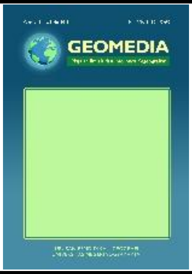

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Effect of Volcanic Sand-Biocarbon-Zeolith Filtration on pH, EC, and TDS values of karst groundwater

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A B S T R A K

Filtrasi merupakan proses yang sangat penting karena bentang alam karst secara alami tidak memberikan perlindungan yang baik terhadap air tanah. Penelitian ini bertujuan untuk mengetahui pengaruh filtrasi dengan bahan pasir, biokarbon, dan zeolit terhadap nilai pH, EC dan TDS. Penelitian dilakukan dengan metode eksperimen dengan menggunakan tiga buah tabung filtrasi yang diisi ketiga bahan tersebut. Sampel diambil dari sepuluh sumber air yang berbeda. Hasil analisis menunjukkan bahwa proses filtrasi kombinasi material pasir, biokarbon, dan zeolit berpengaruh terhadap peningkatan nilai pH, penurunan nilai EC dan TDS. Proses filtrasi melalui kombinasi material pasir vulkanik, biokarbon dan zeolit secara bersamaan memberikan perubahan nilai pH, EC, dan TDS yang lebih signifikan dibandingkan filtrasi dengan material tersebut secara terpisah. Penelitian menyimpulkan bahwa proses filtrasi dapat meningkatkan kualitas air bawah tanah karst sebagai sumber air bersih.

Keywords:
Karst groundwater
Water quality
Water filtration
pH-EC-TDS

A B S T R A C T

Filtration is a very important process because naturally karst landscapes do not provide good protection against groundwater. This study aims to determine the effect of filtration with sand, biocarbon, and zeolite materials on the pH, EC and TDS values. The research was conducted using an experimental method using three filtration tubes filled with these three materials. Samples were taken from ten different water sources. The results of the analysis show that the filtration process of a combination of sand, biocarbon, and zeolite materials has the effect of increasing the pH value, and decreasing the EC and TDS values. The filtration process through a combination of volcanic sand, biocarbon and zeolith materials simultaneously gives a more significant change in pH, EC, and TDS values compared to filtration with these materials separately. The study concluded that the filtration process can improve the quality of karst groundwater as a source of clean water.

Introduction

The Gunungsewu karst landscape has characteristics that are prone to pollution (Adjie, 2003; Widyastuti et al. 2012; Budiyanto et al. 2018, 2020). The bedrock of the karst landscape is carbonate rock which is easily dissolved by acid water (White, 1988; Veni et al., 2001; Ford and William, 2007). This results in high porosity of the bedrock, due to the formation of joints and joints by the dissolution process. Surface water can enter the groundwater network at a rate that varies according to the size of the porous hole. The influx of water often brings contaminants from the karst surface. Pollutants can quickly enter the underground water system in line with the rate of water infiltration. Water inlets vary in size from micro to large holes such as sinkholes and caves. The larger the inlet of water into the underground system, the more varied the types and sizes of pollutants will be. The entry of these pollutants will directly pollute the karst underground water which is very much needed by the population.

The filtration capability of karst landscapes is generally very low (Ravbar, 2007). The existing soil and vegetation layers do not provide much protection against groundwater (Chen et al., 2021). The carbonate rock which is the bedrock does not support the formation of the soil above it quickly and results in the soil not developing properly. Goldscheider (2002) states that the formation of soil minerals in karst rocks only ranges from 0.1 to 10 mm in a 1000 year period. The thickness of the soil has not been able to completely decompose the pollutant in the infiltration process. Pollutants can enter without significant obstruction. This condition ultimately results in the quality of karst groundwater not meeting the quality standards for clean water or drinking water as exemplified in the study (Matthies et al, 2016). Therefore, when karst groundwater is to be utilized, it is necessary to treat it to reduce the concentration of pollutants in the water (Kaetzl et al., 2020; Clark et al., 2012; Liu et al., 2019; Yogafanny et al., 2014). One of them is to modify the filtration process of this karst groundwater. Physical parameters that can be easily used as identifiers are pH, Electric Conductivity (EC), and Total Disolve Solid (TDS).. According to Widyastuti et al (2012), Purwantara et al (2012) and Budiyanto (2018) that Gunungsewu karst groundwater was polluted by surface pollutants caused by various kinds of human activities. Meanwhile, karst groundwater is used as a source of clean water by the community. So it is very necessary to conduct a study on the effect of filtration on the Gunungsewu karst groundwater.

Studies on the development of the filtration model have been carried out by several previous researchers as carried out in Matthies et al (2016), Yogafanny et al. (2014) and Purwantara et al. (2012). Matthies et al (2016) developed a karst groundwater filtration model using sand and applied it to the Bribin underground river. This model uses a reservoir building filled with lava sand. The model can reduce the concentration of E.coli bacteria. The filtered water is not controlled by a real-time and automated water quality control system so that the water produced is still outside the clean water quality standards. The ability of lava sand to reduce the concentration of E.coli bacteria is also shown by Yogafanny et al., (2014). However, the findings from Rasiska et al. (2017) explain that the sand material lacks the ability to reduce chemical pollutants, so other materials are needed as chemical pollutant filtration. This statement is in line with the pollution conditions that occur in the Gunungsewu karst area, where the existing pollutants are not only biological pollutants, but also physical and chemical pollutants (Budiyanto et al. 2018, 2020; Widyastuti et al. 2012; Purwantara et al., 2012; Irshabdillah and Widyastuti, 2020). Studies on the development of filtration materials for the decomposition of chemical pollutants are shown by Kaetzl et al. (2020) and Liu et al. (2019) which utilize biocarbon materials as filters. The findings show that several types of biocarbon can effectively reduce the concentration of chemicals in water. Various studies conducted by Kaetzl et al (2020), Liu et al. (2019), Yogafanny et al. (2014), Purwantara et al. (2012), and Rasiska et al. (2017) were only carried out on a laboratory scale and only references Matthies et al. (2016) were tested in the actual karst groundwater system. Based on this, this study aims to determine (1) the effect of the combination of sand, biocarbon, and zeolite filtration on the pH, EC, and TDS values of karst groundwater, (2) the magnitude of the change in the value of each of these parameters.

Method

The population observed in this study is karst groundwater. Samples were taken from several different outlets of the Spamdus Genjahan karst groundwater distribution network. The number of samples taken was 10 samples for each treatment group. Water samples were taken using a 10 liter bucket. The water is used for flushing each tube and measuring the value of water quality parameters before and after filtration.

Filtration was carried out using three tubes measuring 3 inches in diameter and 90 cm long. The three tubes are connected by a inch pipe. At the bottom of each tube there is a buffer that prevents the filtration material from mixing with each other. Each tube is sequentially filled with sand, biocarbon, and zeolite. Before being used to carry out the filtration test, each tube was saturated with approximately five liters of sample water. Furthermore, the water that is entirely ditusus until clean. This step is intended to remove the remaining water tested previously, so that the resulting value really comes from the sample.

The filtration process is carried out with each filtration material separately, and the filtration materials combined. The process with separate filtration materials is carried out by filtering the sample water with each filtration material. While the filtration process, which uses a combination of the three materials, is carried out using a series of three tubes filled with volcanic sand, biocarbon, and zeolite. Prior to the filtration process, each water sample was measured for pH, EC and TDS values. The value of each of these parameters is recorded as the value of water quality before filtration.

The filtration process with separate materials is carried out by adding water to each tube, each containing volcanic sand, biocarbon, and zeolith. Water is flowed through each tube containing the filtration material. The water that comes out of each tube is collected using a sample glass. The water is then re-measured the parameters of pH, EC and TDS. The results of this measurement are recorded as the post-filtration water quality value of each filtration material.

The filtration process with combined materials is carried out by entering water into the first tube containing sand. The amount of water entered is approximately three liters. Water is flowed through a tube containing a combination of sand, biocarbon, and zeolite materials. The water that comes out of the last tube is accommodated sufficiently by using a sampling glass to measure the parameters of pH, EC, and TDS. The results of the measurement of these parameters are recorded as water quality values after the filtration process of a combination of volcanic sand, biocarbon and zeolite materials.

The pH, EC, and TDS values were recorded in a table using a spreadsheet. The value of each parameter is graphed to represent the different conditions before and after the filtration process. The change in the value of each parameter is calculated by the percentage method with the following formulation.

$$\frac{(Value\ after\ filtration - Value\ before\ filtration)}{Value\ before\ filtration} \text{ x } 100\% \quad ..(1)$$

The amount of change is taken from the absolute value of the calculation results using equation (1). A positive value indicates an increasing change, while a negative value indicates a decreasing change.

Different tests were carried out to determine the significance of differences in water quality parameter values before and after the filtration process. Different tests were carried out statistically using the T test on water quality data before and after filtrationi.

Result and discussion

This study succeeded in testing each of 10 samples of karst groundwater before and after the filtration process from each treatment group. Parameter values of pH, EC and TDS before and after filtration were recorded in the table for later analysis. The results of the filtration from each treatment group are described as follows.

pH, EC, and TDS values filtered with separate filtration materials

Separate filtered pH value

The test process as shown in Table 1 shows that in general the filtration material will increase the pH value. The highest increase was found in the sample water which was filtered using sand material. The increase in pH value in the filtration process using volcanic sand is 0.02 to 0.23 from the value before filtration. Filtration using biocarbon material resulted in the largest increase of 0.18 as shown in sample number 6. The filtration process using zeolite can increase the pH value from 0.01 to 0.16. This group test gave the results of the pH value as shown in Table 1.

Table 1. pH value change before and after filtration

Result	Before filtration	After Filtration		
		Volcanic Sand	Bio carbon	Zeolith
Average	7.846	7.958	7.898	7.904
Average change		0.112	0.052	0.058
Max change		0.23	0.18	0.16
Min change		0.02	-0.05	0.01
Stand. Dev.		0.078	0.068	0.044

Source: measurement test results

The filtration process using volcanic sand material has a wider range of pH value increases than biocarbon or zeolite. This is indicated by the standard deviation value of the pH increase of the three filtration results of the three materials which are 0.078, 0.068, and 0.044, respectively. This value indicates that the results of filtration using volcanic sand will provide a more diverse variation in pH increase compared to biocarbon or zeolite materials.

Figure 1 shows the rate of increase in the filtration rate of volcanic sand material giving the highest increase in pH. The increase in the pH value of sand filtration is almost twice that of biocarbon and zeolite materials. However, changes in the pH value of the three filtration materials showed significant differences. The level of increase in the pH of each filtration material can be seen clearly in Figure 1.

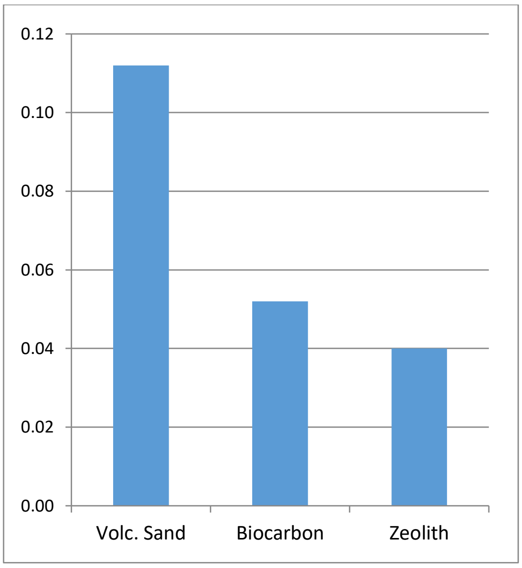

Figure 1. Graph of the rate of increase in pH for each filtration material

This is evidenced by the T-test values of 0.0014, 0.0382, and 0.0025 respectively. This value indicates a significant change in the real pH value from the value before and after the filtration process.

Separate filtered EC value

The measurement of EC values change before and after filtration is shown in Table 2 below.

Table 2. EC value change before and after filtration

Result	Before filtration (μS/cm)	After filtration		
		Volcanic Sand (μS/cm)	Biocarbon (μS/cm)	Zeolith (μS/cm)
Average	641.2	594.2	622.2	619.2
Average change		-47	-19	-22
Max change		138	156	156
Min change		0	70	42
Stand. Dev.		50.326	72.260	68.935

Source: measurement test results

The mean Table 2 shows the change in the EC value of the sample water before the filtration process and after the filtration process. The results of filtration using volcanic sand filtration material showed a decrease in values in all samples. The largest decrease in EC value from this filtration was 138 μS/cm and the smallest was 0 μS/cm. Meanwhile, the filtration process using biocarbon and zeolite materials showed variations in the response. As many as 60% of the samples showed a decrease in the EC value and 40% showed an increase in the EC value. The largest decrease in EC values in biocarbon and zeolite filtration materials showed similarities, reaching 156 μS/cm. Meanwhile, the increase in value produced by filtration of biocarbon and zeolite media is not the same. The largest increase in biocarbon reached 70 μS/cm while in zeolite it was 42 μS/cm. The results of the analysis show that the pattern of increasing and decreasing EC values from the filtration of the three materials is not always in harmony in each sample. The magnitude of the average change can be clearly seen in Figure 2.

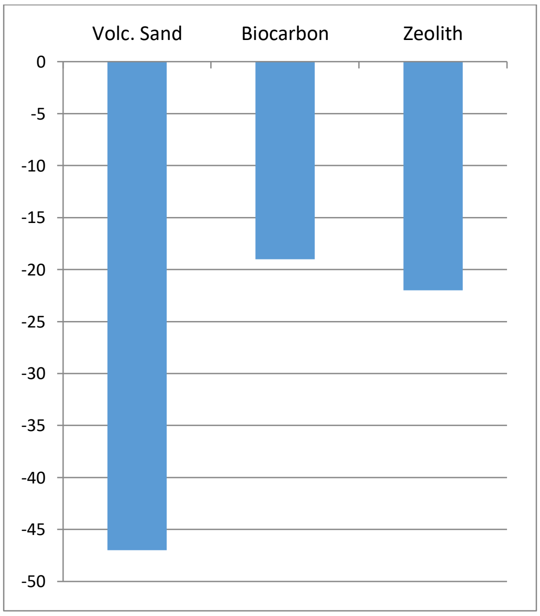

Figure 2. Graph of the rate of decline in EC values for each filtration material

Figure 2 shows that in general the three filtration materials are able to reduce the EC value with the largest decrease in the filtration process using volcanic sand material. The difference test using the T test method shows the values of 0.0161, 0.427, and 0.339 respectively. This value indicates a significant change resulting from the filtration process using volcanic sand. This is indicated by a decrease in the EC value in all samples.

The filtration process using biocarbon and zeolite materials did not show a significant difference in EC values from the water samples before the filtration process and after the filtration process. This is indicated by the increase in the EC value of several samples after the filtration process with biocarbon and zeolite materials separately. However, most of the others showed a decrease in EC values, so that on average the EC values obtained from filtration with biocarbon and zeolite materials were lower than before the filtration process.

Separate filtered TDS value

The measurement of the value of the filtered TDS parameter can be seen in Table 3 below.

Table 3. TDS value change before and after filtration

Result	Before filtration	After filtration		
		Volcanic Sand (ppm)	Biocarbon (ppm)	Zeolith (ppm)
Average	320.8	303.5	309.2	307.8
Average Change		-17.3	-11.6	-13
Max change		60	87	80
Min Change		0	38	19
Stand. Dev.		16.316	36.604	34.868

Source: measurement test results

The mean values from Table 3 show a decrease in TDS values for all filtration materials. The decrease in TDS value indicates the amount of dissolved solids in the sample water can be captured by the three materials. The volcanic sand material separately was able to absorb as much as 17.3 ppm of dissolved solids from the test sample water. This value is the most entrapment value compared to biocarbon and zeolite materials. Furthermore, the different test values using the T Test method showed the values were 0.011, 0.361, and 0.292 respectively. The T test value indicates that a significant change in the TDS value is obtained from the filtration using volcanic sand material. The filtration process using biocarbon and zeolite materials does not produce a significant change in the TDS value. The magnitude of the decrease in the TDS value can be seen clearly in Figure 3 below.

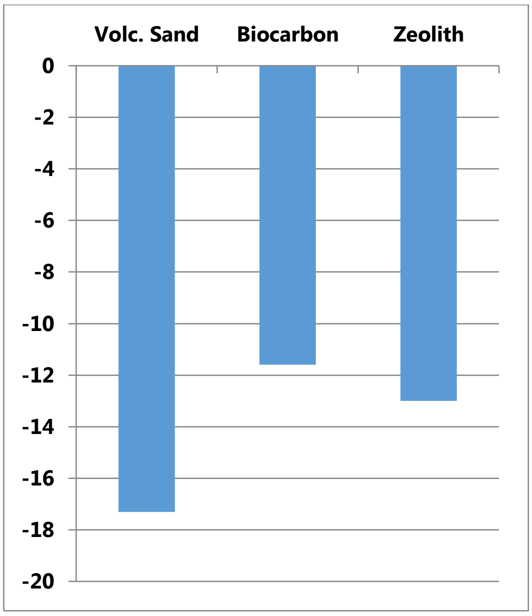

Figure 3. Graph of the rate of decline in the value of TDS on each filtration material.

Values of pH, EC, and TDS as a result of filtration with a combination of volcanic sand, biocarbon and zeolith

The test results of pH, EC, and TDS parameters from the filtration process with a combination of volcanic sand, biocarbon and zeolite materials are shown in Table 4.

Table 4. pH, EC, TDS value before and after filtration with combination material filtration

	pH	EC (µS/cm)	TDS (ppm)
Average	8.08	599	300
Average change	0.29	-50	-23.4
Max change	0.82	110	46
Min change	0.07	10	5
Stand. Dev.	0.219	29.814	11.918

Source: sample test results

Table 4 is the values resulting from testing the samples before and after the filtration process. In general, it can be seen that there is a change in the values before and after the filtration process for all parameters. Changes that occur in the form of increasing and decreasing parameter values that occur in each sample.

pH value of combined filtration

The results of the filtration process showed an increase in the pH value in all samples. The increase in the pH value ranged from 0.07 to 0.82. The results of the measurement of pH parameters showed that the karst groundwater samples before filtration in this study ranged from 7.44 to 8.29. The average pH value of the sample is 7.79. The pH value of the water increases after the filtration process is carried out. The range of pH values after the filtration process is between 7.62 to 8.45. The average pH value after filtration is 8.08. The average value of pH before and after this filtration showed an increase of 0.29. The percentage calculation shows an increase in pH of 4.8% from the previous value. The pH value before and after the filtration process can be seen in Figure 4.

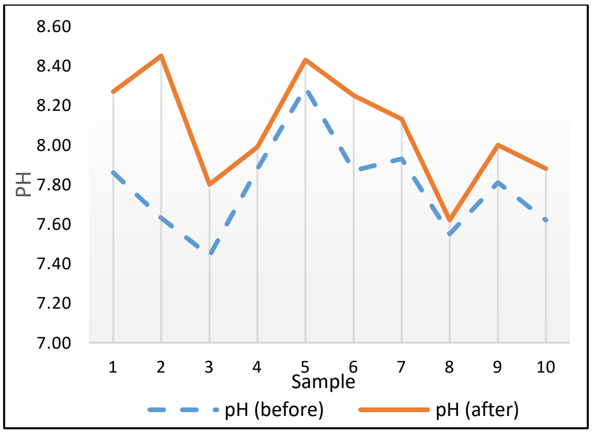

Figure 4. Graph of pH before and after filtration

The pH value before the filtration process of each sample is in the blue dotted line. The pH value of each sample increases to a point on the red line. Based on Figure 1, it is known that the increase in the pH value of each sample is not the same. The biggest increase occurred in sample number two which reached 10.75% of the original value. The smallest change occurred in sample number 8, which was 0.93% of the original value. Prior to the filtration process, the highest pH value was found in sample number 5, namely water samples from resident wells. However, sample number 8 which is also a resident well water shows a different pH value. This condition is possible because the two wells have different groundwater networks. Water is taken by means of a bucket and immediately tested for pH in that place. The lowest pH value is found in sample number 3, namely water that has been accommodated in an open tub.

The value of the T test on the pH parameter values before and after filtration resulted in the Sig value. (2 tailed) of 0.002. This value is below the 0.05 significance limit. Based on this value, it means that there is a significant difference between the pH value before and after the filtration process. This fact shows that the filtration process can change the pH value significantly. The pH value of karst groundwater can be significantly increased through a filtration process using volcanic sand, biocarbon and zeolite materials.

EC value of combined filtration

The results of the measurement of EC parameters from the samples in this study showed a distribution of values between 510 µS/cm to 790 µS/cm. This range of EC values has an average of 649 µS/cm. This value is the EC value before the filtration process is carried out. The test results show a decrease in the value of this EC parameter. The EC value after the filtration process changed to between 478 µS/cm to 708 S/cm with an average value of 599 µS/cm. The change in the average value shows a decrease of 50 µS/cm or 7.7% from the previous value. According to Figure 5 can be clearly seen that the highest EC value is from sample number 8. The water comes from resident wells. Sample number 10 has the lowest EC value. This sample comes from the outlets of the groundwater distribution network in people's homes. The largest change in EC value occurred in sample number 2, and the smallest was in sample number 5. The largest change in EC value was 110 μS/cm or 15.36% of the previous value. The smallest change is 10 μS/cm or 1.76% of the previous value. Changes that occur in the form of a decrease in the concentration value of the EC parameter in the water after the filtration process is carried out. The concentration of EC values before and after filtration can be seen in Figure 5.

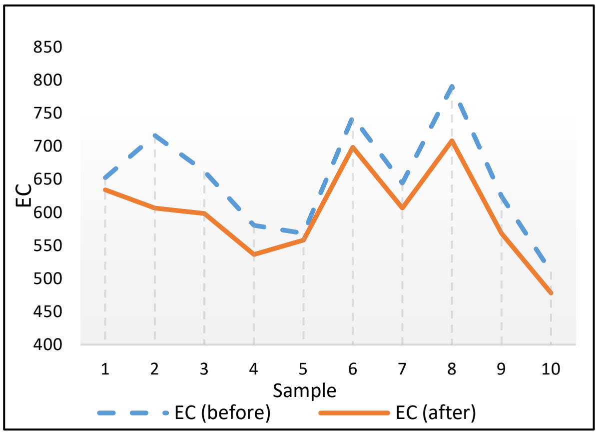

Figure 5. Graph of EC concentration before and after filtration

T test results show the value of Sig. (2 tailed) of 0.000 which means this value is below the value of 0.05. The results of this calculation indicate that there is a significant difference between the EC parameter values before and after filtration. Based on the results of these calculations, it is known that the karst groundwater filtration process using volcanic sand, biocarbon, and zeolith materials is able to significantly reduce the EC value.

filtered TDS value

The results of the TDS parameter measurement show a pattern that is in line with the EC value. The range of TDS values before the filtration process is between 252 ppm to 395 ppm with an average of 323 ppm. This value decreased after the filtration process was carried out to between 239 ppm to 349 ppm with an average of 300 ppm. The range and mean of TDS values showed a decrease in concentration due to the filtration process. Based on the calculation results, it is known that the average decrease in TDS concentration is 23.40 ppm. This value means a decrease of 7.24% from the previous TDS value.

The biggest change in TDS value occurred in sample number 2 while the smallest change occurred in sample number 5. The change in TDS value in sample number 2 was 37 ppm or 10.5% of the previous value. The change in value in sample number 5 is 5 ppm or 1.8% from the previous value. Changes in TDS concentration values can be seen in Figure 6.

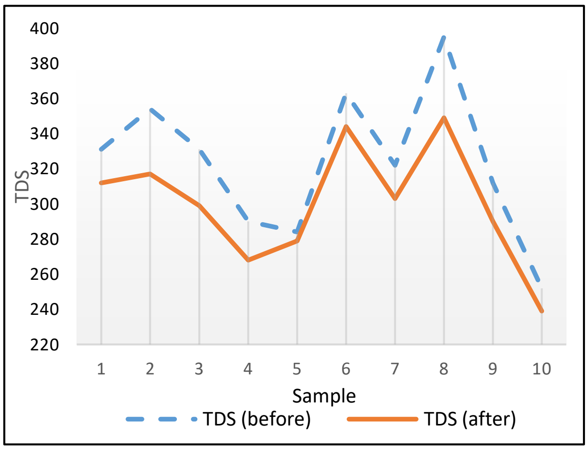

Figure 6. Graph of TDS concentration before and after filtration

The T test of the TDS value before and after the filtration process showed the Sig value. (2 tailed) of 0.000. This value indicates a significant difference between the TDS values before and after filtration. Based on these results, it is known that the filtration process using volcanic sand, biocarbon and zeolite can significantly reduce the TDS value..

Discussion

The filtration process with volcanic sand, biocarbon and zeolite materials changes the pH, EC and TDS values. These changes are in the form of an increase in the pH value, and a decrease in the value of EC and TDS. These changes are values resulting from filtration with volcanic sand, biocarbon, and zeolite materials separately or in combination. These results indicate that the three materials can have similar effects on pH, EC and TDS parameters in the filtration process, either separately or in combination..

Changes in pH value with volcanic sand material separately showed a more significant difference than the biocarbon and zeolite filtration material or with the three materials combined. This finding is in line with the conclusion from Laghari et al. (2018) that filtration with a combination of slow sand and fast sand material is able to increase pH more effectively. This finding indicates that an increase in pH can be obtained by a slower filtration process. The results of this study are in line with this, where when the filtration process time is longer, there is a more significant increase in the pH value. The results of this study are also in line with Heriyani and Mugisidi (2016) which carried out the filtration process with silica sand, activated carbon, and zeolite materials against flood water. The conclusion of the study stated that the increase in the pH value with time. The increase in the pH value is also in accordance with the tests carried out by Rahayu et al. (2015) on sugar factory wastewater. Giving zeolite can increase the pH value of the sugar factory liquid waste. Filtration on volcanic sand, biocarbon and zeolite materials will bind H+ ions and leave OH- ions, thus increasing the pH value of the water. The pH value from the measurement results before the filtration process showed strong karst groundwater characteristics ranging from 7 to 8. The filtration results increased the pH value. However, the measurement results show that water can still be used for water and sanitation purposes in accordance with the Regulation of the Minister of Health of the Republic of Indonesia in 2017.

The filtration process results in a corresponding decrease in the EC and TDS values. This condition is similar to the conclusion from Thirumarlini et al. (2009) which shows a correlation between EC and TDS values in natural water. However, the findings from Rusyidi (2018) show that the correlation between EC and TDS is not always linear, depending on the material contained in the water, in addition to the salinity factor.

The test results in this study indicate that the filtration process with a combination of filtration materials provides a more significant reduction in EC and TDS values when compared to the filtration process with separate materials. In filtration with separate materials, it was shown that the EC and TDS values decreased only for volcanic sand materials. Meanwhile, the filtration process on biocarbon and zeolite materials did not significantly decrease.

The different conditions shown in the previous reference indicate the fact that filtration using the slow sand and fast sand methods by Laghari et al. (2018) on natural water tends to increase the EC and TDS values. This difference is possible because the sample water in this study comes from the Gunungsewu karst groundwater which has naturally higher EC and TDS values compared to the sample water in that study. This filtration process in this study was able to reduce the EC and TDS values through the process of reducing the dissolved material content in the water. Kaetzl et al. (2020) and Liu et al. (2019) statements that are in line with this study, where the addition of biocarbon and zeolite will be able to reduce the concentration of particulate carbon, ammonia-nitrogen, Cu^{2+}, Cd^{2+}, Fe^{2+}, Zn^{2+}, Mn^{2+}, and Pb^{2+}. Reducing these particles will reduce the EC and TDS values of the water.

Conclusion

Based on the results and discussion in this study, it can be concluded that: (1) the filtration process using volcanic sand, biocarbon and zeolite materials is able to increase the pH value, and reduce the EC and

TDS values. (2) The use of volcanic sand, biocarbon and zeolite simultaneously gives better results than the filtration process with separate materials. The filtration process is proven to improve the quality of karst underground water as a source of clean water. Based on the results of this study, it is recommended that karst underground water first carry out a filtration process before being used for various purposes.

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