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UPFLOW ROUGHING FILTER IN SERIES AS ALTERNATIVE PRETREATMENT IN WATER TREATMENT PLANT SIWALANPANJI, SIDOARJO, INDONESIA

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ABSTRACT

Turbidity 2500 NTU produced by raw water of the Buduran River is not able to be processed by Water Treatment Plant (WTP) Siwalanpanji Sidoarjo. It is because the WTP used Siwalanpanji ultrafiltration water treatment only treated turbidity below 100 NTU. therefore, a preliminary process is required to reduce the turbidity which is almost 100 NTU. Processing uses the principle of filtration with the variation of diameter of small to big media is suitable for it. It used gravel filter media in varied diameter for 6 compartments called Upflow Rouhging Filter In Series (UFRS). UFRS is able to reduce 2500 turbidity NTU with an infiltration rate of 1 m/h 95.95%.

KEY WORDS : Infiltration, Pretreatemnt, Turbidity, *Upflow roughing filter*

INTRODUCTION

Siwalanpanji Water Treatment Plant (*IPA*), Delta Tirta Sidoarjo PDAM (*Indonesian Water Utility Company*), has 2 alternatives for water treatment after the collecting well unit, namely ultrafiltration In the process, the provision of raw water to be processed by the ultrafiltration unit in Siwalanpanji *IPA*, this turbidity must not exceed the value of 100 NTU because it can decrease the effectiveness of ultrafiltration membranes. The turbidity value in Buduran River raw water captured by the Siwalan IPA intake unit often exceeds the permitted conditions. The turbidity value of the raw water used by Siwalanpanji IPA comes from the Buduran River is 27 NTU (during the dry season) and a maximum of 2175 NTU (during the wet season).

The very high turbidity in the raw water of Siwalanpanji *IPA* requires a treatment that has a filtration principle. Filtration is one of the principles of conventional water treatment in reducing pollutants. RF (Roughing Filter) is used as a preliminary treatment at PDAM Sidoarjo. The type of RF reactor used is URFS (Upflow Roughing Filter In Series). The study was conducted in wet season (February - March), because in this season the turbidity reached up to 2175 NTU. Another parameters to be analyzed is the turbidity in the 2000 range with a standard deviation of 2.5%. In previous studies of HRF (Horizontal Roughing Filter), it was able to reduce turbidity by 82% with gravel filter media (Ochieng and Otieno, 2006). With the same filter media VRF (Vertical Roughing Filter), it can reduce turbidity by 63.4% (Dastanaie, *et al*., 2007). Water treatment plants Siwalanpanji treating raw water using UFRS as Pre treatment could remove total nitarte in dry and rainny seaseon for respectively 72.6% and 44.2%. UFRS that choosen is addeb by geotextile with velocity 1m/hour (Kusuma *et al.,* 2016).

In addition to reducing turbidity, RF can reduce algae, total coli, color and heavy metals (Jayalath, 1994, Ochieng *et al*., 2004, Nkwonta and Ochieng, 2009). According to Nkwonta and Ochieng (2009), HRF has a better performance than VRF. The percentage of allowance is best achieved at low filtration speeds (Boller, 1993). Previous studies found that HRF was able to reduce turbidity by 92-97% and Parasite egg by 90.1% (Al-bayatti and Habeeb. 2009 and Mahvi, *et al.*, 2001). Also, RF can reduce turbidity of Fe and Mn and coliform respectively by 67%, 85% and 95%, 94% (El-Taweei and Ali, 1999; Pacinni. 2005; Dome. 2000; Mahvi. 2004; Dastanaie. 2007)

MATERIALS AND METHODS

In this research, URFS efficiency will be tested to reduce turbidity, with variations of filtration speed and the presence or absence of geotextile use.

Media Selection

The method in the study is to reduce the turbidity of 2500 NTU, by filtering with the gravel media of Compartment I = (10-15) mm; Compartment II = (16-20) mm; Compartment III = (21-25) mm; IV compartment = (26-30) mm; Compartment V = (31-35) mm; Compartment VI = (36-40) mm

Reactor Dimension

Real Q = 250 L/s = 900 m^3/ hour
URFS land area = 40% of the area provided = 40% x 2000 m^3 = 800 m^2
P: l ratio = 6: 1
• Real URFS dimension:
A = P x l = 6l x1
800 = 6 l2
l = 11 m
p = 66 m
• Dimension of the URFS reactor model
From the ratio P: l = 6: 1, the dimension used in the reactor is as follows, it can be seen in Figure 1 for more details. Planned RF test laboratory scale reactors:
Length: width (1 compartment) = 1: 1
Length = 25 cm x 6 compartments = 150 cm
Width = 25 cm

Determination of the artificial turbidity value

The Determination ofturbidity value used as a variation of this study is <100 NTU and 2500 NTU. The turbidity cannot be exact at 2500 NTU of its value; therefore, a deviation level of 10% is applied. Turbidity obtained with a deviation of 10% is
• Turbidity of 2500 ± 10% NTU

For the specification of turbidity can be obtained by applying the following equation:

C total =

Q1 = Debit of raw water for dilution (m^3/s), planned to be 250 m^3 / s

Q2 = Debit of sludge (m^3/s)

C1 = the concentration of raw water for dilution (mg/L)

C2 = sludge concentration (mg /L).

Determination of variations in filtration speed

- For filtration speed of 1 m^3/m^2/hour, an influent discharge of 0.375 m^3 / hour is obtained
  $V_{filtration}$ = 6 m^3/m^2/hour
- For filtration speed of 3 m^3/m^2/hour, an influent discharge of 1.125 m^3/hour is obtained

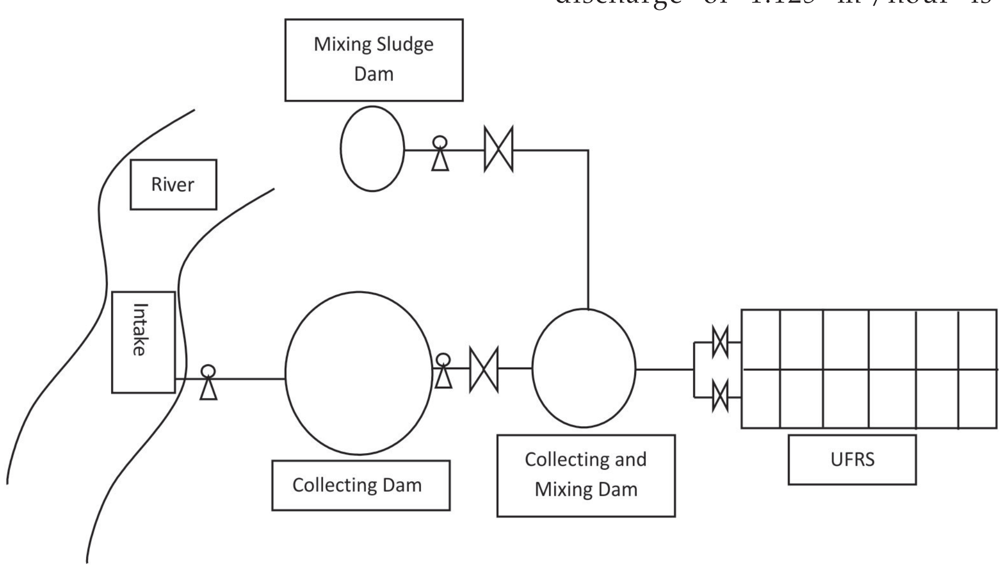

Fig. 1. Scheme of Reactor Installation Plan for Upflow Roughing Filter in Series Test at Siwalanpanji WTP Information Sizing of gravel media on Compartment I = (10-15) mm; Compartment II = (16-20) mm; Compartment III = (21-25) mm; IV compartment = (26-30) mm; Compartment V = (31-35) mm; Compartment VI = (36-40) mm

Fig. 2. The sludge stirring basin.

$V_{filtration} = 18\ m^3/\ m^2/\ hour$

Geotextile

Geotextiles are permeable polymeric materials which are in the shape of woven, knitted, non-wovenused in geotechnical work and other civil engineering. Geotextile has a function as follows: Non Woven Geotextile serves to prevent the carrying of soil particles in the water flow. Because the nature of the Non Woven Geotextile is permeable, water can pass through the Geotextile but the soil particles are retained. Applications as filters are usually used in subdrain projects (underground drainage).

Research Implementation

This research will be carried out at the beginning of April 2012 until the end of June 2012. The place of research was in Siwalanpanji IPA and the raw water used is Buduran river water. Analysis of pollutant parameters was carried out in ITS Environmental Engineering laboratory. Sampling was conducted at 10:00 a.m. The samples used are raw water samples at URFS inlets and URFS outlets. The running was done for 10 hours to form a clogging pattern and the sample was taken every 2 hours. Analysis of pollutant parameters would be done in duplo.

RESULTS AND DISCUSSION

In this study, 2500 NTU turbidity can be reduced with variations in flow velocity 1 m/hour and 3 m/hour. At a velocity variation of 1 m/hour with an analysis of 2500 NTU turbidity reduction, it is known that using RF with geotextile results in greater removal than without using geotextile. The flow rate of 1 m/h URFS without geotextile resulted in a percentage of removal that was not much different from the UFRS with a running speed of 3 m/hour. It can be concluded that in order to get a turbidity removal percentage of 95%. Moreover, it is better to use 3 m/hour because it speeds up hydraulic time and saves land.

Small drainage rate results in a better removal percentage. The ability of the existing mini test plant is only able to drain raw water with a flow rate of 3

Table 1. Results of turbidity removal percentage

Hour	Turbidity Removal Percentage (2500 NTU)			
	1 m/hour		3 m/hour	
Hour I	96.09	95.10	95.49	94.42
Hour II	96.16	95.63	95,91	94.93
Hour III	96.33	96.17	95.54	94.98
Hour IV	96.10	95.84	96.03	
Hour V	96.17	95.75	96.07	
Total	96.17	95.70	95.81	94.80

Fig. 3. Sludge used for turbidity determination of 2500 NTU

Fig. 4. Storage tank for outlets

m/hour, more than the flow rate, raw water experiences over flow. Figure 4 illustrates the 2500 NTU turbidity removal percentage between 1m / hour flow rate with a flow rate of 3 m/hour.

It shows that the RF that is suitable to be applied in Siwalan IPA to reduce 2500 NTU turbidity is by using RF 1 m/hour without geotextile. The RF is chosen because of the consideration of the results of better removal percentage that is equal to 95.70% and the treatment is not too difficult compared to geotextiled URFS. This is because the sludge attached to the geotextile is very thick so it requires high pressure water to wash which can damage the biofilm attached to the geotextile.

Roughing filter is a preliminary treatment to reduce the turbidity of water passing through the reactor containing coarse media such as gravel or pottery. This RF has been used by more than 25 countries, including Argentina, Bolivia, Madagascar, Ghana, India, Australia, and so on. RF is mostly used as a preliminary treatment for remediating large amounts of particles that cannot be carried out by SSF (Losleben, 2004). SSF uses media with a diameter of 0.15 mm - 0.35 mm while RF uses a media diameter greater than 2 mm. When treating high turbidity water with prelimin ary processing using RF, SSF has the advantage that the turbidity removal work is smaller thus SSF does not clog frequently. To minimize the frequency of RF cleaning and prolong RF operation, the incoming turbidity ranges from 20-150 NTU (Wegelin *et al*., 1987).

Roughing filters usually use gravel with different diameter sizes, where in the initial section using large diameter gravel, and the next part uses small diameter gravel, and so on. Therefore, each of these parts filters solids of varying sizes (Wegelin *et al*., 1987). Particle removal efficiency of pollutants in RF depends on the filter design and water quality parameters (Boller, 1993; Collins, 1994; Wegelin *et al*., 1987). The effluent from the RF should no longer contain 2-5 mg / l solids to meet the quality of the raw water entering the SSF. This filtration improves the physical quality of water because it can eliminate suspended solids and reduce turbidity. However, it is expected that bacteriological quality of water also increases because this filtering is effective in removing viruses and bacteria whose size is between 0.2 - 1.0 µm. Based on some literature, it is stated that microorganisms undergo adhesion due to electrolysis bonds to other solids in raw water. Thus, the removal of solids also means a reduction of patoghenic microorganisms. Bacteriological quality can increase to 60-90%, and the number of microorganisms decreases between 1-2 logs (Wegelin, 1996).

The presence of particles of small size in raw water allows precipitation and adhesion to the media and does not use mechanical filtering, therefore, the main filtration process only occurs in RF (Schultz and Okun, 1984). However, the presence of filter media results in lowering the deposition distance and making the particles stick to make the media slippery due to the formation of biofilms on the surface of the media.

The removal of suspended solids requires laminer flow. Biofilms formed on the surface of the media or in the pores of the media hold suspended solids due to the Van Der Waals force and the electrical forces between the particles (Wegelin, 1996). However, if the repulsive force can be overcome, the pulling force between the particles due to the Van Der waals force can occur, the result is flocculation of the particles increasing the speed of settling the particles (Hunter, 1981).

Roughing filter is initially used to separate solids from raw water as some or all of the solids are retained in a distillation pond or pre-sedimentation tank. RF is mostly a physical filtering unit and reduces solid mass. However, with the occurrence of a surface area that is large enough for sedimentation and a small filtration speed, it can support the same adsorption process as biological and chemical processes. Therefore, in addition to material solids separation, RF can also improve water quality in terms of biology and can further improve several other water quality parameters, such as color or a number of dissolved organic matters.

The main process that occurs in RF is sedimentation (Wegelin, 1996). The RF mechanism is to separate solids from water using a multi storage sedimentation system. If there is clogging or deadlock on the RF, cleaning can be done by cleaning the media in a vertical direction on the HRF. Roughing filters were originally used to separate solids from raw water

Colloidal particles in the water can be removed using RF with several filtration mechanisms. According to Wegelin (1996), there are three RF removal mechanisms: filtration on the surface (Cake), filtering filtration, physical and chemical filtration.

The basic principle of RF work is that raw water enters the RF through a medium with a different diameter. The first and sure thing to happen is the separation of solid from raw water without the addition of chemicals and also the reduction of pathogenic microorganisms in raw water.

In Figure 5 raw water enters into the RF inlet and collisions occur between colloidal particles from raw water and filter media to accelerate precipitation. The decrease in turbidity is greater after passing a different diameter size which starts from large to small diameter. Unlike sedimentation, in this process there is a very long deposition resulting in large land requirements as well. This deposition speed depends on the size of the floc formed in the previous processing. The size of the floc depends on the addition of coagulants/chemicals, as the magnitude of the addition greatly affects the operating and keshata costs. RF does not use chemicals in the turbidity removal process.

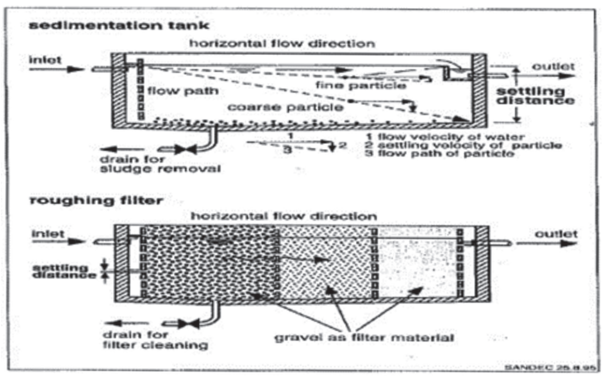

Fig. 5. RF working principle versus sedimentation (Wegelin, 1996)

RF generally has a wide compartment which is filled with filter media with a smaller size in the direction of the water flow or the type of RF used. The other RF can be in the form of multiple compartments where each compartment is filled by medium that has the same diametric size in each compartment. Figure 6 shows three RF configuration models, namely Horizontal Roughing Filter (HRF), Downflow Roughing Filter in series (DRFS) and Upflow Roughing Filter (UFRS).

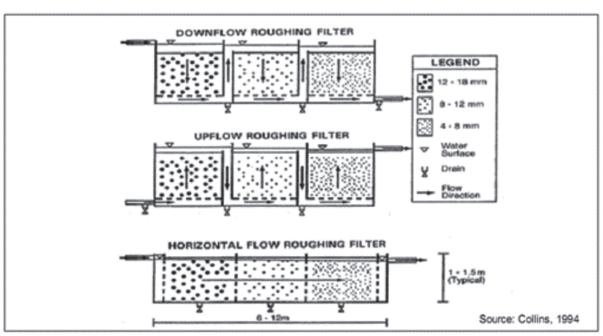

Fig. 6. RF Configuration (Wegelin, 1996)

The design criteria used to conduct RF planning are (Wegelin, 1996):

- Filtrarion Rate (Vf) ranges between 0.3 - 1.5 m^3 / m^2 / hour.
- Depth of RF upflow and downflow between 0.6 - 1.2 m and horizontal flow length between 5-7 m.
- Tub width between 4 - 5 m
- Filter surface area for upflow or downflow between 25 m^2 - 30 m^3 and 4m^2 - 6 m^2 cross area for horizontal flow.
- Gravel media fraction can be seen in Table 2.2 below.

Table 2. RF Media Fraction

Roughing Filter	Filter Media Size (mm)		
Rough material	24 - 16	18 - 12	12 – 8
Normal	18 - 12	12 - 8	4 – 8
Soft material	12 - 8	8 - 4	4 -2

Source: Wegelin (1996)

The types of media commonly used in RF are quartz sand and gravel but can be replaced using clean, insoluble material and mechanically resistant media. Furthermore, alternative filter media that is used must have a surface area that can increase the sedimentation process and have high porosity to place accumulation of particle separation. In the filtration experiment, it was stated that it was not the roughness and shape / structure of the media material from the large filter which affected the removal efficiency of pollutants. Media materials that can be used as filter media are as follows:

- Pebbles from rivers or soil.
- Rocks fragments or from a mine.
- Bricks fragment.
- Plastic meter in the shape of a screw or module (as used in the trickling filter)
- Wood charcoal combustion, although it is a bad risk in washing it but useful in remediating organic substances.
- Coconut fiber.

Ochieng, (2006) states that coal fragments and advanced agricultural waste (charcoal from corn cobs), can also be effectively used as preliminary processing media. Those filter media are natural alternatives if there is no gravel commonly used. Filter media that have the best performance in previous studies are coal and charcoal fragments rather than using gravel. The study was the result of

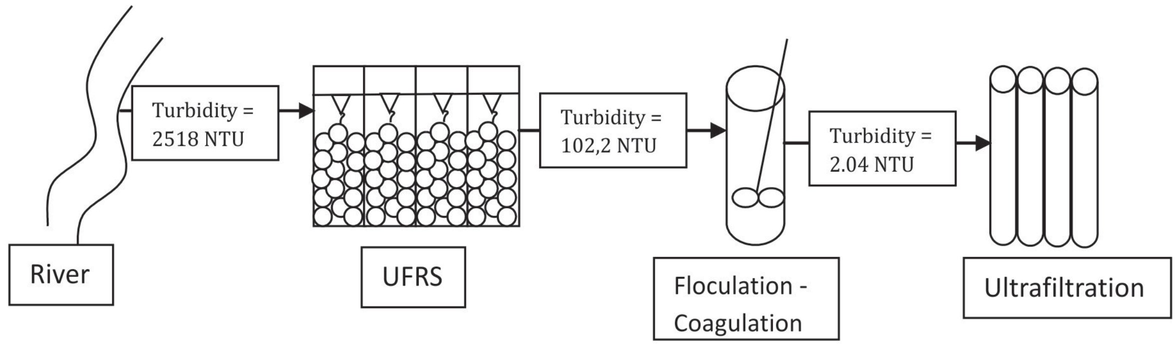

Fig. 6. High turbidity water treatment configuration

experiments of wood and coal charcoal which have a high specific surface area and porosity which can increase the sedimentation process rather than using gravel. In the previous research, the filtering system was carried out in various forms and directions of flow and summarized in the following table. From previous research using the roughing filter principle was used as a benchmark for determining the use of UFRS in treating high turbidity. The results showed that UFRS had not been able to reduce turbidity to 100 NTU. Moreover, 100 NTU turbidity is used as influent which is allowed to enter ultra filtration. Also, an extended treatment is needed in reducing turbidity.

Therefore, the average reduction of UFRS with a speed of 1 m / hour with an inlet turbidity value of 2518.8 NTU and outlets can be reduced on average to 102.2 NTU with a percentage of removals at 95.95%. Turbidity of 102.2 NTU must be reduced using coagulation until it is allowed to through the ultrafiltation process. The organic coagulant is recommended to avoid the chemical, such as using the Opuntia spp coagulant. It has ability to reduce turbidity to 2.04 NTU. The process using media porous has potential to reduce turbidity, TSS, and total coli more than 80% (Kusuma *et al.*, 2018a; Kusuma *et al.*, 2018b; Kusuma *et al.*, 2018c). However to improve the performance of the roghing filter, aeration process is recommended to added.

CONCLUSION

The physical process in UFRS can reduce turbidity at a value of 2500 NTU with an infiltration rate of 1 m/ hour of 95.95%. The porous media in roughing filter has potential to reduce the turbidity, TSS, and total coli.

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