Relevance between filtration rate and filter media thickness in downflow filter systems

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Abstract. One of the simple, easy and inexpensive water treatment technologies is the Sand Filtration technology. Sand Filtration is one of the very small grains of sand as a filter media. This study is an experiment. The objective to be achieved in this study is to analyze the difference in the thickness of the sand filter media to the filtration speed and the amount of filtration discharge, which is the object of research is the raw water of the Departemen engineering Hasanuddin University with treatment using a long reactor 50 cm, width 50 cm and height 150 cm. Down Flow filtering method with sand thickness varies namely 20 cm, 30 cm, 50 cm, besides that it also uses 15 cm gravel and 5 cm fibers. Testing is done by screening, calculating the speed of water through the filter and checking the flow of water.

The results were obtained with a thickness of 20 cm sand filtration media resulting in a filtration flow of 0.000199 m³/second with flow rate filtration 0.000794 m/second, a thickness of 30 cm sand filtration media resulting in a filtration flow of 0.000220 m³/second with rate filtration 0.00879 m/second while 50 cm sand produces filtration flow 0.000242 m³/second with rate filtration 0.00969 m/second. It can be concluded by increasing the thickness of the filtration media filtration discharge and filtration speed also increases.

1. Introduction
Water has an important role in human survival. All daily activities are inseparable from dependence on water. Water is a natural resource that is needed for the lives of many people, even all living things. Therefore water resources must be protected so that humans and other living things can still use it. The use of water for various purposes of future generations. At present, the main problems faced by water resources include the quantity of water that has been unable to meet the increasing needs and the declining quality of water for domestic needs.

Efforts to meet the needs of clean water development must be done well so that not only can meet the requirements in the long term, but also can maintain the sustainability of its existence. Water sources that can be used to meet the needs of clean water for human settlements can come from various sources including surface water, river water, swamp/lake water, shallow groundwater, deep groundwater, and springs. One of the simple, easy and inexpensive water treatment technologies is the sand filter technology. Sand Filtration is one of the techniques used to improve water quality. Sand filters use very small grains of sand as a filter media [1].
Filtration is the process of filtering particles physically, chemically and biologically to separate or filter out particles that are not deposited by sedimentation through porous media. During the filtration process impurities in the filter media will cause blockages in the pores of the media so that the pressure loss will increase [2].

Ideal media for filter media are media that have a large surface area per volume body, lowcost, durable, and not easily clogged. In general, the material avoids the many holes in the media, and as a place to fill biomass. Stone media has been developed into plastic, and redwood media [3].

1.1. Quartz / silica sand
Quartz is the result of weathering rocks that contain major minerals such as quartz and feldspar. The purpose of silica sand is to eliminate the physical properties of water, such as turbidity / muddy water and eliminate odours in water. In general, silica sand is used in the initial stages as a filter in the treatment of dirty water into clean water.

1.2. Active charcoal
Charcoal is a form of carbon that has a black porous colour and it is obtained from the combustion without oxygen to raw materials for coconut shells, cattle bones, saws and coke or coal. The structure of activated carbon is in the form of amrof and has certain crystalline properties, porous, a large surface area so that it is able to absorb organic compounds, odour, colour, taste, and non-biodegradable compounds.

1.3. Zeolites
Zeolite is an aluminosilicate that has a porous structure with channels in a crystalline frame, in which water molecules and alkali metal ions occupy it. The basic units forming zeolites are SiO₄ and AlO₄ which form a tetrahedral. The units of the unit bind to form anionic networks in three dimensions. The ratio between Si and Al ranges from 1: 1 to 100: 1. The most stable structure is zeolite. The ratio of Si and Al is 1: 1. The above properties zeolite can work as ion exchange and as a filter through selective adsorption or molecular rejection due to molecular rejection due to differences in molecular size and other factors.

Effective Size (ES) or the effective size of filter media is the size of the top filter media that is considered the most effective in separating impurities that are 10% of the total depth of the filter media layer or 10% of the weight fraction, this is often expressed as d₁₀ (diameter at percent10) [4]. Uniformity Coefficient (UC) or uniformity coefficient is the uniformity of filter media which is expressed by the ratio between the diameter size at 60% weight fraction to the effective size or can be written \( UC = d_{60} / d_{10} \). d₆₀ is the grain diameter at a stop. Permeability is defined as the nature of a porous material that allows seepage flow from liquid in the form of water or oil to flow through the pore cavity.

The soil pores are interconnected from one another so that water can flow from a high-energy point to a lower-energy point [5]. The amount of permeability is determined by effective porosity. Soil permeability depends on the texture and structure of the soil, both of which depend on the number of pores of the soil, the size of the soil comb and the twists of the flow and humidity of the flow of water in it. Soil permeability will control how quickly water can infiltrate into the soil which will cause runoff and erosion. To measuring the velocity of water flow through a pore cavity, the Darcy equation is used, which reviews the relationship between velocity and hydraulic gradient. Given the equation as follows [5]:

\[
\begin{align*}
    v &= i \cdot k \\
    Q &= i \cdot k \cdot A
\end{align*}
\]

Where:
\( v \) = flow velocity (cm / sec)
\( i \) = hydraulic gradient
\( k \) = permeability coefficient (cm / sec)
Q = seepage discharge (m³ / sec)
A = cross section area flowed (m²)

2. Experimental Program
The method used in this study is an experimental laboratory. The research will be carried out in the Hydraulics Laboratory and Environmental Engineering Laboratory, Department of Civil Engineering, Faculty of Engineering, Hasanuddin University in Gowa. This study aims to analyze the difference in thickness of the sand filter media (Sand Filtration) on the filtration speed and the amount offiltration discharge using a downflow filter system. Media that will be used in this study are beach sand, zeolite stones and palm fiber.

Next, create a filtration model from acrylic material, in the form of a rectangular cube with dimensions of 50x50x150 cm³ as the filtering reactor (filtration) and dimensions of 100 cm x 100 cm x 100 cm as a water reservoir, the water used is raw water at the Hasanuddin University engineering faculty. For filter analysis, a set of filters no. 4, 10, 18, 40, 60, 100, 200 is used. Downstream beach sand filter system is water treatment which is flowing water through a sand filter media, with the direction of flow from the top of the sand media to the bottom of the sand media (downflow), so that the filtering results are below.

3. Result and Discussion
As the initial process, sand sifting is done to get the ES and CU values in accordance with SNI 03-3981-2008 [6]. Sand sifting process is carried out at the Civil Engineering Laboratory of Hasanuddin University by using sifter No. 3/8, 4, 10, 20, 40, 50, 60, 70, 120, 200. Besides that, sand density is also tested obtained the specific gravity of beach sand (Gs) 2.660, Cu = 2, so that the beach sand meets the requirements and is fit to be used as a filter media in water treatment according to SNI standards the coefficient of permeability obtained 0.0065 cm / s. This shows that beach sand is included in the permeability group that escapes water K> 1 x 10⁻⁴ (cm / s), so that beach sand meets the requirements to be used as a filtration media. The results of the measurement of discharge and velocity on the sand filter thickness variations of 0.2 m, 0.3 m and 0.5 m with 3 times the volume of 0.05 m³, 0.1 m³ and 0.15 m³ are as follows.

![Figure 1. Relevance between sand thickness and inflow discharge (Qin).](image-url)

Figure 1 it can be seen with a sand thickness of 20 cm obtained the amount of incoming flow 0.000527 m³/sec for water volume 0.05 m³, 0.000685 m³/sec for water volume 0.1 m³ and 0.000708 m³/sec for water volume of 0.15 m³. For 30 cm sand thickness, the incoming debit is 0.000612 m³/sec for water volume 0.05 m³, 0.000626 m³/sec for water volume 0.1 m³ and 0.000678 m³/sec for water volume 0.15 m³.
For sand thickness of 50 cm, the incoming discharge is 0.000610 m$^3$/sec for the volume of water 0.05 m$^3$, 0.000641 m$^3$/sec for the volume of 0.1 m$^3$ and 0.000648 m$^3$/sec for the water volume of 1.5 m$^3$. With the addition of the incoming volume will affect the incoming discharge, as well as the addition of thick sand will also affect the incoming discharge.

![Figure 2](image1.png)

**Figure 2.** Relevance between sand thickness and filtration discharge.

From the figure 2 obtained with a sand thickness of 20 cm obtained the amount of filtration discharge 0.00011 m$^3$/sec for the water volume of 0.05 m$^3$, 0.000199 m$^3$/sec for the water volume of 0.1 m$^3$ and 0.000232 m$^3$/sec for the water volume of 0.15 m$^3$. For 30 cm sand thickness, the incoming debit is 0.000208 m$^3$/sec for the water volume of 0.05 m$^3$, 0.000220 m$^3$/sec for the water volume of 0.1 m$^3$ and 0.000181 m$^3$/second for the water volume of 0.15 m$^3$.

For sand thickness of 50 cm, the incoming discharge is 0.000218 m$^3$/sec for the volume of water 0.05 m$^3$, 0.000242 m$^3$/sec for the volume of 0.1 m$^3$ and 0.000231 m$^3$/second for the water volume of 1.5 m$^3$. With the addition of the thickness of the sand, the filtration flow also increases, this is because the thicker the sand, the more pores the sand absorbs water, causing the filtration discharge to increase.

![Figure 3](image2.png)

**Figure 3.** Relevance between sand thickness and inflow filtration rate.
From the figure 3 obtained with a sand thickness of 20 cm obtained the magnitude of the incoming water velocity is 0.002107 m/sec for the water volume of 0.05 m$^3$, 0.002741 m/sec for the water volume of 0.1 m$^3$ and 0.002833 m/sec for the volume water 0.15 m$^3$.

For 30 cm sand thickness, the incoming debit is 0.002448 m/sec for the water volume of 0.05 m$^3$, 0.002506 m/s for the water volume 0.1 m$^3$ and 0.002712 m/s for the water volume 0.15 m$^3$. For sand thickness of 50 cm the incoming discharge is 0.002441m/sec for the volume of water 0.05 m$^3$, 0.002592 m/sec for the volume of 0.1 m$^3$ and 0.002562 m/sec for the water volume of 1.5 m$^3$. The speed at which water enters does not significantly affect the thickness of the sand, the speed at which water enters depends on how much volume the water enters.

![Figure 4. Relevance between sand thickness and filtration rate.](image)

From the figure 4 obtained with a sand thickness of 20 cm obtained the amount of filtration speed of 0.000443 m/sec for the water volume of 0.05 m$^3$, 0.000794 m/sec for the water volume of 0.1 m$^3$ and 0.001015 m/sec for the volume of water 0.15 m$^3$. For 30 cm sand thickness, the incoming debit is 0.000832 m/sec for the water volume of 0.05 m$^3$, 0.000879 m/sec for the volume of 0.1 m$^3$ and 0.000724 m/sec for the water volume of 1.5 m$^3$. For sand thickness of 50 cm, the incoming discharge is 0.000871 m/sec for the volume of water 0.05 m$^3$, 0.000969 m/sec for the volume of 0.1 m$^3$ and 0.000936 m/sec for the water volume of 1.5 m$^3$. Filtration speed affects the thickness of the sand, the thicker the sand the less the filtration speed.

4. Conclusion

From the results of the analyst, it can be concluded that the relationship of filtration speed affects the thickness of the sand. The thicker the sand the greater the filtration discharge and the less the filtration speed is due to the fact that the sand has pores so that the water will enter the sand pores.

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