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Effectiveness of Malimpung Quartz Sand as Single Medium on Water Filtration

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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 effectiveness of Malimpung quartz sand at the flow rate and turbidity level using a single medium filter. 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. We used two unlike types of diameter: uniform and non-uniform grain diameter. Moreover, we used three different thickness of filter medium: 50, 60 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 (g cm^{-3}). The effectiveness of the sand can be seen from the large output discharge and low water turbidity level.

Key words: Quartz sand, filtration, effectiveness, grain diameter, soil

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 (Kusnaedi, 2010).

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 (Environmental Protection Agency, 1995). In a granular medium filtration, the mechanisms are as follows:

- Mechanical filtering (mechanical straining)
- Sedimentation
- Absorption or electrokinetic force
- Coagulation in the filter bed
- Biological activities

Filtration is performed to separate liquid mixtures and delicate suspended solids as much as possible using porous medium or material (Environmental Protection Agency, 1995). 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.

Treated water is liquid substance containing materials such as fine grains or dissolved ingredients with

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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 (Kusnaedi, 1995, 2010).

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.

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°C hexagonal crystal form and specific heat of 0.185 (Kusnaedi, 2010).

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). 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.

The transfer of water through the soil in a saturated condition: Darcy's Law is used to calculate the permeability and the transfer of water through the soil in a saturated condition. In fact, Darcy's Law also involves hydraulic transferability and gradient as parameters. Darcy's Law depicts the flow of water in saturated conditions quantitatively (Kusnaedi, 1995).

Darcy's Law: Darcy's Law is formulated as:

$$q = J \times K \times i \tag{1}$$

Where:

J = Velocity of water flow
K = Hydraulic transferability
I = Hydraulic gradient

Darcy's Law shows that J, the speed of water flow is proportional to i, the hydraulic gradient. The value of K, hydraulic transferability is a constant which confirms the proportional relationship between the flow velocity and hydraulic gradient. In determining the hydraulic transferabilities, the variables such as speed of water flow and hydraulic gradient were usually varied. In Darcy's Law, the saturated hydraulic transferability is a constant that indicates the linear relationship between J and i as shown in Fig. 1. The slope of line J/i shows the relationship between the speed of water flow and hydraulic gradient.

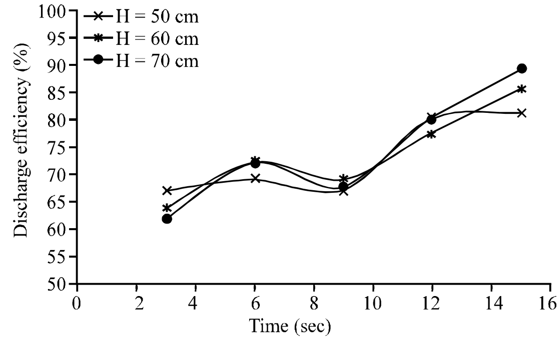

Fig. 1: Discharge efficiency of non-uniform grain diameter

Water flow velocity (J): Water flow velocity is formulated as follows:

$$J = Q/(A \times t) \tag{2}$$

Where:

J = Water flow velocity
Q = Water displacement through the cross-sectional (A)
t = Time

MATERIALS AND METHODS

Research materials: The apparatus used in this research was a filtration unit with 60 cm in length, 60 cm in width and 160 cm in height. 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.

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, 0.84 and 0.425, 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, 60 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 sec. 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 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 and 70 cm of thickness were identicle, except the highest layer became 30 and 40 cm, respectively. Furthermore, these methods were done in the same manner for the uniform diameter experiment.

RESULTS AND DISCUSSION

Characteristics testing of malimpung quartz sand: The result of the sieve and density tests of Malimpung quartz sand can be seen in Table 1 and Fig. 2. Furthermore, the specific weight of Malimpung quartz sand are presented in Table 2.

In Table 1 and Fig. 2, we can see that the value of U_c was 1.7. In Table 2, G_s, the average specific gravity of coarse sand sample was 2.66 (g 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.

Artificial water testing: The test results of 50 NTU artificial water filter medium with a uniform diameter (0.84 mm of grain diameter) can be seen in Table 3.

Figure 3 shows that the discharge efficiency at 50 cm of thickness was quite large, i.e., 50 cm (92.72%). This can be happened due to the thickness of the first stream, the flow rate of water filled the cavity between the filter medium was still high. The filtration mechanism was not performed perfectly. In another hand, discharge efficiency

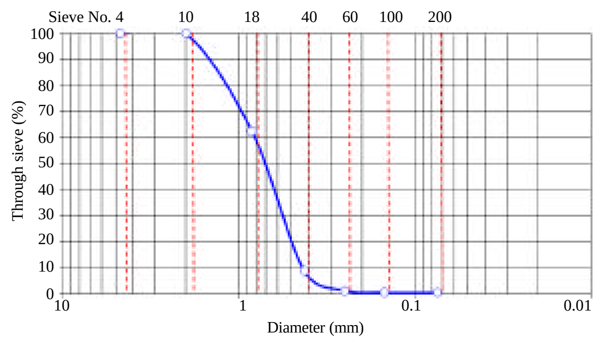

Fig. 2: Sieve curve of Malimpung quartz sand

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

Filter No.	Diameter (mm)	Suspended weight (G)	Cumulative weight (G)	Percentage Restrained	Percentage Get away
4	4.750	0	0	0.00	100.00
10	2.000	0	0	00.00	100.00
18	0.840	188	188	37.60	62.40
40	0.425	268	456	91.20	8.80
60	0.250	38	494	98.80	1.20
100	0.150	4	498	99.60	12.40
200	0.075	0	498	99.60	12.40
Pan	0.000	2	500	100.00	0.00

Table 2: The specific weight of Malimpung quartz sand

Parameters	Experiment No. I	Experiment No. II
Rough samples		
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 (°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	

Table 3: Discharge efficiency of uniform grain diameter

	Filter thickness of 50 cm			Filter thickness of 60 cm			Filter thickness of 70 cm		
Time (sec)	Q_{in50} (mL sec^{-1})	Q_{out50} (mL sec^{-1})	Discharge efficiency (%)	Q_{in60} (mL sec^{-1})	Q_{out60} (mL sec^{-1})	Discharge efficiency (%)	Q_{in70} (mL sec^{-1})	Q_{out70} (mL sec^{-1})	Discharge efficiency(%)
3	415.56	292.89	70.48	415.56	273.11	65.72	415.56	275.00	66.18
6	356.50	263.78	73.99	356.50	258.11	72.40	356.50	263.33	73.87
9	335.48	244.19	72.79	335.48	232.41	69.28	335.48	235.19	70.10
12	289.72	247.50	85.43	289.72	232.81	80.35	289.72	230.61	79.60
15	261.29	242.27	92.72	261.29	234.33	89.68	261.29	233.11	89.22

Table 4: Discharge efficiency of non-uniform grain diameter

	Filter thickness of 50 cm			Filter thickness of 60 cm			Filter thickness of 70 cm		
Time (sec)	Q_{in50} (mL sec^{-1})	Q_{out50} (mL sec^{-1})	Discharge efficiency (%)	Q_{in60} (mL sec^{-1})	Q_{out60} (mL sec^{-1})	Discharge efficiency (%)	Q_{in70} (mL sec^{-1})	Q_{out70} (mL sec^{-1})	Discharge efficiency (%)
3	415.56	278.00	66.90	415.56	264.89	63.74	415.56	257.11	61.87
6	356.50	246.11	69.04	356.50	256.94	72.07	356.50	256.67	72.00
9	335.48	225.93	67.34	335.48	231.48	69.00	335.48	227.78	67.90
12	289.72	231.94	80.06	289.72	224.58	77.52	289.72	232.72	80.33
15	261.29	211.78	81.05	261.29	223.33	85.47	261.29	232.44	88.96

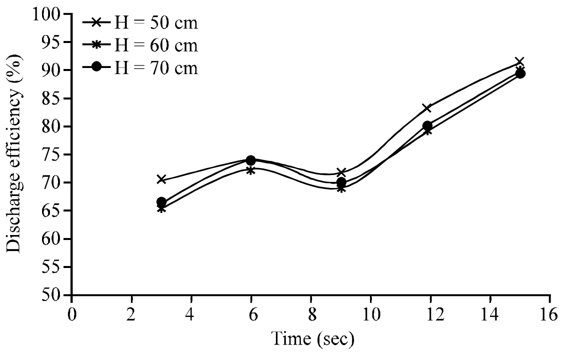

Fig. 3: Discharge efficiency of uniform grain diameter

at 60 and 70 cm of thickness have same tendency of values for all variations of time (89.68 and 89.22%). This was due to the mechanism of granular medium filtration (mechanical straining, sedimentation, adsorption, biological activity) were already on going.

The discharge efficiency values at 60 and 70 cm of thickness were almost the same with 50 cm of thickness. This was probably because of sediments was dredged as 1~2 cm on the upper surface of the filter medium on each additional filter medium thickness. Therefore, the flow rate can be maintained at 50 cm of thickness. The discharge efficiency to grain diameter is not uniform for all variations of thickness can be seen in Table 4.

Figure 1 shows the fluctuation with same tendency in all thickness. The largest discharge efficiency was found at 70 cm of filter medium thickness (88.96%). However, the discharge efficiency at 50 and 60 cm of thickness has a little difference (81.05 and 85.47%). This was caused by the composition of filter medium layers that span from the bottom to up (fine grain to coarse grain diameter) were not impaired in the base and middle layer. The addition of filter medium thickness was given on the top layer only, i.e., the filter medium with 2 mm of diameter. The fairly large grain diameter resulted in a high flow velocity and a high porosity. Table 5 shows the turbidity levels of uniform and non-uniform diameter for all variations of thickness.

Figure 4 shows the turbidity levels for uniform grain diameter. It tends to gradually decline as the increment of

Table 5: The turbidity level of uniform and non-uniform grain diameter

	Filter thickness of 50 cm		Filter thickness of 60 cm		Filter thickness of 70 cm	
Time (sec)	Uniform	Non-uniform	Uniform	Non-uniform	Uniform	Non-uniform
3	6.70	9.08	9.23	7.63	7.10	3.14
6	4.96	13.97	6.61	5.88	6.38	3.76
9	4.42	11.96	5.33	4.62	5.38	3.52
12	3.68	8.28	3.82	4.07	4.47	2.99
15	2.69	5.01	2.80	2.50	3.69	2.33

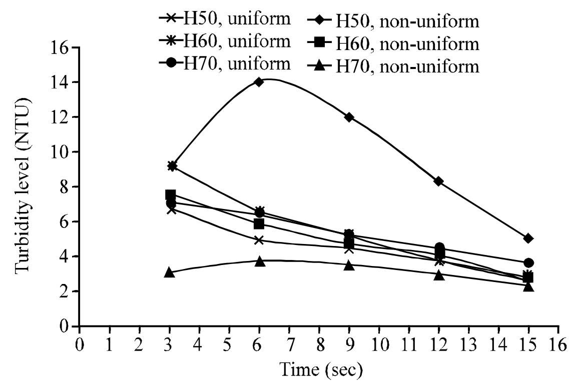

Fig. 4: Comparison on turbidity levels of uniform and non-uniform grain diameter

impregnation time through the cavity of the filter medium. The lowest turbidity level (2.69 NTU) was found at 50 cm of thickness at 15 sec of drainage time. The turbidity level for non-uniform grain diameter was increased in 6 sec at 50 cm of thickness. Nevertheless, a regularly decrease was found at end time. The lowest turbidity level (2.33 NTU) was ccurred at 70 cm of thickness at 15 sec of the drainage time.

In uniform grain diameter (0.84 mm) at 50 cm of thickness that was the beginning of drainage, the filtration mechanism was not performed perfectly. Therefore, the output water was still clean (low turbidity level) and proportional to the magnitude of discharge efficiency.

Almost the same result was obtained in non-uniform grain diameter with 70 cm of filter thickness where a fairly large grain diameter as 2 mm placed on the top layer. In the such condition, a large flow rate and duration of see page of water passed through the filter medium were resulted in. Furthermore, a low turbidity level and proportional to the magnitude of discharge efficiency were obtained.

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