IDENTIFICATION OF OPTIMUM FILTER MEDIA CONFIGURATION TO IMPROVE THE TREATMENT EFFICACY OF PEBBLE MATRIX FILTERS (PMF)

C.P.G. Jayalath[1], N.S. Miguntanna[2], P.R.U.W. Samarasinghe[3] and C. Kariyawasam[4]

[1] Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Sri Lanka. Email: jayalathcpg@gmail.com
[2] Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Sri Lanka. Email - nadeekas@cee.ruh.ac.lk
[3] Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Sri Lanka. Email - u_wimukthi@yahoo.com
[4] Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Sri Lanka. Email - cyril@eie.ruh.ac.lk

ABSTRACT

The Pebble Matrix Filtration is a non-chemical, sustainable pretreatment method to protect Slow Sand Filters from high turbidity. High filtrate turbidity of a PMF is badly affected to the quality of drinking water. This paper presents a study on investigation an optimum filter media configuration for PMF to improve its turbidity removal efficiency using wasted natural pebbles. The laboratory scaled model was used to test six filter media configurations for minimum effluent turbidity while fixing the influent turbidity into 60 NTU. Optimum configuration was selected as which gave the maximum turbidity removal efficiency. Finally, the performance of the selected optimum configuration was tested by changing the influent turbidity. Lab tests results verify that the efficiency of the PMF increases when the mean diameter of pebbles in filter media is decreased and the sand proportion in the pebble-sand mix bed is increased together.

***Key words*:** Nonchemical pretreatment, Pebble matrix filtration, Turbidity removal

1. INTRODUCTION

The Pebble Matrix Filtration is a non-chemical, sustainable pretreatment method to protect slow sand filters from high turbidity during heavy monsoon seasons in tropical countries [1]. The first full-scale Pebble Matrix Filter (PMF) unit in Sri Lanka has been constructed in the water treatment plant, Kataragama. Unexpectedly, high filtrate turbidity has been noted which has badly affected to the quality of water and hence to people who use the water of the treatment plant for their day to day activities [2]. Therefore, it is required to find out efficiency improvement methods to this PMF in order to provide safe drinking water. This paper presents investigation of an optimum filter media configuration for PMF using wasted pebbles in order to improve its treatment efficiency.

2. METHODOLOGY

2.1 Site Visit to the Kataragama Water Treatment Plant

One site visit was conducted to realize the existing circumstances of the treatment plant and issues associated with the Pebble Matrix Filter (PMF) and hence to define the scope and to plan the research methodology of this project. In this context, the history of current PMF filter at the treatment plant site, problems encountered while installing and operation stage, remedial actions which have been taken to overcome issues related with the filtering process, records of the turbidity measurements of the inflow and outflow of the PMF, temporal variation of turbidity, expected efficiency level and the achieved efficiency of the current PMF were investigated.

2.2 Construction of a Model of the PMF

Figure 1 shows a schematic diagram of the filter model. The height; length and width of the model are 90 cm, 60 cm and 30 cm respectively. The lower compartment of the model with 18 cm height is to collect filtered water. Overflowed water above the weir at the influent is collected to the existing compartment located next to the wire of the model. One inch diameter circular pipes with taps were fixed at end of pipes in either sides of the bottom of the lower compartment, one as the effluent of the filtered water and the other one as the effluent of the overflowed. An iron mesh (Type No. 06) wrapped up with linen net cloth was placed at the bottom of the upper compartment to pass the filtered water easily into the lower compartment.

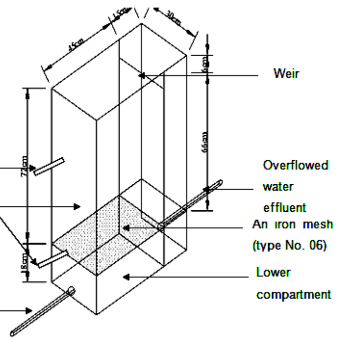

Figure 1: Schematic Diagram of the Filter Model

Two 5 mm diameter glass tubes with cellulose hoses were fixed at the end of each tube at depths of 20 cm and 72 cm from the top of the model respectively. These hoses were attached to a vertical timber plate and the whole compartment was used as the piezometer to measure the head loss through the filter bed.

2.3 Preparation of Filter Materials

The pebbles remaining after sieving river sand were used as the filter media. Initially, pebbles were collected from construction sites. After that, Impurities were removed manually and pebbles were sorted. River sand was used to mix with pebbles to prepare the required pebble-sand mixture of the filter bed. After sorting all the pebbles and sand at the initial stage; they were cleaned using water. At the end of every run, filter media was taken out from the experimental setup and put into a bucket and cleaned too. After cleaning the pebbles, they were sieved to sort them into different pebble sizes such as pebbles with diameters of 5.6mm, 6.7mm, 8mm, 9.5mm, 12.5mm, 19mm, 25mm and above, referring to methods given in BS 1377-Part 2. After that, six filter media configurations were selected using different sand proportions and pebbles in different sizes.

2.4 Lab Testing

The primary objective of the lab testing is to find out the optimum filter media configuration that most efficiently removes turbidity of influent water, out of six configurations. Laboratory scale filter consisted of three distinct layers. The bottom layer of 60 mm depth acted as a support for the filter bed. The middle and top layers formed the filter bed. The middle layer consisted with pebbles and sand into different ratios. The top layer consisted of only pebbles. Twelve experimental series were conducted so that there were two experimental series for each of six different configurations of the pebble-sand mixed bed. The selected mean diameters were 7.2 mm, 11.6 mm and 20.0 mm. Pebbles of each mean diameter was mixed with sand into 3:2 and 1:1 ratios (pebbles: sand).The influent was fixed into 60 NTU in all experimental series. While the filter was being operated for two and half hours, the effluent turbidity was measured at every ten minutes. The configuration that gave the highest turbidity removal efficiency was selected as the optimum configuration. After that, the selected optimum configuration was tested twice per each of different influent turbidity values of 200 NTU, 300 NTU, 400 NTU and 500 NTU in order to observe the response of the selected configuration for high influent turbidities.

2.5 Data Analysis

The collected data was analyzed using regression analysis techniques to examine complex relationships between variables. In this context, “Minitab 16” Statistical Software was used. Besides, suggestions were made to improve the PMF filtering process further.

3. RESULTS

Table 1 shows the details of filter media configuration and turbidity removal efficiencies achieved when influent turbidity is 60 NTU. Configuration 2 which consisted of pebbles with mean diameter of 7.2 mm and pebble: sand proportion of 1:1 gave the highest turbidity removal efficiency as 90.2%.

Table 1: Details of filter media configurations and turbidity removal efficiencies

Con. No.	Mean diameter of pebbles (mm)	Pebble : Sand volume ratio	Head loss (cm)	Efficiency (%)
1	7.2	3:2	6	72.4
2	7.2	1:1	7	90.2
3	20.0	3:2	1	66.9
4	20.0	1:1	1	70.0
5	11.6	3:2	5	76.0
6	11.6	1:1	6	83.4

It is well known that small grains give high turbidity removal efficiencies while leading to high head losses [3]. That is because, when the mean diameter of pebble particles is getting reduced, surface area per unit volume of the filter materials is getting increased. Consequently, vacant sites for adsorption to take place escalate when the surface area per unit volume becomes greater. Ultimately, the adsorption is dominant and responsible for a greater turbidity removal.

Correspondingly, head loss is higher when the grain size is small because of the low permeability of the grain bed. A similar phenomenon can be applied for the case of higher sand proportion in the pebble-sand mixed. Consequently, it is comprehensible that Configuration 2 triumphs the high treatment efficiency of 92% since it has the least mean diameter of pebbles as 7.2 mm and pebble: sand ratio of 1:1 in the pebble- sand mixed bed.

Figure 2 indicates that once the influent turbidity increases the turbidity removal efficiency declines correspondingly.

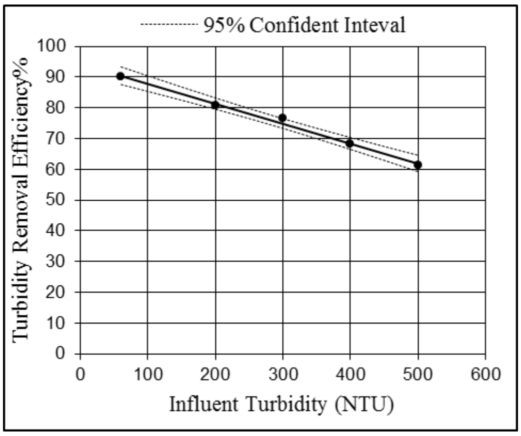

Figure 2: The variation of turbidity removal efficiency with influent turbidity

This phenomenon can be described as below. Even though the adsorption amount is increased as soon as the influent turbidity is increased because there is much adhesion to filter media due to a lot of turbid particles, the turbidity removal percentage gets decrease [4]. Therefore it is logical that the effluent turbidity increases when the influent turbidity increases. The formula for the regression line of the variation of turbidity removal efficiency with influent turbidity is shown in eq. (01).

$$y = -18.91 + 0.38x \qquad (01)$$

Where,
y = Effluent Turbidity Concentration (NTU)
X = Influent Turbidity Concentration (NTU)

The correlation coefficient (R) was 0.973 and it is very close to 1. Therefore it indicates very strong linear correlation between two parameters. The regression results tell that the predictor (Influent turbidity) is significant because of its low P-value (P =0). Influent turbidity accounts for 99.3% of the variance of effluent turbidity. Specifically; for each 1% increase in the amount of influent turbidity, the percentage of turbidity removal efficiency is expected to decrease by 0.065%. All the data points of the variation of turbidity removal efficiency with influent turbidity lie within the 95% confidence interval.

4. CONCLUSION

It can be concluded that the efficiency of the PMF increases when the mean diameter of pebbles in filter media is increased and the sand proportion in the pebble-sand mix bed is increased together. Furthermore, the turbidity removal efficiency decreases gradually once the influent turbidity increases. Estimated results are reliable for the variation of turbidity removal efficiency with influent turbidity because, all the data points lie within the 95% confidence interval.

5. REFERENCES

[1] Rajapakse, J.P. and Ives, K.J., 1990 "*Pre filtration of very highly turbid waters using Pebble Matrix Filtration*", Journal of IWEM, 4 (2): pp.140–7

[2] Rajapakse, J.P., Sumanaweera, S., Gallege, S. and Thillainathan, V., (2010). "*First Full Scale Trials of Pebble Matrix Filtration*", International Conference on Environment 2010 – Green technologies for the benefits of bottom billions, Malaysia.

[3] Ives, K. J. (1969). "*Theory of Water Filtration*", 8th Congress Vienna, IWSA, vol. 1. pp. K3—K29. Published in London.

[4] Jahn, S. A., 1984. "*Effectiveness of Traditional Flocculants as Primary Coagulants and Coagulants Aids for the Treatment of Tropical Raw Water with more than a Thousand-fold Fluctuation in Turbidity.*" Special Subject No. 615, IWSA congress, Monastir (Tunisia), pp. SS8-SS10.