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by Hary Pradiko

Determination of Reactor Diameter of Wastewater Treatment for Vehicle Wash Facilities Using RA 52 Modified Zeolite Filtration Media

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***Abstract*— One of the wastewater from community activities that not processed through a wastewater treatment plant is vehicle wash's wastewater. This wastewater will potentially pollute the water environment and increased the need for dissolved oxygen for chemical processes (COD) and surfactant. To treat this polluted, wastewater treatment plants are needed. One of the wastewater treatment can use filtration or granular media using modified type RA 52 zeolite. The research aims to reduce the levels of surfactant and COD in vehicle wash's wastewater using several reactor diameters and the zeolite filter media in batch system. The filtration reactor used has a media height of 90 cm, and the size of zeolite media is 1 mm. The results showed that the optimal condition was reach on a variation reactor diameter of 10 cm with a contact time of 5 minutes. Efficiency obtained for removing surfactant from wastewater using the zeolite media is 100% from the initial concentration of 351.81 mg/L and for reducing COD levels with efficiency of 99.84% from the initial results of 4597.94 mg/L. The filtration results can meet the standard requirements set by the Republic of Indonesia Minister of Environment Regulation Number 5 of 2014.**

Keywords*— *reactor diameter, vehicle wash's wastewater, zeolite filtration media, COD, surfactant

I. Introduction

Pollution of wastewater from community activities is increasing, especially in big cities in Indonesia [1], [2]. This pollution will reduce the quality of clean water sources in the Bandung City-Indonesia, such as the Cikapundung River and the Cikapayang River [3], [4]. One of the activities of the community that produces a lot of wastewater is the vehicle wash facilities.

There are many vehicle wash facilities found in Indonesia, especially in metropolitan city like Bandung. Most vehicle wash facilities in Bandung City use clean water from the ground or called groundwater. Recorded groundwater use in the city of Bandung in 2006 reached 76.8 million m^3/ year. This will reduce the soil water capacity which has been less and less due to land conversion [5]. In addition, this business will cause environmental pollution as a result, because there are detergents or anionic surfactant that are contained in the wastewater.

Water saving efforts can be done by recycling wastewater. Recycling wastewater is a wastewater treatment that can be used again. About 60-85% of the total volume of clean water needs will become wastewater [6]. Wastewater is the residual water released from households, industries or other public places, and generally contains ingredients or substances that can danger for human health and environment [7].

One of the wastewater treatment is by filtration [8]. Filtration is a wastewater treatment system that uses solid and porous media to separate suspended solids, colloids and other substances from the liquid [9].

Media that is often used in filtering is zeolite sand [10]. Zeolites have unique ion exchange properties in their structural characteristics [11]. Along with the times, zeolite has been modified with the aim of improving the quality of wastewater treatment. One of the modified zeolites is Treated Natural Zeolite (TNZ), which is a natural zeolite with the same type of structure, which has been modified by the physical method, by heating the zeolite, then zeolite is broken down using a breaker stone, then sifted into certain size granules [12]. Activation activated by chemistry is the second modification after going through physical modification.

Treated Natural Zeolite (TNZ) has anionic exchanger, which is able to exchange negative ions contained in zeolite with negative ions present in wastewater [13]. Based on the description above, a study was need to recycle the vehicle wash's wastewater using a filtration process with Treated Natural Zeolite (TNZ) media in a batch system, which is expected to reduce COD and surfactant concentrations in wastewater.

II. Research Objectives

The purpose of this research was to reduce the levels of COD and surfactant in the vehicle wash's wastewater by varying the reactor diameter of the filtration and determining the contact time of the vehicle wash's wastewater treatment with modified RA 52 zeolite media (TNZ) in batch system.

III. Research Methods

A. *Limitation of Research*

The limits used in this research are as follows:

- Wastewater for this research comes from one of the vehicle wash facilities in the city of Bandung
- The processing media in this study were modified RA 52 zeolite media (TNZ) with a grain diameter of 1 mm.
- The processing flow system in this research is a batch system (no wastewater flow)

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- The diameter of the processing reactor used is 10, 15 and 20 cm.
- The height of the zeolite media used is 90 cm.
- The time of contact processing and sampling used is every 5 minutes as much as 6 times, starting in the 5th, 10th, 15th, 20th, 25th, and 30th minutes.
- The sample water quality parameters examined were only COD for each sample and Surfactant for each sample with the best COD allowance.

B. Tools and Materials

In this research three tubular reactors were used with a diameter of 10 cm, 15 cm and 20 cm and had a height of 100 cm. The media used is the Treated Natural Zeolite (TNZ) type RA 52 media. The use of zeolite as a filter media is based on research conducted by Prasetyo [14] which succeeded in treating domestic wastewater containing soap with phosphate removal of 89.35%. This is also reinforced by the research of Sisyanreswari [15] which succeeded in processing laundry wastewater with the efficiency of reducing COD to 75.36% and Phosphate by 95.01%. The raw water used in this research is an artificial vehicle wash's wastewater that has the same concentration as wastewater taken from the vehicle wash facilities. This research does not use original wastewater, because the original wastewater from the vehicle wash facilities has been diluted by rinsing water, so the concentrations of COD and surfactant in original wastewater are low and very fluctuating depending on the amount of dilution. This condition will complicate the analysis process. To solve this problem, artificial wastewater is used in this research, so that the concentration of COD and wastewater surfactant is stable and high enough to test the maximum capability of the treatment system. The production of raw water is done by dissolving the raw material of vehicle washers that are used at the vehicle wash facilities using tap water at the Unpas Environmental Engineering Water Laboratory.

C. Method

This research is experimental, using a pretest and posttest research system, namely research by measuring COD and surfactant in artificial vehicle wash's wastewater before and after passing through a filtration reactor tube containing modified RA 52 zeolite media. There are several variables that are estimated to affect the removal of COD and surfactant. These variables are media height, reactor diameter, diameter of the media, and contact time of artificial vehicle wash's wastewater with zeolite media in the filtration reactor. In this research only 2 variations were presented, namely variations in reactor diameter and variations in contact time, because this research is the initial stage of a research series related to recycling of vehicle wash facilities wastewater. In addition, there are not many journals that discuss the variation in reactor diameter and contact time between wastewater from vehicle wash facilities and zeolite media. The research flow chart can be seen in Fig. 1.

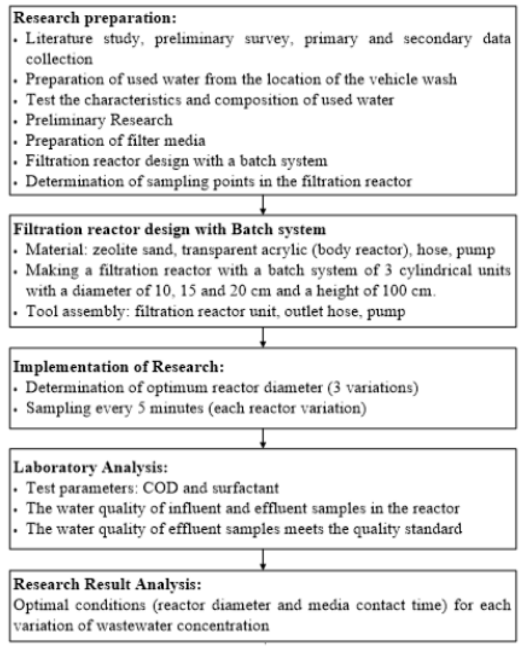

Fig. 1. The Research Flow Diagram

D. Research Design

The design of the research can be seen in Fig. 2. The transparent tube filtration reactor made of acrilic with a reactor diameter of A = 10 cm, B = 15 cm, and C = 20 cm, reactor height of 100 cm, and maximum media height in in a reactor of 90 cm.

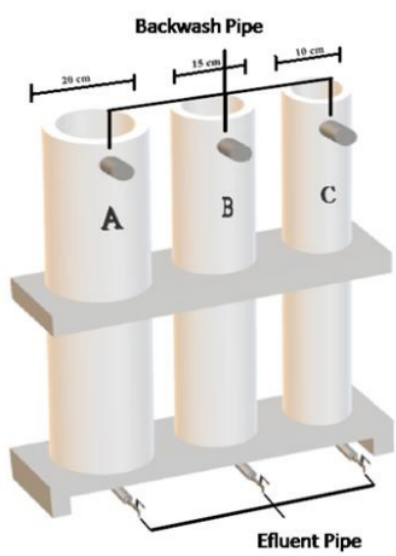

Fig. 2. Research Reactor

E. Implementation of Research

1) Making Raw Water

The raw water used in this study is artificial wastewater, with preparation as follows:

- Sampling of wastewater from the vehicle wash facility to check COD and surfactant concentrations.
- Artificial wastewater is made by mixing soap obtained from the vehicle wash facility with tap water from the Water Laboratory of Environmental Engineering Unpas in accordance with known concentrations of COD and surfactant before.
- Artificial wastewater is made by mixing 53.88 mL of soap with tap water 15 liters of Unpas Environmental Engineering Water Laboratory.

2) Reactor Diameter Variations

The reactor tube variations used were tube A (diameter 20 cm), B (diameter 15 cm), and C (diameter 10 cm) with the contact time of media with wastewater in the reactor for 5, 10, 15, 20, 25, and 30 minutes. The size of the reactor diameter was chosen based on the level of ease of installation and placement in the vehicle wash facility, and according to the size of the filter units that are sold on the local market. The grain size of zeolite used is 1 mm. The selected reactor diameter is determined from the most optimum removal for COD and surfactant parameters contained in wastewater, and meets the wastewater quality standards specified in the applicable regulations. Illustration of reactor conditions for several variations in reactor diameter using media height of 90 cm can be seen in Fig. 3.

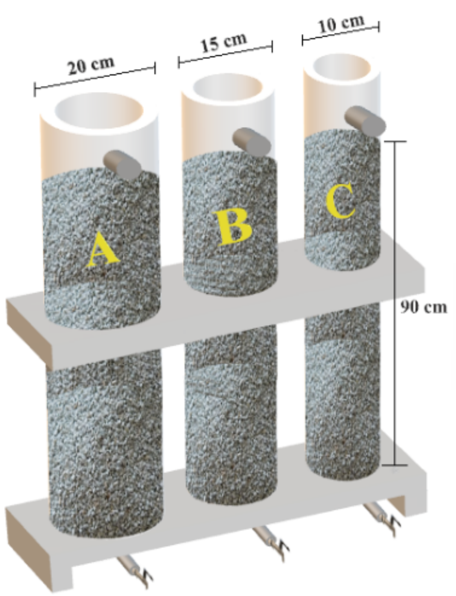

Fig. 3. Illustration of Reactor Conditions for Several Reactor Diameter Variations.

3) Time Variations in Media Contacts

This research uses combination processes which is adsorption process and filtration process with a batch system, so that during the treatment process the wastewater does not flow but the wastewater is left idle for a specified time. Wastewater is only flowed when entering the wastewater into the reactor and at the sampling time. The wastewater is entered from the top of the reactor manually and flows by gravity. After all the media in the reactor were submerged, then the detention time (td) variation was carried out. This is done to get the optimum contact time in COD and surfactant removal. The variation of contact time carried out in this research was 5, 10, 15, 20, 25, and 30 minutes.

4) COD and Surfactant Tests

Examination of COD and surfactant concentrations was carried out before and after processing. COD examination was carried out on all samples of wastewater. Samples with the best reduction results in COD testing will be examined for surfactant concentration.

The principle of examining COD is that organic matter is oxidized with excess $K_2Cr_2O_7$ solution in acidic conditions. The excess $K_2Cr_2O_7$ is titrated again with a solution of Ferrous Ammonium Sulfate (FAS) $Fe(NH_4)_2(SO_4)_2$ using the Ferroin indicator. A standard solution of Fero Ammonium Sulfate (FAS) is standardized to determine the actual concentration of the solution. The COD examination method is as follows [16]:

- Prepare equipment as follows: beaker, measuring cup, watch glass, spatula, analytic balance, 10 ml measuring pipette, drop pipette, test tube, block digester, statif and clamp, burette, 50 ml erlenmeyer, test tube rack, measuring flask, UV-Visible Spectrophotometer.
- Take the sample as much as 2.5 mL and put in a test tube.
- Add the sample with the 1.5 mL digestion solution and 3.5 Reactions of Sulfuric Acid-Silver Sulphate.
- Shake 10 times, then heat the block digester for 2 hours.
- After cooling, put the sample into an erlenmeyer flask and add 1 drop of Ferroin indicator.
- Titrate the sample with FAS solution (Ferro Ammonium Sulfate) until the sample color becomes brick red.
- Calculate the volume of the used FAS solution.

The principle used in surfactant examination is Methylene Blue Anionic Surfactant (MBAS), where anionic surfactant contained in wastewater react with methylene blue to form blue ion pairs which dissolve in organic solvents. The blue intensity formed is measured by a spectrophotometer at a wavelength of 652 nm. Uptake that is measured is equivalent to the level of anionic surfactant. Surfactant examination methods are as follows [16]:

- Prepare equipment as follows: beaker, measuring cup, watch glass, spatula, analytic balance, 10 ml measuring pipette, drop pipette, 10 and 25 ml goiter pipette, test tube, statif and clamp, burette, 50 ml erlenmeyer, tube rack, reaction, measuring flask, Separating Funnel, UV-Visible Spectrophotometer.

- Take the sample as much as 100 mL, and put in a separating funnel.
- Add the sample with 20 mL of methylene blue solution and 10 mL of cloroform.
- Close the sample container and shake for 1 minute.
- Remove the sample and separate the surfactant that has been bound by methylene blue.
- Add cloroform with the same treatment 2 times.
- Put back the collected surfactant phase into a separating funnel and add 50 mL of washing solution.
- Close the sample container and shake for 1 minute.
- Add 10 mL of cloroform, remove the surfactant phase, and hold it into a measuring flask.
- Add cloroform with the same treatment 2 times.
- Dispose of the water in the separating funnel and continue adding cloroform with the same treatment 2 times.
- Insert the solution into the cuvette, and then read using a UV-Visible Spectrophotometer.

5) *Data Analysis*

The results of COD and surfactant tests that have been processed are then compared with COD and surfactant levels before processing. The efficiency of each variation can be determined by using formula [17]:

$$E = (C_0 - C_t) / C_0 \times 100\ \% \quad (1)$$

Where:

E = Efficiency (%)

C_0 = Initial COD and surfactant concentration (mg/L)

C_t = COD and surfactant concentration after processing (mg/L)

IV. Results And Discussion

A. Reactor Diameter Variations

Determination of the optimum reactor diameter was carried out using a tubular reactor with a diameter of D1 = 10 cm, D2 = 15 cm, and D3 = 20 cm, reactor height 100 cm and the height of the modified zeolite media in the reactor was 90 cm. The test uses a modified 1 mm zeolite media grain. The COD and surfactant values obtained can be seen in Table I and Table II.

TABLE I. Results of COD on Reactor Diameter Variations

Vari-ation	Reactor Diameter (cm)	Contact Time (minutes)	COD		
			Initial Concen-tration (mg/L)	*Treated Concen-tration (mg/L)*	*Removal (%)*
D1	10	5	452.26	7.54*	98.33
		10		11.31	97.50
		15		30.15	93.33
		20		79.14	82.50
		25		60.30	86.67
		30		105.53	76.67
D2	15	5	452.26	28.38*	93.72
		10		60.30	86.67
		15		71.61	84.17
		20		90.45	80.00
		25		105.53	76.67
		30		94.22	79.17
D3	20	5	527.63	11.31*	97.86
		10		48.99	90.71
		15		60.30	88.57
		20		82.91	84.29
		25		79.14	85.00
		30		94.22	82.14

Description: * Best COD concentration

TABLE II. Results of Surfactant on Reactor Diameter Variations

Vari-ation	Reactor Diameter (cm)	Contact Time (minutes)	Surfactant		
			Initial Concen-tration (mg/L)	*Treated Concen-tration (mg/L)*	*Removal (%)*
D1	10	5	351.81	0	100
D2	15	5	251.25	1.24	99.51
D3	20	5	317.5	14.16	95.54

Based on Table I and Table II, it can be seen that variations in reactor diameters and contact time affect the removal of COD and surfactant. The initial concentration of COD was 452.26 - 527.63 mg/L and the surfactant was 251.25 -351.81 mg/L. Both of these parameters showed a significant decrease in concentration after being processed using all variations in the reactor diameter. Graphically, a decrease in COD concentration on variations in reactor diameter can be seen in Fig. 4.

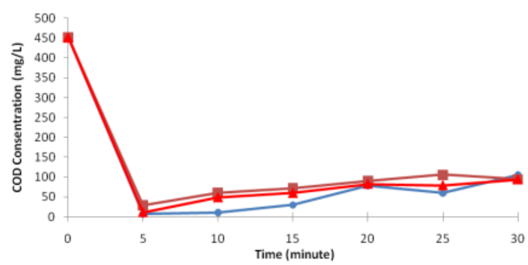

Fig. 4. COD Concentration Decreasing in All Diameter Variation. ●: D1 Variation. ■: D2 Variation. ▲: D3 Variation.

From Fig. 4, in all variations in reactor diameter in the 5th to 30th minute there was a decrease in COD concentration, with a decrease in reactor diameter of 10 cm to 7.54-105.53 mg/L, at a reactor diameter of 15 cm experiencing the decrease was 28.38-105.53 mg/L, and the reactor diameter of 20 cm decreased by 11.31-94.22 mg/L. The best COD removal was obtained at the contact time for 5 minutes and the time was chosen to conduct surfactant examination. The results of this COD removal are in line with the research conducted by Sisyanreswari [15], where zeolite media has very good adsorption power to decrease in

TSS, COD, and Phosphate in Laundry Waste. Graphically, a decrease in surfactant concentration in several variations in reactor diameter can be seen in Fig. 5.

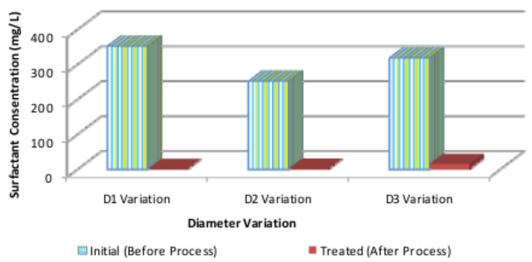

Fig. 5. Surfactant Concentration Decreasing in All Diameter Variation. ●: D1 Variation. ■: D2 Variation. ▲: D3 Variation.

From Fig. 5, it can be seen that the concentration of surfactant has decreased. In a reactor with a diameter of 10 cm, the concentration of surfactant drops to 0 mg/L; in a reactor with a diameter of 15 cm, the concentration of surfactant dropped to 1.24 mg/L; and in a reactor with a diameter of 20 cm, the concentration of surfactant dropped to 14.16 mg/L. During the removal process, Treated Natural Zeolite (TNZ) type RA 52 exchanges SO_4^{2-} ions contained in zeolites with $RO\text{-}SO^{3-}$ ions contained in wastewater [15]. When SO_4^{2-} ions have run out and zeolite cavities have been filled with $RO\text{-}SO^{3-}$, zeolite is unable to carry out ion exchange processes. This means that zeolite has reached its saturation point. To regenerate zeolite, ammonium sulfate $(NH_4)_2SO_4$ salts are used. During the regeneration process, zeolite will exchange $RO\text{-}SO^{3-}$ ions with SO_4^{2-} ions. $RO\text{-}SO^{3-}$ will be released from zeolite and replaced with SO_4^{2-} ions [14]. The results of the percentage of COD removal with variations in reactor diameter can be seen in Fig. 7.

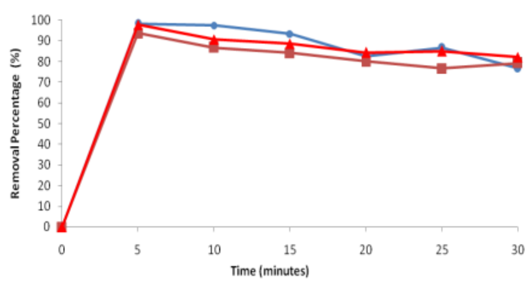

Fig. 6. The Percentage of COD Concentration Increasing in All Diameter Variation. ●: D1 Variation. ■: D2 Variation. ▲: D3 Variation.

From Fig. 7, the percent decreasing of COD concentration in the reactor with a diameter of 10 cm is 98.33%; in a reactor with a diameter of 15 cm by 93.72%, and in a reactor with a diameter of 20 cm at 97.86%. The best percentage of removal was obtained at the contact time for 5 minutes at each variation of the reactor diameter. There is a possibility that the optimum conditions for COD removal are achieved at the time of contact less than 5 minutes. But because in this research the sampling process takes time so that the sample volume is sufficient for COD inspection, then the sampling time interval is set to 5 minutes. Decreasing the percentage of COD removal after contact for 5 minutes occurs because there are some pollutants that have been absorbed by the zeolite released and dissolved back into the solution [18]. The release of pollutants from zeolite bonds is caused by a weak bond between zeolite and pollutants due to the thick layer of pollutants around the zeolite [19].

In surfactant removal, the the examination result of surfactant removal at the contact time of 5 minutes obtained a percentage of removal in a reactor with a diameter of 10 cm by 100%, in a reactor with a diameter of 15 cm at 99.51%, and a reactor with a diameter of 20 cm at 95.54%.

From both the COD and surfactant parameters the best result was obtained from a reactor with a diameter of 10 cm. This result raises the assumption that the smaller the reactor diameter is used, the better the results obtained and the greater the reactor diameter used the worse the results obtained. However, this statement still needs to be proven by further research using reactor diameters smaller than 10 cm or larger than 20 cm.

The use of zeolite media with a size of 1 mm in this research gives quite good results. The results of this research are in line with the research conducted by Prasetyo [14], where 1 mm media grain size has very good adsorption power with a percentage of removal of 95.77%. According to Pratiwi [17], the smaller the size of the zeolite diameter, the greater the contact surface area. The large surface area causes more space and more pores in the zeolite. The empty space on zeolite functions as a place to attach pollutant particles adsorbed and the pores on zeolite function as the entry path of wastewater containing pollutant particles which will be adsorbed. The more empty space and pores make zeolite able to adsorb more and more pollutant particles [20].

The larger the reactor diameter, the worse the removal occur. This happens because the ratio between wastewater and zeolite media is not balanced. The more media volume, the better the results obtained [21]. This research is in line with the theory which states that the greater the load of wastewater, the more the amount of solute can be adsorbed until a certain balance is reached, where the rate of the absorbed substance is the same as the substance released from the adsorbent [15].

B. *Comparison of Results with Quality Standards*

After examining COD and surfactant from reactor diameter variations, then the results are compared with the quality standards contained in the Minister of Environment Regulation of the Republic of Indonesia No.5 of 2014, with COD quality standard of 180 mg/L and the surfactant quality standard is 3 mg/L.

From Table I and II, the concentration of treated samples that met the quality standard was obtained from reactors with a diameter of 10 cm with COD of 7.54 mg/L and for surfactant of 0 mg/L, and from a reactor with a diameter of 15 cm with COD of 28.38 mg/L and for surfactant at 1.24 mg/L. The results of processing samples that did not meet the quality standards occurred in a reactor with a diameter of 20 cm which produced a surfactant concentration of 14.16 mg/L. Thus the selected reactor is a reactor with a diameter of 10 cm, because the reactor produces processing effluent with the smallest concentration of pollutants.

C. *Test Results for Zeolite Adsorption Ability*

Testing of zeolite adsorption ability was carried out using the selected reactor configuration, namely using zeolite with grain size of 1 mm, media height in the reactor 90 cm, using a reactor with a diameter of 10 cm and contact time for 5 minutes. This test is carried out by weighing zeolite media before and after use. The zeolite media is first dried in the sun to remove water content. After the zeolite is dried, the two zeolite media are weighed. The results is that the initial zeolite (before processing) has a weight of 6.52 kg, while the final zeolite (after processing) has a weight of 6.56 kg. This shows that there is a final weight difference and an initial weight of 40 grams from 3.4 liters of artificial vehicle wash's wastewater sample. From the weight difference of zeolite media shows that the adsorption process that has occurred in zeolite media has taken place. According to Kundari and Wiyuniati [22], the adsorption event is a surface phenomenon, namely the addition of concentration or weight of certain components on the surface between two phases (the initial phase and the final phase). Referring to the theory and the results of weighing the initial and final zeolite weight, it can be believed that in this research the adsorption process occurred.

V. CONCLUSIONS

The conclusions were obtained that decreasing the concentration of COD and surfactant in vehicle wash's wastewater using batch reactors with a diameter of 10 cm and a modified RA 52 type zeolite media height of 90 cm in the 5th minute of contact time showed the best results, by reducing the COD concentration from the initial concentration of 452.26 mg/L to 7.54 mg/L (98.33% efficiency) and the surfactant concentration from the initial concentration of 351.81 mg/L to 0.00 mg/L (100% efficiency). The process that occurs in this research is an adsorption process, where there has been a weight addition in zeolite media of 40 grams after processing vehicle wash's wastewater using the reactors.

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