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Rainwater Treatment Using Treated Natural Zeolite and Activated Carbon Filter

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Abstract—Rainwater is an alternative sources of drinking water. The rainwater treatment process should be conducted before the rainwater can be consumed. One of the water treatment process is filtration. Zeolites and activated carbon are often used as filtration media due to its high availability and water pollutants removal efficiency. This research aims to measure filtration efficiency and the production cost of rainwater filtration treatment using modified/treated natural zeolite (TNZ) and activated carbon filter. Types of filter media used in this research are TNZ RC.32 (adsorbent for total dissolved solid, total suspended solid, CO2 and alkalinity), TNZ RC.42 (cation exchanger for Fe, Mn, color, and organic matter) and activated carbon filter. The research is conducted using four variations of filters configuration and two variations of reactor volume. The parameters tested are turbidity, total dissolved solid, pH, organic matter, and coliform. Reactor debit used is 0.01 l/sec. Filter configuration of TNZ RC.32 and activated carbon filter with 1.5 liter reactor volume has the highest organic substances removal efficiency by 58.85% and the lowest reactor production cost of Rp. 560,600. The results of rainwater treatment meets Indonesian drinking water regulation quality standards.

Keywords—Activated Carbon, Filtration, Rainwater, Treated Natural Zeolite

INTRODUCTION

Rainwater is an alternative sources of drinking water which is not widely used in Indonesia although its rainfall is quite high between 2000-4000 mm/year. Rainwater needs to undergo treatment process before it can be used as drinking water. This is due to air pollutants contamination from industry's exhaust gases and transportation emissions. Moreover, the condition of the rooftop catchment area used in the rainwater harvesting that affect the quality of the rainwater collected.

Problems faced by Indonesia's households in using rainwater as an alternative source of drinking water is unavailability of inexpensive and simple rainwater processing methods which can be performed by every households. Appropriate rainwater treatment method is required to be develop.

Common rainwater treatment used are water pH correcting process, water purification and removal of bacteria. Water purification process generally conducted using filtration. Several studies of rainwater filtration treatment technology has been carried out, ranging from simple filtration using sand, fibers, and charcoal filtration media to the latest media, such as the use of reverse osmosis.

Study on rainwater treatment using filtration with granular activated carbon as a pre-treatment, followed by membrane filtration indicated that the filtration system can reduce turbidity, organic matter and heavy metals contained in rainwater up to the quality of drinking water [1].

This research aims to examine the application of filtration technology using modified/treated natural zeolite (TNZ) media in order to obtain the most effective and efficient filter composition. TNZ used in this research is local natural zeolite that has received physical and chemical treatment. TNZ is composed by many different types of natural zeolites and each type has different functions. This research conducted using TNZ and activated carbon filter media. The filter media selection is based on its availability, removal efficiency, low cost and simple operational processes.

METHODOLOGY

This research is an experimental research. Five steps were conducted in order to measure filtration efficiency and the production cost of rainwater filtration treatment. The steps are as follows:

a. Rainwater quality assessments

The rainwater is collected from houses with tile rooftop. Tiled rooftop was chosen because the majority of houses in Indonesia is using tile rooftop. The rainwater assessed is collected after more than 5 minutes duration of the rainfall. The first 5 minutes of the rainwater is not being assessed because it will rinse or cleans the house rooftop from dust and dirt. So the rainwater quality is not suitable for drinking water. The rainwater quality can be seen in below table.

Table 1. The Rainwater Quality

pH	Turbidity (NTU)	TDS (mg/l)	Organic matter (mg/l)	Bacteria
6,06	17,34	21,67	77,22	2400+

Configuration of filtration reactor design and variations

The research conducted with four variations of filters configuration and two variations of reactor height of 30 cm and 60 cm and volume of 1.5 liters and 3 liters respectively. Cartridge reactor of 1.5 liters volume diameter is 1 ½ inch and 20 cm of height. Whereas cartridge reactor of 3 liters volume diameter is 2 inches and 55 cm of height

The rainwater is collected from a building with tile rooftop. This is due to the majority of the households in Indonesia are using tile rooftop. The rainwater collected is rainwater after more than 5 minutes duration of the rainfall.

Type of TNZ used in this study are RC.32, RC.42 and activated carbon. Active carbon used is activated carbon made from coconut shell. Function of each filter media used are as follows:

- TNZ RC.32 function is to reduce TDS, TSS, CO2 and alkalinity
- TNZ RC.42 function is to reduce the content of Fe, Mn, odor, color and organic substances.
- Activated carbon function is to reduce organic matter, odor, color and flavor.
- Fiber filter size of 3 micron function is to eliminate turbidity, TDS and color.

The parameters tested are physical parameters (turbidity, TDS), chemical parameters (pH, organic matter) and bacteriological parameter (coliform). The rainwater tanks and filtration reactors are arranged in series. Conducted research design is as follows:

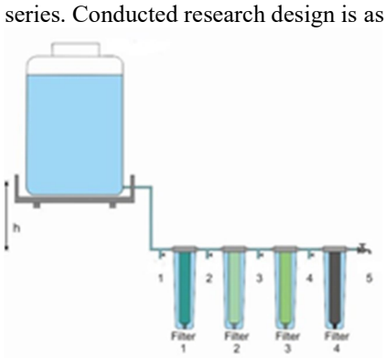

Figure 1 Filtration Reactor Design

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The height difference (h) used is 20 cm whereas the debit (Q) used is 0.01 l / sec. It is used with the assumption that small debit is expected to give better filtration results compared to larger debit. Filter 1, 2, 3 and 4 contain different types of filter media based on configuration planned.

b. Measurement of reactor inlet and outlet flow rate

In this research, the speed at the beginning and the end of the treatment process is assumed to be the same. In order to achieve the same flow rate, it is necessary to modify the reactor design and calculate the reactor configuration height difference. The calculation is using Bernoulli equation as follows:

$P + ½ \rho v^2 + \rho g H = \text{constant}$

$P_1 + ½ \rho v_1^2 + \rho g H_1 = P_2 + ½ \rho v_2^2 + \rho g H_2$

With $P1 = 3920$ Pa

ρ water $= 1000$ kg/m^3

$g = 9{,}8$ m/s^2

$H_1 = H_2 = 70$ cm $= 0{,}7$ m

$V_1 = 0{,}0787$ m/s

$V_2 = 0{,}0669$ m/s

$P_1 + ½ \rho v_1^2 + \rho g H_1 = P_2 + ½ \rho v_2^2 + \rho g H_2$

$P_1 - P_2 = ½ \rho (v_5^2 - v_1^2) + \rho g (H_5 - H_1)$

$3920 - P_2 = \{½ (1000) (0{,}0669^2 - 0{,}0787^2)\} + \{(1000) (9{,}8) (0{,}7 - 0{,}7)\}$

$3920 - P_2 = \{½ (1000) (0{,}0669^2 - 0{,}0787^2)\} + 0$

$3920 - P_2 = -0{,}85904$

$P_2 = 3920{,}85904$ Pa

The speed of the tap 1 and tap 2 is expected to be at the same value (V1 = V2 = 0.0787) then the difference between the required height is

$P_1 + ½ \rho v_1^2 + \rho g H_1 = P_2 + ½ \rho v_2^2 + \rho g H_2$

$P_1 - P_2 = ½ \rho (v_5^2 - v_1^2) + \rho g (H_5 - H_1) -0{,}85904$

$= \{½ (1000) (0{,}0787^2 - 0{,}0787^2)\} + \{(1000) (9{,}8) (H_2 - 0{,}7)\} - 0{,}85904 = 0 + 9800H_2 - 6860$

$9800H_2 = 6859{,}14096$

$H_2 = 0{,}69$ m

$H1 - H2 = 0{,}70 - 0{,}69 = 0{,}01$ m $= 1$cm

The reactor altitude difference required is 1 cm.

c. Filtration result assessments

The rainwater quality is assessed after it undergone the filtration treatment process. The parameters tested are turbidity, total dissolved solid, pH, organic matter, and coliform.

d. Production cost calculation

The production cost of rainwater filtration treatment using modified/treated natural zeolite (TNZ) and activated carbon filter is calculated based on the filter types used and configuration.

RESULT AND DISCUSSIONS

The rainwater quality is assessed after it undergone the filtration treatment process. Parameters tested results are as follows.

a. Physical and Chemical Parameters

Preliminary analysis of the rainwater physical quality results using each type of the filter media can be seen in the following table:

Table 2 Preliminary Rainwater Physical Quality Result

Type of filter	pH (6,5-8,5)*	Turbidity (5)*	TDS (500)*	Organic matter (10)*
TNZ RC.32	6,91	1,40	14,67	17,74**
TNZ RC.42	6,85	1,86	15,33	8,87
Activated Carbon	7,01**	1,35	14,00	5,54

*Indonesia water quality standard

** Above quality standard

From the preliminary results TNZ RC.32 and activated carbon are chosen as filter media. TNZ RC.42 is eliminated due to its high turbidity result.

In the following study, fiber filter size of 0.3 microns is added into the filtration configuration to reduce turbidity and TDS.

The filtration configuration is as follows:

- TNZ RC.32 - Activated Carbon (TNZ RC.32 – AC)
- TNZ RC.32 - Activated Carbon - Fiber Filter (TNZ RC.32 – AC – FF)

The filtration result is as follows:

Tabel 3 Filtration Physical Parameter Results

Filter configuration	pH (6,5- 8,5)*	Turbidity (5)*	TDS (500)*	Organic matter (10)*
Filter with Volume 1,5 Liter				
RC.32-CA	6,78	0,73	20,00	7,37
RC.32-CA-FF	6,97	0,60	19,33	6,32
Filter with Volume 3 Liter				
RC.32-CA	6,83	1,52	16,00	18,96
RC.32-CA-FF	6,88	0,40	17,70	16,85

*Indonesia water quality standard

The filtration result comparison table shows that all physical and chemical parameters have met the Indonesia water quality standard [2].

Rainwater treatment using natural zeolite filtration is effective to reduce total coliform, turbidity, total dissolved solids and total hardness [3]. Zeolite and activated carbon also effective in reducing hardness level by 94.36% with 70 cm media thickness [4]. Moreover, turbidity and rainwater contaminants/pollutants can be reduced using thin film composite membranes and ultraviolet [5].

b. Bacteriological Parameter

Preliminary bacteriological analysis of the rainwater sample shows that the rainwater contains 2400+ coliform bacteria and E.coli. The coliform bacteria might be contaminated the rainwater runoff in the rooftop catchment area. Source of contamination usually is from bird droppings or other animal.

In contrast of the preliminary result, the bacteriological parameter of filtered rainwater using RC.32-CA and RC.32-CA-FF filter media showed negative result of coliform bacteria and E.coli. The bacteria has been filtered by the filter media [6]. TNZ pore size is 10^{-7} up to 10^{-9} m whereas the bacteria size is 10^{-6} m [6]. Rainwater filtration system using filtration membranes with pore size of 20 mm followed by disinfection with ultraviolet light, proved effective in reducing the total coliform, fecal coliform and turbidity. Filtration and disinfection system is capable of removing total coliform by 96%, whereas for fecal coliform removal efficiency is 97% and turbidity removal efficiency average of 42% [7]

c. Cost Aspects

Removal efficiency and the production cost calculation of each filter reactor is as follows:

Table 4 Removal Efficiency And Production Filter Cost

Filter configuration	Volume 1,5 Liter		Volume 3 Liter	
	Removal efficiency (%)	Cost (Thousand Rp)	Removal efficiency (%)	Cost (Thousand Rp)
Turbidity				
RC.32-CA	26,01	566.8	10,06	903
RC.32-CA-FF	38,85	746.8	76,33	1.233
TDS				
RC.32-CA	33,33	566.8	1,91	903
RC.32-CA-FF	28,87	746.8	1,27	1.233
Organic matter				
RC.32-CA	58,85	566.8	25,00	903
RC.32-CA-FF	64,71	746.8	33,35	1.233

Filter configuration of TNZ media RC.32 and activated carbon filter media with 1.5 liter reactor volume has the highest TDS and organic substances removal efficiency and the lowest reactor production cost.

CONCLUSIONS

Filter configuration of TNZ media RC.32 and activated carbon filter media with 1.5 liter reactor volume has the highest organic substances removal efficiency by 58.85% and the lowest reactor production cost of Rp. 560,600. The results of treated rainwater have met Indonesian drinking water regulation quality standards.

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