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Performance of Single Medium Filtration using Malimpung Quartz Sand

Suryani Syahrir[1], Mary Selintung[2], Saleh Pallu[3], Arsyad Thaha[4]

[1] Doctoral Program Student in Civil Engineering, Hasanuddin University. Jalan Perintis Kemerdekaan KM-10,

[2] Lecturer of Civil Engineering Department, Hasanuddin University, Jalan Perintis Kemerdekaan KM-10, Tel. 0411-587636

[3] Lecturer of Civil Engineering Department, Hasanuddin University, Jalan Perintis Kemerdekaan KM-10, Tel. 0411-587636

[4] Lecturer of Civil Engineering Department, University of Hasanuddin, Jalan Perintis Kemerdekaan KM-10, Tel. 0411-587636

Abstract

Filtration is a separating process between solids and fluid, either liquid or gas, using a porous medium or other permeable materials. Filtration is used to remove the suspended solids and colloids as much as possible. In filtration process, water seeps and passes through the filter medium. The suspended solids will be accumulated on the surface of filter and collected throughout the depth of the medium. Quartz sand is an excellent medium for water filtration. In this research, Malimpung quartz sand was used as the single filter medium. The sand comes from Malimpung, Pinrang, South Sulawesi Province, Indonesia. The purposes of this research are to analyze the performance of a single-medium water filtration using Malimpung quartz sand. The experiment method consists of two stages. Firstly, testing of the sand whether meets the filter medium standard or not. It was performed at the Soil Mechanics Laboratory of Hasanuddin University. Secondly, testing of the sand in a filtration apparatus with diameter of grain: 0.4 [mm] ~ 0.8 [mm] and thickness of medium filter: 50 [cm], 60 [cm], and 70 [cm]. The results showed that the Malimpung quartz sand meets the standard of filter medium with value of U_c as 1.7 and G_s as 2.66 [gr/cm^3]. The output discharge was bigger than the calculated Darcy discharge and the clearing of turbidity achieved was 94.9%.

Keywords: quartz sand, filtration, performance, grain diameter.

1. Introduction

Water is the most basic need for creatures. The water should meets the minimum standard either in quality or quantity. The water should be available in qualified health conditions which can be viewed from the aspects of physics, chemistry, and biology [1]. Based on some recent researches, significant decrease of iron and manganese can be obtained by filtration using single, dual, or three filter mediums. Furthermore, the influence of the sand grain diameter and thickness to reduce the iron content in the water also has given good results. This research focuses on analyzing the effectiveness of the Malimpung quartz sand as a single medium filter. Filtration is a separating process between solids and fluid, either liquid or gas, using a porous medium or other permeable materials. Filtration is used to remove the suspended solids and colloids as much as possible. In filtration process, water seeps and passes through the filter medium. The suspended solids will be accumulated on the surface of filter and collected throughout the depth of the medium. Filters also have the ability to separate all sizes particulates including algaes, viruses, and soil colloids [2,3].

In a granular medium filtration, the mechanisms are as follows:

a. mechanical filtering (mechanical straining)
b. sedimentation
c. absorption or electrokinetic force
d. coagulation in the filter bed
e. biological activities [3,4].

Filtration is performed to separate liquid mixtures and delicate suspended solids as much as possible using porous medium or material. Filtration can be used as the initial or primary treatment. In a raw water treatment where the coagulation process is not necessary to be performed, the fresh water can be filtered with any kind of filter, including coarse sand. Rough filter materials can store sludges in high capacity due to its ability to withstand the penetration of suspended particles in a sufficient depth. The filtration characteristic is stated in water flow. Each filtration is selected based on technical and economic considerations [5]. Treated water is liquid substance containing materials such as fine grains or dissolved ingredients with sediment. Therefore, the materials can be separated from the liquid by filtration. If the treated water has a uniform size of solids, the appropriate filter is a single medium. Conversely, the proper filter is a dual or three medium [1,6]. The important part in filtration is the filter medium. It can be composed of natural silica sand, anthracite, or garnet sand. Generally, these mediums has various on size, shape and chemical composition [2,3]. Quartz sand is also known as white or silica sand resulted from weathering of rocks containing minerals such as quartz and feldspar. The weathering results are washed and carried away by water or wind and deposited on the edges of rivers, lakes, or seas. Quartz sand is mineral composed of silica crystals (SiO_2) and contains a compound of impurities during the deposition process. Quartz sand has combined composition of SiO_2, Fe_2O_3, Al_2O_3, TiO_2, CaO, MgO, and K_2O, with translucent white or other colors depending on the compound of impurities. It has a hardness of 7 Mohs scale, specific weight of 2.65, melting point of 17~150 [^{o}C], hexagonal crystal form, and specific heat of 0.185 [1]. The filter medium is selected using sieve analysis. The results of a sieve filter medium are described as the accumulation distribution curve to find the effective size and uniformity of desired medium (expressed as uniformity coefficient) [2,3]. To determine the feasibility of sand as a filter medium in water filtration, uniformity coefficient (U_c = 1.2 ~ 1.8) and specific weight of the sand (G_s = 2.65 ~ 2.67) could be used [8]. Filtering is the best process to remove the particles from the water flowing through the base of the sand. The particles have a diameter that is too large to get through the pores of the sand, therefore they will be trapped and separated from the flowing water. There are two important process that happens when the particles are physically filtered out of the water. First, the particles move into the sand and the second is the particle is trapped between the grains of sand.

1.1Hydraulic Permeability And Conductivity

To determine the hydraulic permeability, we have to consider about the flow concept formulated by Henry Darcy (1856). Darcy in his experiments found the proportional relationship between the water flow rate (Q) through the sand (homogeneous) with a flow cross-sectional area (A) and loss of energy (energy loss or hydraulic gradient), $J = (h_1 - h_2) / L$ which can be written as follows (Bear and Verrujit, 1990):

$$Q = K\,A\,J \qquad (1)$$

where $h_1 - h_2 = \Delta h$ is the press-height difference between two points on the sand with different distances along the L (Figure 1), q is the flux flow (Q / A) [m/s]. K is the coefficient of hydraulic proportionality or conductivity.

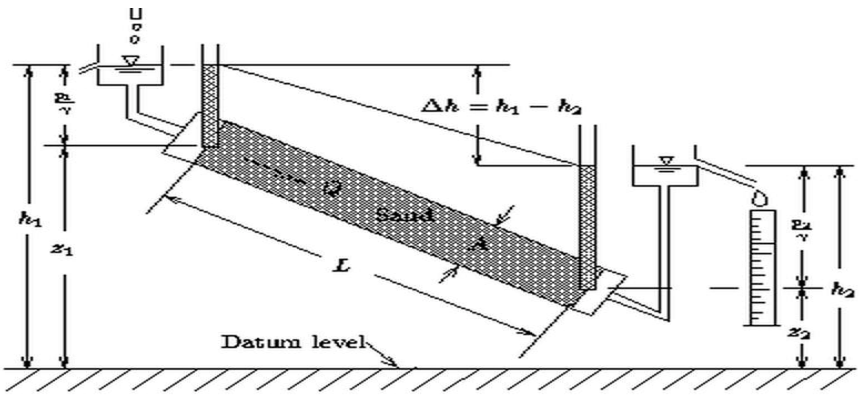


Figure 1. The flow through the sand-column to demonstrate the law of Darcy [9]

1.2Water Flow Velocity (J)

Water flow velocity is formulated as follows:

$$J = Q / (A.\, t) \qquad (2)$$

where:

J = water flow velocity,
Q = water displacement through the cross-sectional (A), and
t = time.

2. MATERIAL AND METHOD

2.1Research Materials and Tools

The apparatus used in this research was a filtration unit with 60 [cm] in length, 60 [cm] in width, and 160 [cm] in height as shown in figure 2. It was made of acrylic material with 1 [mm] in thickness. A turbidity Meters TU-2016 was used to test the level of turbidity. Furthermore, a set of sieve tool number 4, 10, 18, 40, 60, 100, 200 with a pan and shaken by a Motorised Dynamic Sieves Shaker was used for sieve analysis. The materials were Malimpung quartz sand, fibers, and artificial water with 50 NTU of turbidity.

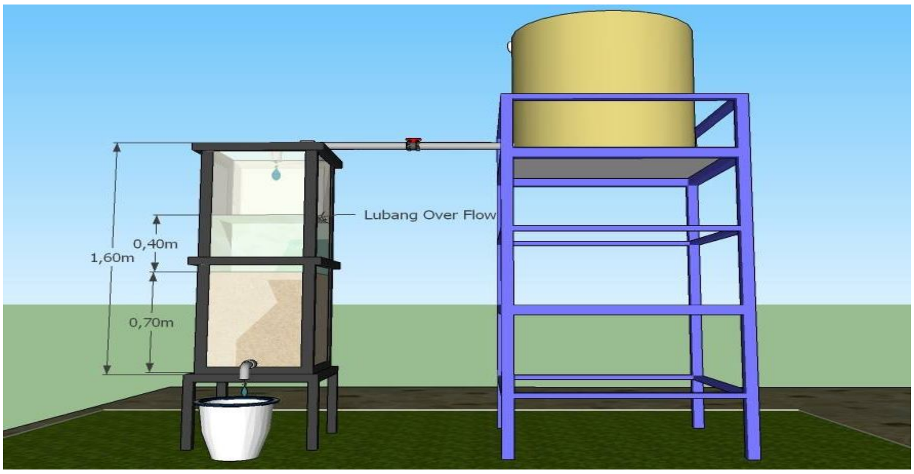
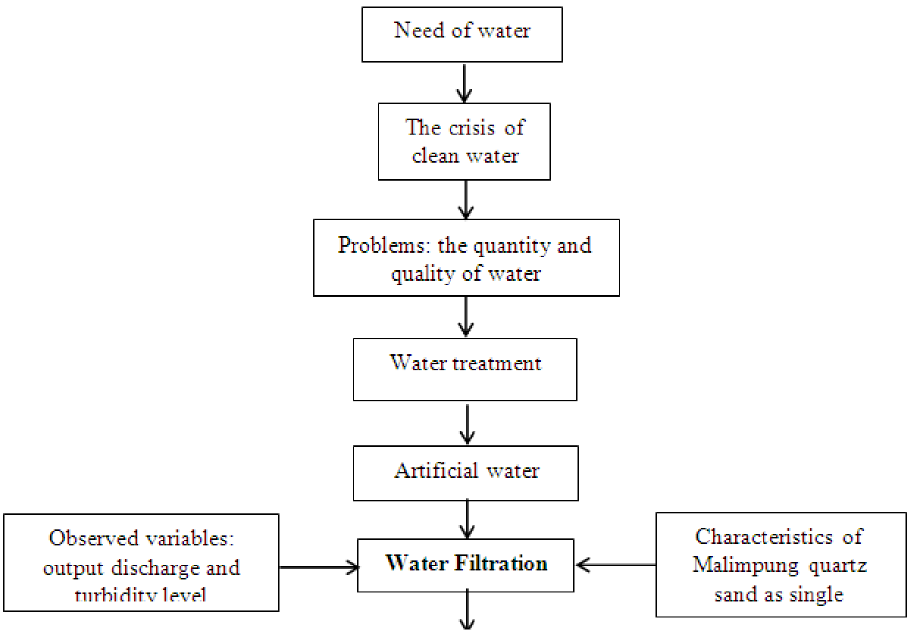


Figure 2. Scheme of the filtration tool

2.2 RESEARCH METHOD

There were two diameter types of quartz sand grain used in this research, i.e. the uniform and non-uniform diameter. Quartz sand passed the sieve number 18 (grain diameter 0.84 [mm]) were used for non-uniform diameter experiment. Quartz sand passed sieve number 10, 18 and 40 (grain diameter: 2 [mm], 0.84 [mm], and 0.425 [mm] respectively) were used for uniform diameter experiment. Otherwise, fibers were used as medium buffers in order to avoid the sand carried by water when the valve was opened. Variations of filter medium thickness were 50 [cm], 60 [cm], and 70 [cm]. The water level above the filter medium must be kept at 40 [cm]. Therefore, the filtration unit was designed to overflow at the level by making holes in the apparatus. At the beginning, the fibers were inserted into the filtration apparatus. Water was flown to clean the fibers from dirt and grime. Then, the filter medium with a uniform diameter of grain were inserted into the appliance at 50 [cm] of level. Furthermore, 50 NTU artificial water was flown into the filtration apparatus until the water reaches 40 [cm] of level above the filter medium. For Q_{in}, intake discharge, water were collected before passed the filter medium of quartz sand with time variation of 3, 6, 9, 12, and 15 seconds. Subsequently, for Q_{out}, output discharge,, water were collected after passed the filter medium of quartz sand with the same variations of time. These procedures were repeated for 60 [cm] and 70 [cm] of thickness. For non-uniform diameter experiment, the thickness of quartz sand was 50 [cm]. Its compositions from the bottom to the top of filtration apparatus were 10 [cm] for 0.425 [mm], 20 [cm] for 0.84 [mm], and 20 [cm] for 2 [mm] of diameter. The composition for 60 [cm] and 70 [cm] of thickness were identicle, except the highest layer became 30 [cm] and 40 [cm] respectively. Furthermore, these methods were done in the same manner for the uniform diameter experiment. The overall framework of this research can be seen in Figure 3.



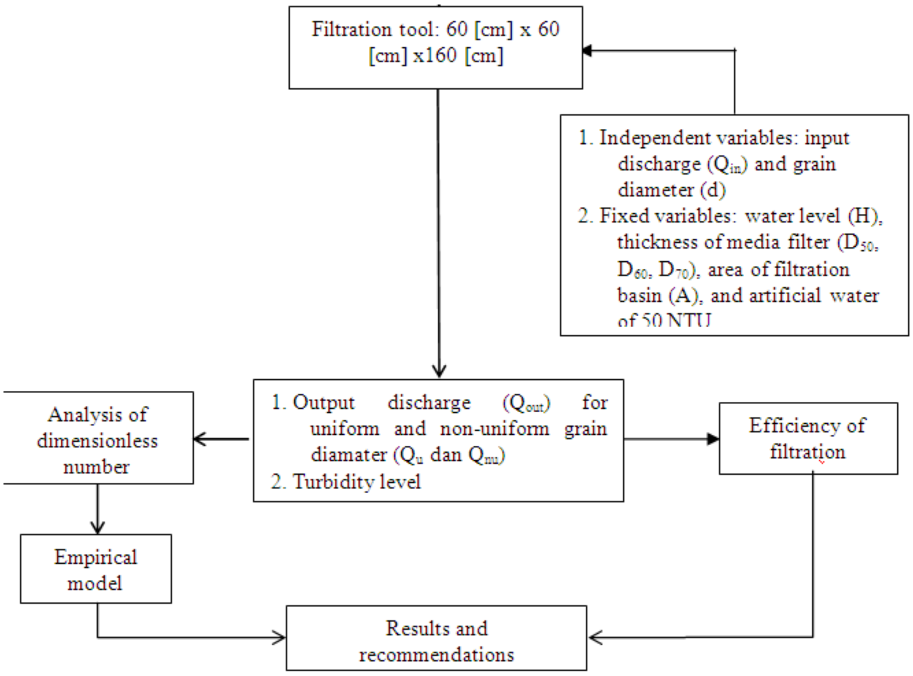


Figure 3. Framework of research

3.RESULTS AND DISCUSSION

3.1Characteristics Testing of Malimpung Quartz Sand

From the characteristic sensing using EDXRF QUANT'X ARL, we obtained SiO_2 as 97.07%. Therefore, Malimpung quartz sand can be used as a filter media. Further results of test sieve and density can be seen in Figure 4 and Table 1. Figure 3 shows that the value of *Cu* is 1.7. Furthermore, the specific weight of Malimpung quartz sand is shown in Table 1.

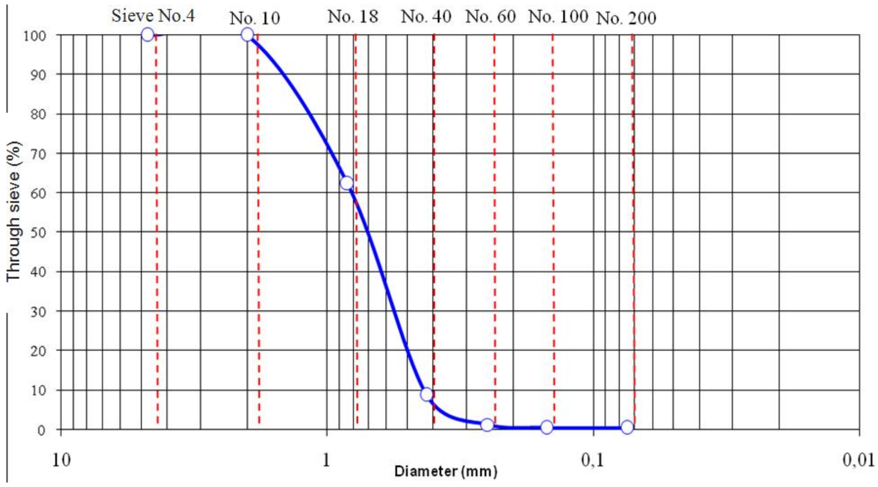


Figure 4. Sieve curve of Malimpung quartz sand

Table 1: The result of a sieve and density test of Malimpung quartz sand

Filter No.	Diameter (mm)	Suspended Weight (G)	Cumulative Weight (G)	Percent (%)	
				Restrained	Get away
4	4.75	0	0	0	100.00
10	2.00	0	0	00.00	100.00
18	0.84	188	188	37.60	62.40
40	0.425	268	456	91.20	8.80

60	0.25	38	494	98.80	1.20
100	0.15	4	498	99.60	12.40
200	0.075	0	498	99.60	12.40
Pan	0	2	500	100.00	0

Table 2: The specific weight of Malimpung quartz sand

Parameters	**Experiment No.**	
	I	**II**
Pycnometer weight, W_1 (g)	45	46
Pycnometer + water weight, W_2 (g)	142	144
Weight of pycnometer + water + soil, W_3 (g)	173.3	175.1
Dry soil weight, W_s (g)	50	50
Temperature, ^{o}C	27	27
Correction factor, a	0.9983	0.9983
Specific gravity, G_s	2.669	2.641
Average Specific Gravity, G_s	2.66	

In Table 1 and Figure 4, we can see that the value of C_u is 1.7. In Table 2, G_s, the average specific gravity of coarse sand sample was 2.66 [gr/cm^3]. These values meet the requirements of Awwas (American Water Works Association Standard). Therefore, Malimpung quartz sand can be used as filter medium in a water filtration.

3.2 Performance testing of filtration

The experimental result for thickness of the filter media: 50 [cm], 60 [cm], and 70 [cm] are presented in Table 3 below.

Table 3: Experimental result for media thickness of 50 [cm]

thickness (D) (cm)	**time (t) (detik)**	**Q_{in} (cm^3/det)**	**Q_{out} (cm^3/det)**	**discharge ratio (%)**	**turbidity (NTU)**
50	3	463.33	287.00	61.94	6.85
50	3	416.67	295.00	70.80	6.65
50	3	366.67	296.67	80.91	6.59
50	6	357.83	265.00	74.06	5.29
50	6	350.00	263.33	75.24	4.90
50	6	361.67	263.00	72.72	4.70
50	9	336.67	245.89	73.04	4.51
50	9	344.44	244.44	70.97	4.41
50	9	325.33	242.22	74.45	4.34
50	12	291.67	249.17	85.43	3.90
50	12	290.00	245.83	84.77	3.60
50	12	287.50	247.50	86.09	3.53
50	15	253.33	242.47	95.71	2.80
50	15	263.87	243.00	92.09	2.73
50	15	266.67	241.33	90.50	2.55

Table 3 shows fluctuations in discharge ratio as the increasing time whereas the turbidity levels is decrease. Figure 5 shows the relationship between turbidity levels and time for D = 50 [cm] in logarithmic pattern with a coefficient of determination R^2 = 0.965 or R = 0.982. Furthermore, figure 6 shows the relationship between discharge ratio and time for D = 50 [cm] in a linear pattern with a coefficient of determination R^2 = 0.703 or R = 0.838.

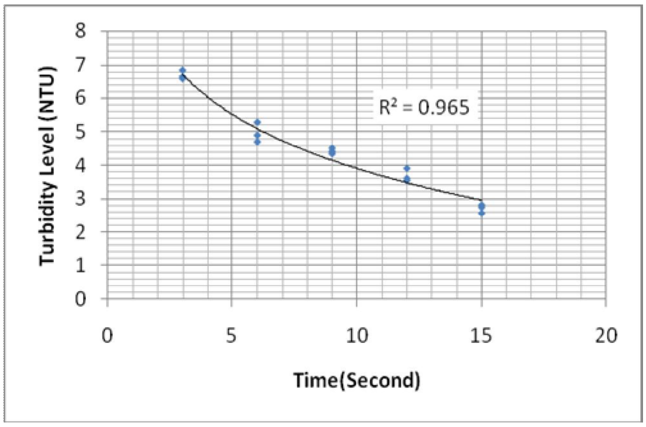


Figure 5. Relationship between turbidity level and time for media thickness of 50 [cm]

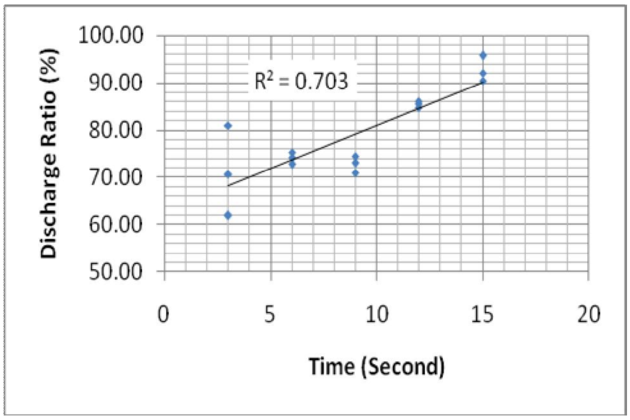


Figure 6. Relationship between discharge ratio and time for media thickness of 50 [cm]

Table 4: Experimental result for media thickness of 60 [cm]

thickness (D) (cm)	time (t) (detik)	Q $_{in}$ (cm^3/det)	Q $_{out}$ (cm^3/det)	discharge ratio (%)	turbidity (NTU)
60	3	463.33	270.00	58.27	9.38
60	3	416.67	276.67	66.40	9.22
60	3	366.67	272.67	74.36	9.10
60	6	357.83	255.33	71.36	7.00
60	6	350.00	261.50	74.71	6.50
60	6	361.67	257.50	71.20	6.32
60	9	336.67	228.89	67.99	5.73
60	9	344.44	233.89	67.90	5.30
60	9	325.33	234.44	72.06	4.95
60	12	291.67	231.92	79.51	4.20
60	12	290.00	233.33	80.46	3.78
60	12	287.50	233.17	81.10	3.49
60	15	253.33	234.80	92.68	3.10
60	15	263.87	234.40	88.83	2.75
60	15	266.67	233.80	87.68	2.55

The experimental result for the thickness of filter media of 60 [cm] shows almost the same result for the thickness of 50 [cm]. It has fluctuations in the discharge ratio although it generally increase with the increasing of time whereas the turbidity levels decrease.

Figure 7 shows the relationship between turbidity levels and time for *D* = 60 [cm] in logarithmic pattern with a coefficient of determination R^2 = 0.981 or R = 0.999. Figure 8 shows the relationship between discharge ratio and time for *D* = 60 [cm] in a linear pattern with a coefficient of determination R^2 = 0.726 or R = 0.852.

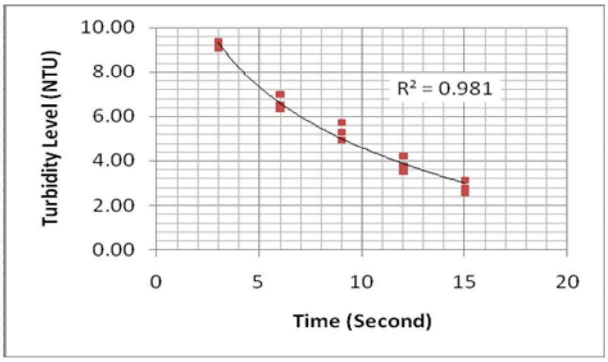


Figure 7. Relationship between turbidity level and time for media thickness of 60 [cm]

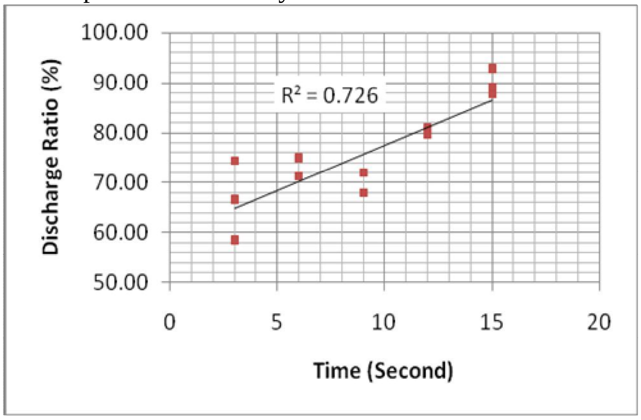


Figure 8. Relationship between discharge ratio and time for media thickness of 60 [cm]

Furthermore, the experimental result for filter media thickness of 70 [cm] can be seen in Table 5 below.

Table 5: Experimental result for media thickness of 70 [cm]

thickness (D) (cm)	time (t) (detik)	Q_{in} (cm^3/det)	Q_{out} (cm^3/det)	discharge ratio (%)	turbidity (NTU)
70	3	463.33	280.00	60.43	7.40
70	3	416.67	267.33	64.16	7.11
70	3	366.67	277.67	75.73	6.78
70	6	357.83	260.33	72.75	6.56
70	6	350.00	268.00	76.57	6.37
70	6	361.67	261.67	72.35	6.20
70	9	336.67	234.67	69.70	5.50
70	9	344.44	235.56	68.39	5.35
70	9	325.33	235.33	72.34	5.28
70	12	291.67	229.50	78.69	4.58
70	12	290.00	230.67	79.54	4.46
70	12	287.50	231.67	80.58	4.38
70	15	253.33	232.00	91.58	4.24
70	15	263.87	233.33	88.43	3.58
70	15	266.67	234.00	87.75	3.25

Table 5 shows experimental result of the thickness of filter media of 70 [cm] that has the same trend value to 50 [cm] and 60 [cm]. However, the level of turbidity in thickness of 70 [cm] increased than in thickness of 50 [cm] and 60 [cm].

Figure 9 shows the relationship between turbidity levels and time for *D* = 70 [cm] in logarithmic pattern with a coefficient of determination R^2 = 0.906 or R = 0.952. Figure 10 shows the relationship between discharge ratio and time for *D* = 70 [cm] in a linear pattern with a coefficient of determination R^2 = 0.704 or R = 0.839.

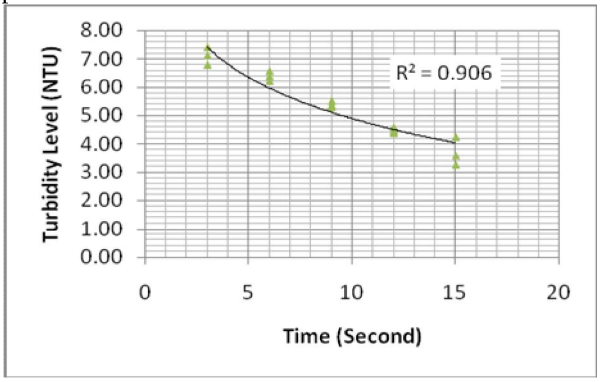


Figure 9. Relationship between turbidity level and time for media thickness of 70 [cm]

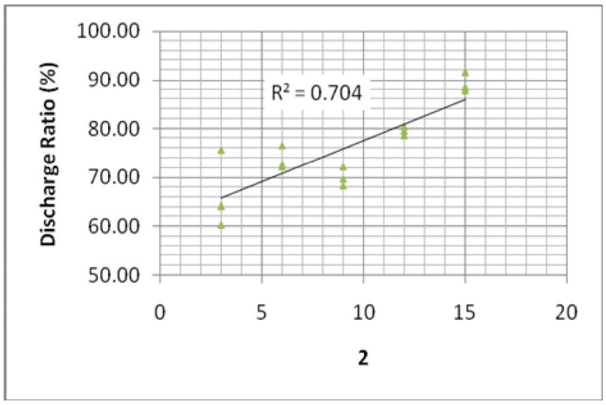


Figure 10. Relationship between discharge ratio and time for media thickness of 70 [cm]

3.3Discussion

A large discharge ratio as 92.72% is obtained in experiment for filter media thickness of 50 [cm]. This can be explained due to the thickness of a first flow where the flow rate of water that fills the cavity between the filter media is still high. It has not happened yet a filtration mechanism perfectly. The experimental results in the thickness of 60 [cm] and 70 [cm] shows the same trend value for all variations of time due to the mechanism of granular media filtration such as mechanical straining, sedimentation, adsorption, and biological activity are already under way.

The difference of discharge ratio in 60 thickness of [cm] and 70 [cm] are not too large, i.e. 89.68% and 89.22% than in the thickness of 50 [cm]. This condition is allowed by existance of additional thickness of the filter media on the top layer of the filter media. It has a thickness of 1 [cm] ~ 2 [cm] on each addition in order that the flow rate is maintained in the starting time of drainage.

All filter media thickness produces R> 0.6 and approaching a value of 1. This suggests that the ratio of discharge using Malimpung quartz sand as filter media with a grain diameter of 0.4 [mm] ~ 0.8 [mm] yield good output discharge. It can be used as a filter media in drinking water treatment.

4.CONCLUSIONS

1. Malimpung quartz sand as a filter media with grain diameter of 0.4 [mm] ~ 0.8 [mm] result in a greater output discharge than the Darcy formula.
2. The output turbidity level using the single filter medium is 2.55 NTU with a clearance percentage as 94.9%.

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AUTHOR

Suryani Syahrir received the B.Eng. and M.Eng. degrees in Civil Engineering from Hasanuddin University in 2000 and 2008, respectively. Since 2010 until now, she has been studying in Doctoral Course of Civil Engineering Departement of Hasanuddin University. Her interest is water filtration field. She is a lecturer of Civil Engineering Departement of Sekolah Tinggi Teknik Baramuli Pinrang since 14 years ago.