International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I8P229
Volume 69 Issue 8, 237-242, August, 2021

Raw Water Treatment Model With Combined System of Downflow – Upflow Filter

Yolly Adriati[1], Muhammad Saleh Pallu[2], Mary Selintung[3] and Bambang Bakri[4]

[1]*Doctoral Course, Civil Engineering Department, Hasanuddin University, Jalan Poros Malino, KM-6 Gowa, Phone 08122`809711.*

[2]*Civil Engineering Department, Hasanuddin University, Jalan Perintis Kemerdekaan KM-10 Phone 081241706215.*

[3]*Civil Engineering Department, Hasanuddin University, Jalan Poros Malino, KM-6 Gowa, Phone 082399429958.*

[4]*Civil Engineering Department, Hasanuddin University, Jalan Poros Malino, KM-6 Gowa, Phone 082293714321.*

yollyadriati@eng.uir.ac.id, salehpallu@gmail.com, mary.Selintung@yahoo.com, bambangbakri@gmail.com

Abstract *- Treatment with a combined system of downflow and up-flow filters is a straightforward raw water treatment system. Filtration technology with flow direction from top to bottom (downflow) and from bottom to top (upflow) is widely applied in small-scale communities, but this method could be developed further. When clogging occurs, it is necessary to wash the media manually. This study analyzes the effect of filters on raw water treatment and analyzes the effectiveness of the turbidity level of raw water treatment with a combination of downflow and upflow system. With beach sand filter media with varying thicknesses of 10 cm, 20 cm and 30 cm, and a combined filter media of beach sand and zeolite with a thickness of 20 cm. The results showed that turbidity was reduced significantly with a combination of downflow and upflow filter system. It also more efficient in the use of filter media thickness, with a low filter media thickness, it could remove 78% to 99% turbidity. This indicates that the downflow and upflow filter combination system can eliminate turbidity with low filter media*

Keywords — *downflow upfow, discharge, speed, filtration, efficiency*

I. INTRODUCTION

Raw water is the beginning of a process in the provision and treatment of clean water. Based on Government Regulation of the Republic of Indonesia No. 16 of 2005, that what is meant by raw water is water originating from surface water sources, groundwater basins, and or rainwater that meets specific quality standards as raw water for clean water [1]. One source of raw water that is still widely used by the community is river water, but not all of them meet health requirements. Factors that can affect the low quality of river water is including season, construction, type and slope of the soil, distance from the source of pollution, and the behavior of living things around it [2]. One of the water treatment techniques that are very suitable to meet the need for clean water in small-scale communities or household scales is the filtration system [3,4]. Filtration technology that is widely applied in Indonesia is usually conventional filtration with the flow direction from top to bottom (downflow) and from bottom to top (upflow) [5].

The part that plays an essential role in filtering is the filter media. This is because the thickness of the filter media affects the filtration discharge, filtration speed, and the final result of filtration [6-7]. This study aims to find the design of the raw water treatment model using a combination of downflow filter system and Up-flow system with varied thickness of the filter media so that the speed and the turbidity of raw water could meet the requirements [8].

II. LITERATURE STUDY

Filtration is a process of separating solids from fluids (liquids or gases) that carry them using a porous medium or porous material to remove as much of the suspended and fine colloidal solids as possible [4].

Based on the direction of flow, filtration is divided into:

- Downflow filtration
- Up-flow filtration
- Up-flow - downflow filtration
- Horizontal flow filtration

A. *Downflow Filtration System*

A Downflow filtration system is a filter system where raw water is distributed into the filtering device with the direction of water flow from top to bottom [5]. In general, the water treatment process with a downflow filtration system consists of a processing unit, namely a water reservoir. The water treatment unit with a slow downflow sand filter is a package where the treatment capacity can be designed with various sizes according to the required needs. Usually, this filter only consists of a tub to hold water and sand filter media. This body is equipped with a bottom-line system, inlet, outlet, and control equipment. The inlet structure is made in such a way that water enters the filter and does not damage or agitate the top surface of the gravel media. Meanwhile, the outlet structure is used to remove processed water and functions as a weir to control the water level above the layer.

B. Upflow Filtration System

The upflow filtration system is a liquid waste treatment system which basically flows liquid waste through a filter media, with the flow direction from below the sand media to the top of the sand media, so that the filtering results are above the raw waste. Filtration with an upflow system is seen as more effective in minimizing deadlocks in the media due to the high turbidity of the raw waste. In addition, with a system like this, it will be easier to wash the media, which is enough to open the drain valve, which will flow cleaner processed products [5].

C. Filter Media and Media Distribution

The filter part that plays an essential role in filtering is the filter media. Filter media is a granular material that has pores. Filter media can be composed of natural silica sand, anthracite, or garnet sand [6]. These media generally vary in size, shape, and chemical composition. The selection of filter media to be used is done by sieve analysis. The sieve results of a filter media are depicted in the distribution accumulation curve. To find the effective size and the desired media uniformity expressed as uniformity coefficient [10-11].

D. Filtration Hydraulics

In principle, the resistance or friction of a flow in an analog grained/porous media (sand filter) with a large number of small pipe flows. The pressure loss in the pipe due to flow friction follows the Darcy-Weisbach equation below [12]

$$h_l = \frac{f.L.V^2}{D_c 2g} \qquad (1)$$

From Darcy Weisbach's formula f' = ¾ f, the Carman – Kozeny equation was obtained [13]

$$h_f = f' \frac{L}{\psi d}\left(\frac{1-\varepsilon}{\varepsilon^3}\right)\frac{V_a^2}{g} \qquad (2)$$

The f'Value is a function of N_{RE}

$$f' = 150\left(\frac{1-\varepsilon}{N_{RE}}\right) + 1{,}75 \qquad (3)$$

The Reynold Number NRE is a function of diameter and flow velocity derived by the formula [14].

$$N_{RE} = \frac{\psi.d.V_a}{\nu} = \frac{\psi.\rho.d.V_a}{\mu} \qquad (4)$$

With :

h_l = pressure loss due to friction (m)
f = Coefficient of roughness
L = media thickness or depth (m)
V = flow speed (m/second)
Dc = Pipe's diameter (m)
P = Specific Gravity
μ = Dynamic Viscosity
ν = Kinematic Viscosity

In addition to the Carman – Kozeny equation, there is an empirical equation to calculate the pressure loss when the filter is clean, namely the Rose equation (Rich, 1974) as follows

$$h_L = 1{,}067 \frac{C_D.L.V_a^2}{\psi.d.\varepsilon^4.g} \qquad (5)$$

Turbidity reduction efficiency can be calculated using the following formula [15].

$$\frac{K_{in} - K_{out}}{K_{in}} \; x\ 100\% \qquad (6)$$

With :

RTurbidity = Turbidity efficiency (%)
K_{in} = Turbidity before filtering (NTU)
K_{out} = Turbidity after filtering (NTU).

III. METHODOLOGY

A. Type of Research

The research used is experimental laboratory research. To obtain research data, the source of data used comes from primary data, namely data obtained directly from physical model simulations in the laboratory and secondary data obtained from the literature on existing research results, both carried out in the laboratory.

B. Research Parameters

The media used in this study are beach sand filter media with a thickness of 10 cm, 20 cm, and 30 cm and a combined filter media (beach sand and zeolite) with a thickness of 10 cm, 20 cm, and 30 cm, zeolite thickness is 20 cm and fibers is 3 cm. This combined media was installed in stages on both the downflow system and the upflow system. The tools used are two units of acrylic filtration reactor model, made with a laboratory-scale of 1: 1 in a rectangular cube with dimensions of 50 cm long, 50 cm wide and 150 cm high. The first reactor is used for downflow system filtration and the second is used for upflow system filtration (combined). A channel was made between down flow and up flow with dimensions of 200 cm long,10 cm wide, and height of 10 cm.

The raw water used is ground well water at the Gowa campus, clouded with a low concentration of 50 NTU, a medium concentration of 200 NTU, and a high concentration of 1000 NTU, which was tested using a Turbidity Meter.

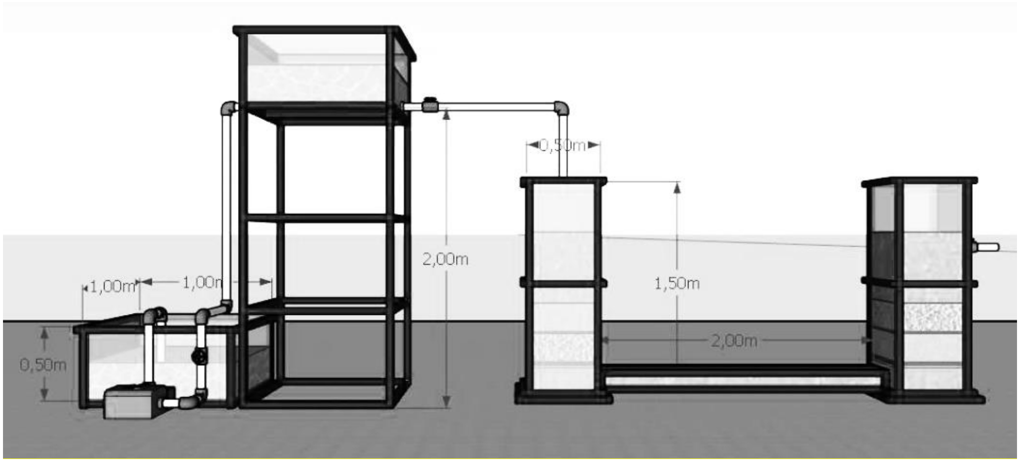

Fig 1. Downflow and upflow Combined Filtration System

Data were collected by observing the time of filtration and sampling (inlet and outlet). Sampling for outlets is carried out at intervals of 5 minutes until the 30th minute of processing, and the sample is tested using a Turbidity meter to check the level of turbidity contained in the sample.

IV. RESULTS AND DISCUSSION

Parameters to describe the downflow and upflow filter combination system are filter media thickness (D), raw water concentration, grain diameter of filter media (beach sand and zeolite), filtration discharge (Q_{out}), filtration speed (v_{out}), loss of energy (hl), hydraulic gradient and turbidity

A. Characteristics of Filtration Media

After sieving for beach sand, the value of Es= D10 = 0,25 (Requirement stated in SNI 03-3981-2008 is 0,2 – 0,4 mm) and Cu = D10/D60 = 2 (Requirement stated in SNI 03-3981-2008 is 2- 3)[2], As for the zeolite media used as a buffer medium, the diameter is 19,1 mm (Requirement stated in SNI 03-3981-2008 is 10- 30 mm)[2]. The test results showed that the specific gravity of beach sand (Gs) is 2,660, and the specific gravity of zeolite is 2,674. In addition to the filter analysis and the density of the filter media, the porosity of the beach sand is 0,43, and zeolite porosity is 0,41. so that beach sand and zeolite meet the requirements and are suitable for use as filter media in water treatment according to SNI standards.

B. Effect of Media Thickness on Discharge and Filtration Speed in Downflow – Upflow Combined Systems

The research was conducted by testing the effect of varied media thickness on the discharge and filtration speed. The filtration system uses a downflow up-flow filter combination system. The filtration media used are beach sand filtration media with three thickness variations, namely 10 cm, 20 cm, and 30 cm.

And a combined filtration media between beach sand, zeolite, and palm fiber with a thickness of zeolite 20 cm and palm fiber 3 cm. three variations of raw water concentration, namely low concentration (50 NTU), medium concentration (200 NTU), and high concentration (1000 NTU). The incoming discharge is 0.597 liters/second or 597 cm^3/second. Every 5 minutes, the discharge is measured. This research lasts for 30 minutes. The results of the measurement and calculation of the discharge can be observed in Figure 2.

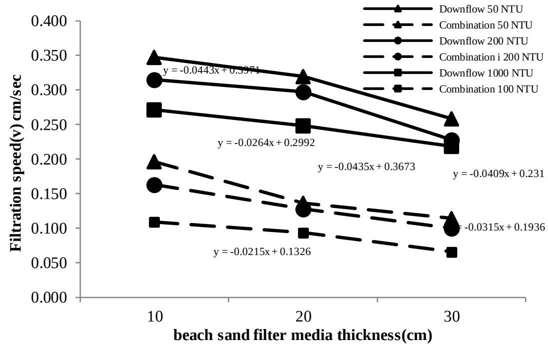

Fig 2. The relation between the thickness of the beach sand media to the discharge in the downflow upflow filter combination system

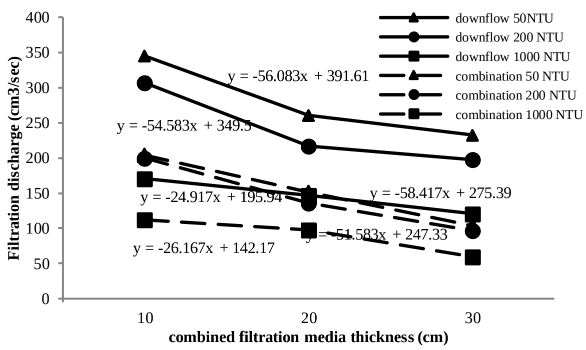

Fig 3. The relation between the thickness of the beach sand media and the combined filter media to the discharge in the downflow upflow filter combination system

Figure 2 shows the relationship between the thickness of the beach sand filter media and the combined media to the discharge discharge (filtration discharge, Q_{out}) by using a combination of Upflow and downflow filters system. Downflow system flow direction from top to bottom and upflow system flow direction from bottom to top.

In the beach sand filter media (a) from three variations of thickness and three variations of raw water concentration, it can be seen that the filtration discharge (Q_{out}) at a thickness of 10 cm with a low concentration (50NTU) the filtration discharge is greater than the thickness variation and other concentration variations in the downflow upflow filter combination system, which is 373.39 cm^3/second in the downflow system and 289.43 cm^3/second in the combination system, this is because the low thickness factor (10 cm) and low concentration (50NTU) causes the filter media pore space to fill faster and fewer particles stick to the filter media, so that the filtration discharge (Q_{out}) becomes greater.

Filtration discharge ratio (Q_{out}) by 62.54% in the downflow system and 35.36% in the combination system. The relationship between thickness and filtration discharge (Q_{out}) tends to be a straight line equation in the downflow system of filtration discharge equation y = -47.613x + 426.87 in the combined system of filtration discharge equations y = -43.967x +248.35.

While in the combined filter media (b) the filtration discharge debit (Q_{out}) smaller than the beach sand filter media, in the downflow filtration discharge system (Q_{out}) is 345,83 cm^3/second, as for combined system is 203,83 cm^3/second, filtration discharge ratio (Q_{out}) 57,76% on the downflow system and 34.14% on the combination system. This is due to increasing thickness of the zeolite filter media (20 cm) and palm fiber (3 cm) so that the pores of the zeolite media are filled with water, and the filtration discharge is reduced.

The relationship between thickness and discharge tends to be a straight line equation in the downflow system, the filtration discharge equation y = -56.083 x + 391.16 in the combined system of filtration discharge equation y = -58.417x +275.39. The thicker the filter media and the higher the concentration of raw water, the smaller the filtration discharge. Changes in the thickness of the filter media and the turbidity concentration of raw water also affect the filtration speed (v_{out}). The filtration speed for beach sand filter media and combined filter media with varying thickness and concentration can be observed in Figure 4.

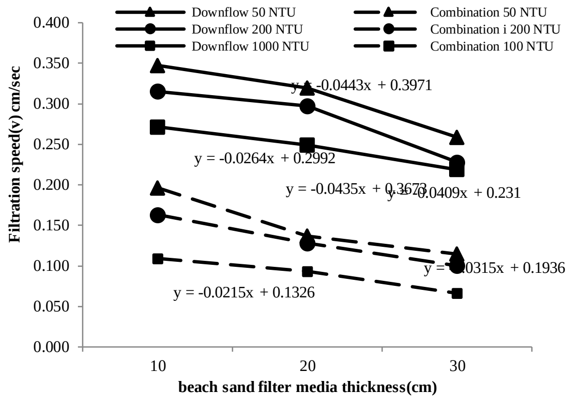

Fig 4. The relationship of the thickness of the beach sand filter media to the filtration speed in the downflow upflow filter combination system

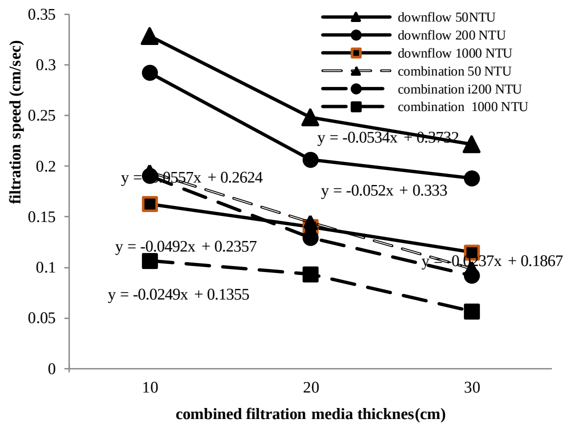

Fig 5. The relationship of the thickness of the combined filter media to the filtration speed in the downflow upflow filter combination system

In the beach sand filter media (a) from three variations in thickness and three variations in the concentration of raw water, it is observed that the filtration speed (V_{out}) at a thickness of 10 cm with a low concentration (50NTU) the filtration speed is greater than the thickness variation and other concentration variations in the downflow upflow filter combination system, which is 0.35 cm/second in the downflow system and 0.28 cm/second in the combination system, this is because low thickness factor (10 cm) and low concentration (50 NTU) causes the flow velocity to be higher. The time required to absorb is reduced so that the filtration rate (V_{out}) become greater. The relationship between thickness and filtration speed (Q_{out}) tends to a straight-line equations in the downflow system, the filtration velocity equation y = -0.0443x + 0.3971 in the combined system the filtration rate equation y = -0.0435x + 0.3673.

While in the combined filter media (b) the filtration speed (Q_{out}) smaller than the beach sand filter media and the downflow system the filtration speed (Q_{out}) of 0.33 cm/second, the combined system of 0.21 cm/second. This is due to increasing the thickness of the zeolite filter media (20 cm) and palm fiber (3cm) so that the time required for absorption is longer. The relationship between thickness and filtration speed tends to be a straight line equation in the downflow system.

The filtration velocity equation y = -0.0534x + 0.3732 in the combined system of the filtration velocity equation y = -0.0237x + 0.1867. The thicker the filter media and the higher the concentration of raw water, the smaller the filtration speed.

The analysis results for the filtration discharge and filtration speed for both the beach sand filter media and the combined filter media, thickness, concentration, and flow direction are very influential. Changes in the thickness of the filter media and the concentration of turbidity affect the discharge (Q_{out}); the thicker the filtration media and the higher the turbidity concentration of the water, the lower the filtration discharge. The relationship between discharge and velocity is directly proportional, where the more significant the filtration discharge, the greater the filtration speed.

The downflow direction will provide a higher flow rate and velocity than the upflow direction, because the downflow direction occurs vertically by gravity from top to bottom while the upflow flow occurs from bottom to top, requiring strong pressure. The higher the thickness of the filter media, the lower the water pressure to go up so that the discharge and filtration speed will be smaller.

C. Headloss

The presence of turbidity or viscosity in raw water will cause shear stress when moving. This shear stress will convert some of the flow energy into other forms of energy. The change in the form of energy causes a loss of energy (*hl)* or *head loss* [9]. In principle, the flow in the filtration media (grained media) is considered flow in many pipes.

The amount of energy loss (head loss) follows the Darcy-Weibach equation [10-11]. The amount of energy loss in the beach sand filter media and the combined filter media can be seen in Figure 6.

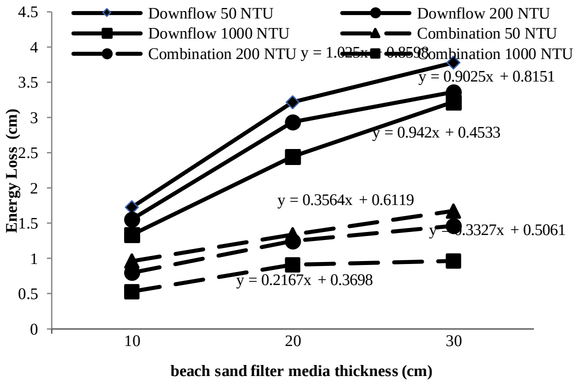

Fig 6. Energy Loss of beach sand filter media

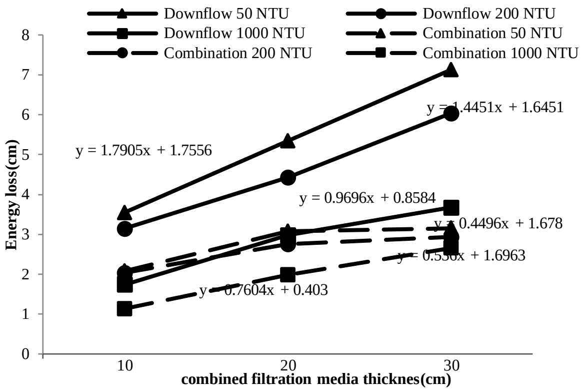

Fig 7. Energy Loss of combined filter media

The most significant head loss in the beach sand filter media occurred at a thickness of 30 cm with a low concentration (50 NTU), which was 3.78 cm in the downflow system and 1.68 cm in the combination system.

While in combined media (b) the most significant energy loss occurred at a thickness of 30 cm with low concentration (50NTU) which was 7.13 cm in the downflow system and 1.4 cm in the combination system.The energy loss in the downflow system is greater than in the combination system (upflow).

This is because in the downflow system where the flow direction from top to bottom is greater, the pressure will cause the shear stress to increase and change the flow energy in other forms, while the upflow flow direction is from down and up the pressure that occurs is not too large so that the shear stress is reduced and the energy loss is small.

D. Efficiency of Turbidity Removal in Downflow – Upflow filter combination systems

A chemical reaction causes this turbidity. Turbidity measurement using a Turbiditymeter, turbidity in water can reduce water quality in terms of aesthetics. Therefore, according to the Regulation of the Minister of Health in 2010[15] the turbidity allowed for clean water is a maximum of 25 NTU.

In the beach sand filter media, the efficiency of turbidity removal for low concentrations (50 NTU) with a thickness of 10 cm in the downflow system is 67.3%, in the combination system, it is 78%. As for the thickness of 20 cm in the downflow system is 77%, the combined system is 85%, the thickness of 30 cm in the downflow system is 86.3%, and the combined system is 91%. The turbidity removal efficiency for medium concentration (200 NTU) and high concentration (1000 NTU) in the downflow system ranged from 82% to 97.3%, and in the combination system ranged from 86.6% to 98%.

In the combined filter media, the efficiency of the removal of turbidity in the filter media at a thickness of 10 cm low concentration (50 NTU) in the downflow system is 79 7%, the combined system is 87%, the thickness is 20 cm, the downflow efficiency is 83.7%, in the combination system 91 %, at a thickness of 30 cm the efficiency of the downflow system is 91.7%, and the combined system is 95.3%. For medium concentrations of 200 NTU and high concentrations (1000 NTU) it ranges from 93.6% to 99.6%.

V. CONCLUSION

Based on the results of the research, it is shown that the treatment of raw water with a combination system of downflow filter Upflow removal of turbidity is quite significant and more efficient in the use of filter media thickness, with a low thickness of filter media it can remove 78% to 99% turbidity. This indicates that the downflow upflow filter combination system can eliminate turbidity with low filter media

REFERENCES

[1] Permenkes nomor 16/Menkes/Per/IV/2005 Syarat baku mutu air bersih.

[2] SNI 6774:2008 tentang spesifikasi unit paket instalasi pengolahan air .

[3] Binie,C; Kimber, M.2013Basic Water Treatment, 5th ed; ICE Publising London, UK.

[4] B Bakri, M.Selintung, RN Hamdani, M. Ihsan, Y. Arai , 2019. The Effectiveness of PAC and Chitosan Usage in Jeneberang River Raw Water Treatment. Systems. IOP Conference Series: Material Science and Engineering 679 (1),012028.

[5] Huisman, L. 1994. Rapid ans Slow Sand Filtration. Lecture Notes. IHE Delt Netherlands.

[6] Joko,T.,Unit Produksi dalam Sistem Penyediaan Air Minum, Graha Ilmu., .(2010).

[7] Maryani, D., Masduqi, A., dan Moesriati, A., Pengaruh ketebalan media dan rate filtrasi pada sand filter dalam menurunkan kekeruhan dan total coliform. Jurnal teknik pomits., 3(2) (2014) Hal D.76-D.81.

[8] Y. Adriati, MS Pallu, M.Selintung, B.Bakri., Relevance Between Filtration Rate and Filter Media Thickness in Downflow Filter Systems. IOP Conference Series: Earth and Environmental Science 419 (1) (2020) 012130

[9] Khambhammettu., Full Scale Evaluation of Upflow Filter A Catch Basin Insert for the Treatment of Stormwater at Critical Source Areas., (2006).

[10] S.Syahrir, M.Selintung, S.Pallu, A.Thaha., Studi Pengolahan air melalui media filter pasir kuarsa (studi kasus malimpung), Disertasi Program Doktor Teknik Sipil Universitas Hasanuddin.

[11] S.Syahrir, M.Selintung, S.Pallu, A.Thaha., Studi Model Efektifitas Medi Pasir Kuarsa Pada Proses Filtrasi Single Medium (Studi Kasus Sungai Tiroang). Repository.stt-baramulli.ac.id., (2012).

[12] M Orianto, W. Pratikono., Mekanika fluida I. Yogyakarta: BPFE UGM., (1989).

[13] Triatmodjo, B., Hidraulika I. Penerbit Beta Offset. Yogyakarta., (2014).

[14] Triatmodjo, B., Hidraulika II. Penerbit Beta Offset. Yogyakarta., (2015).

[15] SS Antaria, M.Selintung, MS Pallu, MP Hatta., Test Of Bio Activator Model With Natural Zeolite form South Sulawesi As Filter Media and Adsorbent Heavy Metal Pb, Ni and Cu. IPTEK Journal of Proceeding Series 1., (2015).