

Potential Use of Bengkulu Coastal Sand as Capillary-Gravitational (Grapilar) Slow Sand Filter Media

Sigit Mujiharjo

Agroindustrial Study Program, Faculty of Agriculture, University of Bengkulu

E-mail: Sigitmujiharjo@aol.com

ABSTRACT

Two-mini standart SSF were joined length side by length side and equiped with inflow container for one side and outflow container for the other side to be operated as media for capillary force, for the inlet side of sand media, and media for gravitational force, for the outlet side of sand media. Filtration tests were conducted by using clear water by varying the pressure head on the system with no head media with head media for the purpose to identify the performance of Bengkulu coastal sand as capillary-gravitational SSF media. Result of test showed that with no head media, there was no water flow through the system, whenever pressure head applied lower than the pressure head level. With head media, on the other hand; the flow would take place eventhough the pressure head much less then the pressure head level. Characteristic of capillary flow was also identified.

Key words: Bengkulu coastal sand, capillary flow, grapilar SSF

INTRODUCTION

Increase of the unavoidable land-to-human-needs-for-settlement conversion would produce effect to increase of rural family requirement of technology for water purification. Water city seems never reach them, the sorrounding water resouces would have been badly polluted that unapropriate to be consumed. An inexpensive, easy to be built and operated, the materials easy to be found and or available around that suitable for a rural people, must be found out. Therefore, for coastal people, slow sand filtration would be the one.

Gravitational filtration by using fine sand as a filter media have a limitation on accumulating the separated pollutants on top of media bed causing clog on filtration process (Williamson, 2008). Stopping the process and cleaning the top part of the sand media are the common ways to solve clogging problem of slow sand filtration. Other way is to do back washing procedures by flowing clean water through the system back way (Rust and McArthur, 2010). Both methods need to disturb filtration process and renew some materials.

Vertical slow sand filter (SSF-V), a modified SSF with horizontal flow process filtration, was introduced by Mujiharjo (2009) for the purpose to have slow sand filter technology with no clog problem and no filtration process disturbance. Minimum pressure head combined with minimum width of sand media required by the system have made this technology was not appropriate for single family use operation.

Pipe slow sand filter (SFF-P), was another modification product SSF also introduced by Mujiharjo *et al.* (2012) to fulfill rural household need of water purification technology relatively free of clog problem and just meet to the requirement. Some household have been able to operate the technology; and a similar modification product have also been identified as cell slow sand filter (SSF-C). Full of care in constructing the technology was one of the problem faced to industrially produced.

Upflow system of sand media is overing technology of filtration having no accumulation of separated pollutants on the media that capable of reducing problems of clog. The design needs to profide pressure head that capable pushing the water flow upward through the sand media and flow over the top of the media bed. Similar to the SSF-V technology; this system was more suitable for a community consumption.

Principally the same as the upflow system, a capillary flow base technology of water purification could probably suitable household needs. Having particle size distribution of 0.05 – 0.25 mm (Mujiharjo *et al.*, 2008) that would be categorized as fine sand (Barfield, *et al.*, 1985). Bengkulu coastal sand is a potensial material as media filtration for water purification based on capillary force technology. However, capability of this sand for such usage has not been exposed. Purpose of this

study was to identify some aspects governing the flow of a water filtration system applying capillary force of the Bengkulu coastal sand.

MATERIALS AND METHODS

Two mini-size of standard systems of SSF to be placed side by side in length; equipped with an inlet and an outlet container placed at both side in length of the SSF to have a capillary –gravitational system of SSF. The size of each mini SSF was 50x20x30 cm; and the height of inlet and outlet container were extended up to 50 cm; as well as the height of the SSF on the outer side was also extended to 50 cm to accomodate additional sand media as head media and pressure head during the test (Figure 1).

Sand that was used as the media was the Bengkulu coastal sand collected from the area of Pantai Panjang beach; while the water applied to run the series of tests was clear water for the purpose as a reference liquid to be tested.

For the purpose to run the test, the pressure head, the head of water in the incoming flow side, was step by step to be increased. In these tests, the pressure head was started at 10 cm below the top of the sand media, up to as high as the top of the sand media. As there was no water flow coming out of the system, the tests were continued by increasing pressure head up to 20 cm above the top of the sand media. Tests were run at every 5 cm of different pressure head and to be repeated 3 times. Parameters recorded, besides the pressure heads were the water flow coming out from the system. Debit of flow was measured by volumetric method.

Series of tests by varying the pressure heads were also done on the system after putting head media, an additional sand media placed on top of the two mini SSF to have the two mini SSF connected; as thick as 1,5 cm. The other test was done by adding more sand media on top of the system to describe the effects of different head media height on the flow of the system.

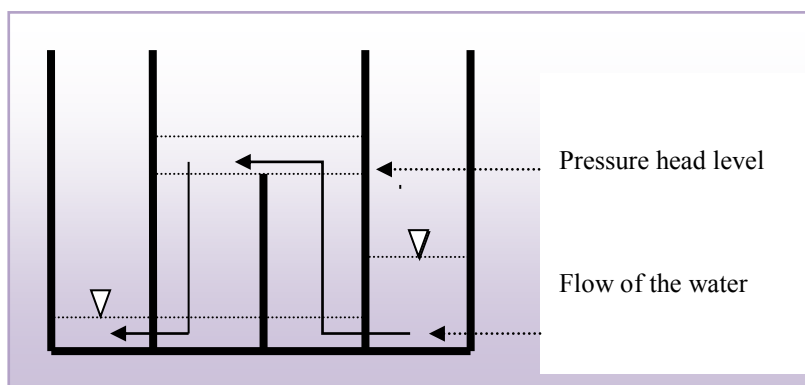


Figure 1. Sket of capillary-gravitational (grapilar) SSF tests

RESULTS AND DISCUSSION

Flow of the System with no Head Media

With pressure head applied was up to as high as the top of sand media, the pressure head level, there was no flow coming out from the outlet system, whenever there was no additional sand media to be put on top of sand media as called head media (Table 1). Under this condition, the applied pressure head was not strong enough to push the water up to the top of the sand media as there was loss of head accordingly following the Darcy's law (Schwab *et al.*, 1981; Abbood, 2009); while capillary forces exist only maximum up to the top of the sand media as there was no more empty pore functioned as capillar; therefore there was no flow through the system.

Table 1. Average flow of the system tested with and without head media

Pressure head (cm) relative to media height	Average flow (ml/s)	
	Without head media	With head media
20	1.43	1.80
0 (level)	0	1.04
-5	0	0.86
-10	0	0.59

As the pressure head was higher than the pressure head level, there was water flowing aside to the outlet side of sand media by overpassing the sand media separator. Debit of flow for step by step pressure head increas was unfortunately not recorded; but at the pressure head appllied was 20 cm above the head level; the flow was 1.43 ml/s in average that was much less then that there was head media. With no head media, the flow was merely governed by the pressure head applied. Depending on the area of the inlet side of sand media, total head loss could be calculated by applying the Darcy’s formula (Schwab *et al.*, 1981) the debit could finally be found. Eventhough there was capillary force that may act in the process of flowing water through the sand media; it was suspected that the flow in the system was mostly governed by the pressure head applied.

Existence of Head Media

Based on an observation, eventhough the applied pressure head was level, there was water flowing through the system whenever there was a head media; the more head media the higher debit was (Figure 2). This could happened as the additional sand media in the inlet side was applying its capillary forces to drive water up and then aside to additional sand media in the outlet side; causing water flows from the inlet side to the outlet side of the head media. Finally, the gravitational force would drive the water in the outlet side of the head media down to the bottom part and leave thesystem. This process was continoues that made the water flow from the inlet to the outlet of the system.

Regression analysis concerning percentage of head media covered and flow produced relationship showed that debit of the system increased as the area of the head media increased; following an equation as $Y= 1.431073+0.10028 X+0.265598 X^2$; with Y was total debit of flow (ml/s) and X was percent of head media covered. The expression of the relation described that the total flow was not a result of mathematical addition of the partial flows. As more water on the inlet side of sand media was pulled into the outlet side of sand media; the available space to store them decreased; as a result there was gradually less amount of water to be transported, every time the head media covered increased. Therefore, the additional debit of flow would decrease as the head media covered increased.

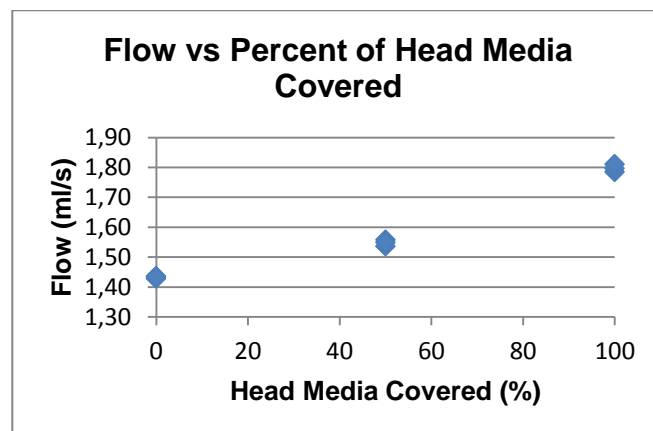


Figure 2. Plot of flow versus percent of head media covered

Although the existence of head media would drive the flow through the system, additional height of the head media would not always increase the flow. Data of the test showed that there was no significant difference debit of flow from the system as the height of the head media was increased; from 1.5 cm to 3.5 cm (Figure 3). Head media in the inlet side, in this case, functions as area to lift thewater up as high as the capability of the capillary forces did; and the maximum lift would be as high

as the top of sand media. As the sand media in the inlet side was connected to the sand media in the outlet side, at the same time, the water would also be attracted to flow aside to the outlet side of media by gravitational force as well as capillary forces of the media in the outlet side. Therefore, depending on area of sand media in the outlet side compared to the one in the inlet side, the height of head media needed by the system to flow water through it was certain; and not fully governed by the height of head media provided.

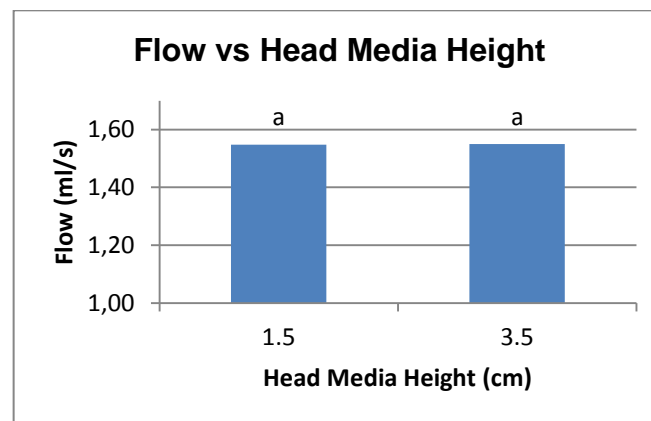


Figure 3. Flows from system with different height of head media

Capillary flow characteristics

Capillary flow occurred whenever the pressure head applied is less than the pressure head level; as the flow through the system was caused by both capillary forces of the sand media as well as pressure head. Capillary force would be governed by the physical laws of surface tension and viscous flow (Miller and Miller, 1956); and depended on the diameter of the capillars, surface tension between air and water, degree of wettability of the sand, atmospheric pressure, and also degree of compressibility of the water (Szymkiewicz, 2013). Theoretically, the capillary force occurred above the pressure head force; but they would possibly collaborate to drive the water move through the sand media.

Based on the research conducted, debit of capillary flow was in relation to the pressure head applied; up to the value of pressure head level, the higher pressure head, the more debit of flow to be had (Figure 4); following an equation of $Y=0,58713+0,621942 X-0,16574 X^2$; with Y was debit of flow (ml/s) and X was pressure head applied; that in this case was the height (dm) of water in the inlet side relative to the pressure head level. The constant value of the equation could be different when different pressure head level was applied; as the driving force of the flow was not only depended on relative height between pressure head applied to the pressure head level; but also be governed by pressure head level itself. The higher pressure head level, the bigger gravitational force that would pull the water in the outlet side of sand media down to the outlet. Therefore, for the same value of relative height (X), the debit of flow (Y) could be higher or lower, depending on the pressure head level.

In terms of equation order, in this result of study was a quadratic equation; was not a linear equation; it was believed that it was caused by the existing capillary forces were not linearly related to the relative height (X). Rise of the water in a capillary tube is mostly depended on the diameter of the tube; not the relative height; the smaller the tube, the higher the water. Therefore, a non-linear equation would be understandable. Moreover, Das and Mirzaei (2012) on the effort of finding dynamic effect in capillary pressure relationship in porous media had concluded that the dynamic coefficient; measurement of saturation change with respect to the time; was a non-linear function of saturation that was depended on media permeability.

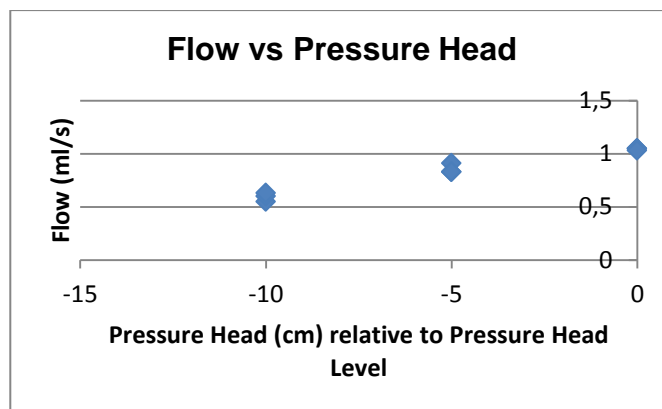


Figure 4. Flow from system with different pressure head of a capillary flow

CONCLUSIONS

Bengkulu coastal sand, having particle size distribution of 0.15 – 0.18 mm that categorized as finesand, is a potential material as water purification filter media use in a capillary based technology. Based on the study conducted, there would be no water flow whenever there was no head media, and the pressure head was lower than the pressure head level. Whenever pressure head higher than the pressure head level, or whenever there was head media, there would be water flow through the system. However, height of head media, for some extend, was not governed the debit of water flow.

Debit that could be had, besides to be determined by size and design of the system, would be depended on pressure head applied; the higher the pressure the more debit could be collected, following a quadratic function, not only a linear function.

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