment surfaces and drains must be done to minimize the accumulation of impurities. Obedience to these practices is a factor in avoiding deterioration of rainwater quality during the storage stage, especially contamination of microorganisms (Koplan et al., 1978; Nalwanga et al., 2018; Palla et al., 2017; Waso et al., 2018).

CONCLUSIONS AND SUGGESTIONS

This study has proven that filtration with silica, zeolite and activated carbon can improve rainwater quality. The combination of the three media can reduce the value of hardness (37.9%), nitrite (73.18%), nitrate (61.32%), and sulfate (54.65%). All parameters are in accordance with regulations. Meanwhile, the combination of thickness that was effective in reducing the values of the four parameters was 20 cm (silica), 40 cm (zeolite), and 40 cm (activated carbon). Further research is needed to determine the saturation level of the filter media.

ETHICAL CONSIDERATIONS

Funding Statement

The authors did not receive support from any organization for the submitted work.

Conflict of Interest Statement

The authors declared that they have no conflict of interests.

REFERENCES

Anie Yulistyorini. (2011). Pemanenan Air Hujan Sebagai Alternatif Pengelolaan Sumber Daya Air di Perkotaan. *Teknologi Dan Kejuruan*, *34*(1), 105–114. https://doi.org/10.17977/tk.v34i1.3024

Asmadi, Khayan, and Kasjono, H. S. (2011). *Teknologi Pengolahan Air Minum* (1st ed.). Gosyen Publishing.

Bae, S., Maestre, J. P., Kinney, K. A., and Kirisits, M. J. (2019). An examination of the microbial community and occurrence of potential human pathogens in rainwater harvested from different roofing materials. *Water Research*, *159*, 406–413. https://doi.org/10.1016/j.watres.2019.05.029

BAPENAS. (2019). *Roadmap of SDGs Indonesia Towards 2030* (Issue November).

Carolin, C. F., Kumar, P. S., Saravanan, A., Joshiba, G. J., and Naushad, M. (2017). Efficient techniques for the removal of toxic heavy metals from aquatic environment: A review. *Journal of Environmental Chemical Engineering*, *5*(3), 2782–2799. https://doi.org/10.1016/j.jece.2017.05.029

Garcia-Montoya, M., Bocanegra-Martínez, A., Nápoles-Rivera, F., Serna-González, M., Ponce-Ortega, J. M., and El-Halwagi, M. M. (2015). Simultaneous design of water reusing and rainwater harvesting systems in a residential complex. *Computers and Chemical Engineering*, *76*, 104–116. https://doi.org/10.1016/j.compchemeng.2015.02.011

García Soler, N., Moss, T., and Papasozomenou, O. (2018). Rain and the city: Pathways to mainstreaming rainwater harvesting in Berlin. *Geoforum*, *89*(May 2017), 96–106. https://doi.org/10.1016/j.geoforum.2018.01.010

Hamilton, K. A., Ahmed, W., Palmer, A., Sidhu, J. P. S., Hodgers, L., Toze, S., and Haas, C. N. (2016). Public health implications of Acanthamoeba and multiple potential opportunistic pathogens in roof-harvested rainwater tanks. *Environmental Research*, *150*, 320–327. https://doi.org/10.1016/j.envres.2016.06.017

Harnowo, A., Hidayah, E. N., and Janah, M. (2019). Kapasitas Adsorbansi Arang Aktif Kulit Kacang Tanah Pada Penyisihan Logam Fe. *Jurnal Mineral, Energi, Dan Lingkungan*, *3*(1), 53. https://doi.org/10.31315/jmel.v3i1.2991

Helmreich, B., and Horn, H. (2009). Opportunities in rainwater harvesting. *Desalination*, *248*(1–3), 118–124. https://doi.org/10.1016/j.desal.2008.05.046

Jamali, B., Bach, P. M., and Deletic, A. (2020). Rainwater harvesting for urban flood management – An integrated modelling framework. *Water Research*, *171*, 115372. https://doi.org/10.1016/j.watres.2019.115372

Jannah, F. H. S. (2019). Pengaruh Tinggi Media Pasir Silika Terhadap Penyisihan Kekeruhan Pada Unit Filtrasi Pengolahan Air Minum. *Angewandte Chemie International Edition, 6(11),* 951–952.

Kisakye, V., and Van der Bruggen, B. (2018). Effects of climate change on water savings and water security from rainwater harvesting systems. *Resources, Conservation and Recycling*, *138*(April), 49–63. https://doi.org/10.1016/j.resconrec.2018.07.009

Koplan, J. P., Deen, R. D., Swanston, W. H., and Tota, B. (1978). Contaminated roof-collected rainwater as a possible cause of an outbreak of salmonellosis. *Journal of Hygiene*, *81*(2), 303–309. https://doi.org/10.1017/S0022172400025146

Kristianto, H. (2017). The Potency of Indonesia Native Plants as Natural Coagulant: a Mini Review. *Water Conservation Science and Engineering*, *2*(2), 51–60. https://doi.org/10.1007/s41101-017-0024-4

Kusnaedi. (2010). *Mengolah Air Kotor Untuk Air Minum*. Penebar Swadaya.

Lee, J. Y., Bak, G., and Han, M. (2012). Quality of roof-harvested rainwater - Comparison of different roofing materials. *Environmental Pollution*, *162*, 422–429. https://doi.org/10.1016/j.envpol.2011.12.005

Leong, J. Y. C., Chong, M. N., Poh, P. E., Hermawan, A., and Talei, A. (2017). Longitudinal assessment of rainwater quality under tropical climatic conditions in enabling effective rainwater harvesting and reuse schemes. *Journal of Cleaner Production*, *143*, 64–75. https://doi.org/10.1016/j.jclepro.2016.12.149

Macomber, P. S. H. (2001). *Guidelines on Rainwater Catchment Systems for Hawaii*.

Marsidi, R. (2001). Zeolit Untuk Mengurangi Kesadahan Air. *Jurnal Teknologi Lingkungan*, *2*(1), 1–10. https://doi.org/10.29122/jtl.v2i1.193

Naddeo, V., Scannapieco, D., and Belgiorno, V. (2013). Enhanced drinking water supply through harvested rainwater treatment. *Journal of Hydrology*, *498*, 287–291. https://doi.org/10.1016/j.jhydrol.2013.06.012

Nair-Bedouelle, S. (2022). *Making a water secure world a reality for all through the Intergovernmental Hydrological Programme*. UNESCO. www.unesco.org

Nalwanga, R., Muyanja, C. K., McGuigan, K. G., and Quilty, B. (2018). A study of the bacteriological quality of roof-harvested rainwater and an evaluation of SODIS as a suitable treatment technology in rural Sub-Saharan Africa. *Journal of Environmental Chemical Engineering*, *6*(3), 3648–3655. https://doi.org/10.1016/j.jece.2016.12.008

Palla, A., Gnecco, I., and La Barbera, P. (2017). The impact of domestic rainwater harvesting systems in storm water runoff mitigation at the urban block scale. *Journal of Environmental Management*, *191*, 297–305. https://doi.org/10.1016/j.jenvman.2017.01.025

Pitulima, J. (2018). Studi Daya Serap Karbon Aktif Batubara terhadap penurunan Kadar Logam Cu dalam Larutan CUSO4. *Seminar Nasional Penelitian Dan Pengabdian Masyarakat*, *ISBN: 978-*, 1–5.

Rambe, A. M. (2009). *Pemanfaatan Biji Kelor (Moringa Oleifera) sebagai Koagulan Alternatif dalam Proses Penjernihan Limbah Cair Industri Tekstil*. Universitas Sumatera Utara.

Retno, E., P, A., Rizki, B., and Wulandari, N. (2012). Pembuatan Ethanol Fuel Grade dengan Metode Adsorbsi Menggunakan Adsorbent Granulated Natural Zeolite dDan CaO. *Simposium Nasional RAPI XI FT UMS-2K012*, 45–50. https://publikasiilmiah.ums.ac.id/xmlui/handle/11617/3786

Sánchez, A. S., Cohim, E., and Kalid, R. A. (2015). A review on physicochemical and microbiological contamination of roof-harvested rainwater in urban areas. *Sustainability of Water Quality and Ecology*, *6*, 119–137. https://doi.org/10.1016/j.swaqe.2015.04.002

Sasongko, E. B., Widyastuti, E., and Priyono, R. E. (2014). Kajian Kualitas Air dan Penggunaan Sumur Gali oleh Masyarakat di Sekitar Sungai Kaliyasa Kabupaten Cilacap. *Jurnal Ilmu Lingkungan*, *12*(2), 72. https://doi.org/10.14710/jil.12.2.72-82

Semaan, M., Day, S. D., Garvin, M., Ramakrishnan, N., and Pearce, A. (2020). Optimal sizing of rainwater harvesting systems for domestic water usages: A systematic literature review. *Resources, Conservation & Recycling: X*, *6*, 100033. https://doi.org/10.1016/j.rcrx.2020.100033

Senthil Kumar, P., Joshiba, G. J., Femina, C. C., Varshini, P., Priyadharshini, S., Arun Karthick, M. S., and Jothirani, R. (2019). A critical review on recent developments in the low-cost adsorption of dyes from wastewater. *Desalination And Water Treatment*, *172*, 395–416. https://doi.org/10.5004/dwt.2019.24613

Sirait, M., Bukit, N., and Simarmata, U. (2014). Sintesis Nanozeolit Alam menggunakan Metode Ball Milling. *Jurnal Sains Materi Indonesia*, *16*(1), 7–11. https://doi.org/10.17146/jsmi.2014.16.1.4326

Syauqiah, I., Amalia, M., and Kartini, H. A. (2011). Analisis Variasi Waktu dan Kecepatan Pengadukan Pada Proses Adsorpsi. *Info Teknik*, *12*(1), 11–20. https://doi.org/10.20527/infotek.v12i1.1773

Taiwo, A. S., Adenike, K., and Aderonke, O. (2020). Efficacy of a natural coagulant protein from Moringa oleifera (Lam) seeds in treatment of Opa reservoir water, Ile-Ife, Nigeria. *Heliyon*, *6*(1), e03335. https://doi.org/10.1016/j.heliyon.2020.e03335

UN. (2020). *World Population Prospects 2019: Highlights | United Nations*. United Nation; United Nations.

Untari, T., and Kusnadi, J. (2015). Pemanfaatan Air Hujan Sebagai Air Layak Konsumsi Di Kota Malang Dengan Metode Modifikasi Filtrasi Sederhana. *Jurnal Pangan Dan Agroindustri*, *3*(4), 1492–1502.

Utami, S., and Handayani, S. K. (2017). Ketersediaan Air Bersih untuk Kesehatan: Kasus Dalam Pencegahan Diare pada Anak. In N. Pangaribuan, I. Winani, M. Toha, & S. Utami (Eds.), *Optimalisasi Peran Saint & Tekhnologi Untuk Mewujudkan Smartcity* (1st ed., pp. 211–236). Universitas Terbuka.

Vialle, C., Busset, G., Tanfin, L., Montrejaud-Vignoles, M., Huau, M. C., and Sablayrolles, C. (2015). Environmental analysis of a domestic rainwater harvesting system: A case study in France. *Resources, Conservation and Recycling*, *102*, 178–184. https://doi.org/10.1016/j.resconrec.2015.07.024

Waso, M., Khan, S., and Khan, W. (2018). Microbial source tracking markers associated with domestic rainwater harvesting systems: Correlation to indicator organisms. *Environmental Research*, *161*(September 2017), 446–455. https://doi.org/10.1016/j.envres.2017.11.043

Wigmans, T. (1986). Fundamentals and Practical Implications of Activated Carbon Production by Partial Gasification of Carbonaceous Materials. In *Carbon and Coal Gasification* (pp.

559–599). Springer Netherlands. https://doi.org/10.1007/978-94-009-4382-7_22

Wurthmann, K. (2019). Assessing storage requirements, water and energy savings, and costs associated with a residential rainwater harvesting system deployed across two counties in Southeast Florida. *Journal of Environmental Management*, *252*(September), 109673. https://doi.org/10.1016/j.jenvman.2019.109673

Yushananta, P. (2021). Tinjauan Faktor Yang Mempengaruhi Kualitas Air Pada Sistem Rain Water Harvesting (RWH). *Ruwa Jurai: Jurnal Kesehatan Lingkungan*, *15*(1), 40. https://doi.org/10.26630/rj.v15i1.2178

Yushananta, P., and Ahyanti, M. (2022a). Novel Copolymer Cationic from Agroindustrial Waste using Microwave. *Open Access Macedonian Journal of Medical Sciences*, *10*(E), 458–464. https://doi.org/10.3889/oamjms.2022.8126

Yushananta, P., and Ahyanti, M. (2022b). Utilization of Banana Pith Starch From Agricultural Waste As A Cationic Coagulant. *Jurnal Aisyah : Jurnal Ilmu Kesehatan*, *7*(1), 165–172. https://doi.org/10.30604/jika.v7i1.856

Yushananta, P., and Bakri, S. (2021). Analisis Pembiayaan Peningkatan Akses Air Minum dan Sanitasi Sehat Dengan Pendekatan Cost Benefit Analysis (CBA). *Jurnal Kesehatan*, *12*(2), 306. https://doi.org/10.26630/jk.v12i2.1855

Zhao, Y., Wang, X., Liu, C., Wang, S., Wang, X., Hou, H., Wang, J., and Li, H. (2019). Purification of harvested rainwater using slow sand filters with low-cost materials: Bacterial community structure and purifying effect. *Science of the Total Environment*, *674*, 344–354. https://doi.org/10.1016/j.scitotenv.2019.03.474

Zhu, J. jun, Yu, L. zhong, Xu, T. le, Wei, X., and Yang, K. (2019). Comparison of water quality in two catchments with different forest types in the headwater region of the Hun River, Northeast China. *Journal of Forestry Research*, *30*(2), 565–576. https://doi.org/10.1007/s11676-018-0688-4

Zhu, K., Zhang, L., Hart, W., Liu, M., and Chen, H. (2004). Quality issues in harvested rainwater in arid and semi-arid Loess Plateau of northern China. *Journal of Arid Environments*, *57*(4), 487–505. https://doi.org/10.1016/S0140-1963(03)00118-6