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Comparative Analysis of Different Uniformities Coefficient of Crushed Glass as Filter Media in Rapid Filtration.

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Abstract- the comparative analysis between the filters having different Uniformity Coefficient (Cu) and different effective size (D_{10}) of crushed glass filter media in rapid filteration is done by measuring turbidity, head loss, Unit Filter Run Volume (UFRV) and backwash water consumption at different turbidity range and constant flow rate (i.e., 1lit/min). CG1, CG and CG3 models filters got Uniformity Coefficient (Cu) as 1.33, 1.70, and 1.33 and effective size as 0.45m, 0.60mm and 0.60mm respectively. The turbidity removal of filters was 94.66%, 90.29% and 83.87% for CG1, CG2 and CG3 filters respectively for influent turbidity range 25-85 NTU. The rate of head loss gained in meter after producing filtrate of 100 m^3 per m^2 area of filter was observed 1.75m, 1.28m and 1.01m for CG1, CG2 and CG3 filters respectively for turbidity range 80-150 NTU. The UFRV for filters was found to be 94 m^3/m^2, 129 m^3/m^2 and 164 m^3/m^2 for turbidity range 80-150 NTU of CG1, CG2 and CG3 filter respectively. The backwash water used of total filtrate volume by filter was found to be 23.13%, 16.17% and 11.76% for CG1, CG2 and CG3 filters respectively for filter run having turbidity range 80-150 NTU. On comparison between filters model CG2 and CG3 with different Cu and constant D_{10}, the turbidity removal efficiency of CG2 having higher value of Cu is more than CG3 filter in all turbidity ranges but UFRV is more of CG3 filter than CG2 filter. The rate of head loss in filter is higher of CG2 than CG3 and backwash water consumption is more of CG3 filter than CG2 filter. On comparison of three, CG1 filter having lower Cu and lower D_{10} have greater turbidity removal efficiency but it clogs faster than others.

Keywords: Crushed glass, Filter Media, Uniformity Coefficient, Effective Size, Unit Filter Run Volume, Head Loss, Turbidity, Efficiency

I. INTRODUCTION:

Water means life. It is one of the most basic elements for all living beings. It is as indispensable as air for us and for all of this water should be safe to drink. From ancient time to present, water filters have evolved out of necessity, first to remove materials that affect appearances, then to remove bad tastes and finally to remove contaminants that can cause diseases and illness. Safe drinking water is defined as water with microbial, chemical and physical characteristics that meet WHO guidelines of national standards on drinking water quality (WHO, 2011).

Amongst all, water filtration is one of the processes involved in ensuring the national standards of drinking water quality. Rapid filtration is one of the filtration processes which are purely a physical drinking water purification method.

Among all the physical parameters, turbidity acts as one of the basic physical parameters which needs to be treated before any further disinfection processes. The glass filtration was first introduced in the late 1990s, is catching on as a direct alternative to sand. Glass filtration is the product not only of the industry's never-ending search for the best media, but also the generous supply of recycled glass. Most beverage companies won't use cullet for new bottles because, they want pretty bottles. That leaves scrap glass to a limited market, which makes it perfect alternative to sand (Aquatics., 2014).

In 2013, the glass waste constitutes out of the total waste generated per day in 56 different municipalities of Nepal are 3 percent of 1,435 ton and 524,000 ton/year i.e., 43.5 ton/day and 15,720 ton/year (ADB, 2013). Thus, crushed glass can act as a perfect replacement of sand as a filter media and also can generate the entrepreneurship opportunities for producing crushed glass if proven better than sand.

Crushed glass is an amorphous (non-crystalline) material with no grain boundaries or uneven boundaries to reduce flow efficiency or to become habitat for contaminant build up. The surface of angular shaped glass particles, under a microscope, is a smooth as a large glass surface. These surfaces are less likely to support algae and fungal growth as per VitroMinerals (2014).

Crushed glass because of its greater angularity, it is expected that the porosity of filters containing crushed glass would be slightly higher leading to smaller head loss than sand. Pulverized glass produced by crushing and sieving recycled glass was employed successfully in wastewater filtration by Elliot (2001).

Crushed glass proves to be an efficient and effective media as alternative to sand in gravity filter in terms of head loss development, filter run length, turbidity removal efficiency and backwash requirements (Dharma, 2019). So, further study is done on different sized crushed glass as filter media in rapid filter to maximize the efficiency of glass filter and minimize the glass waste during the media preparation.

II. MATERIALS and METHODOLOGY:

The methodology of the study consists of design and setup of two rapid filters firstly having identical filter media properties, one CG1 filter having Uniformity Coefficient (C_u) as 1.33 and effective size (D_{10}) as 0.45mm filter media and other CG2 filter having Uniformity Coefficient (C_u) as 1.70 and effective size (D_{10}) as 0.60mm filter media with crushed glass, and regular measurements of turbidity removal of both filters. After fifth filter run with five different turbidity range one of filter is emptied and new filter media of crushed glass having C_u as 1.33 and D_{10} as 0.60mm called CG3 filter is set up and filter is run for five different turbidity range and measures all parameters as done in CG1 and CG2 filter.

The filter media for rapid glass filter is obtained from crushing the beverage bottle by crushing manually. Required quantity and sized were obtained from sieving. The crushed materials were sieved through series of sieve sizes 4mm, 2.36mm, 2mm, 1mm, 0.6mm, 0.425mm, and 0.3mm. The material retained on each sieve were collected separately, washed and cleaned to remove fine particles to avoid the possible negative health impact it might bring. However, water quality test to determine the presence of glass traces was not conducted in this regard. After drying in sun, they were mixed in fixed proportion by weight as shown in appendix B to create 1 kg batch of Uniformity Coefficient (C_u) of 1.3 and effective size 0.45mm for first filter CG1 and Uniformity Coefficient (C_u) of 1.7 and effective size 0.6 mm for second filter CG2. Generally, the depth of filter bed is 60 cm to 75 cm thick with the sand of effective size of 0.45 to 0.70 mm and uniformity coefficient (C_u) of 1.3 to 1.75 (Mota, 2014). Base material aggregate used in this study were of sizes ranging 2-4.75, 4.75-10 mm, 20-28 mm and 28-40 mm each of 10 cm depth.

III. EXPERIMENTAL SETUP

The laboratory models of rapid filters were constructed by fiber glass having internal dimensions (11 X 11 X 290) cm^3. The rapid glass filter has been designed for filtration rate 5000 lit/m^2/hr. Designed of Rapid filter, based on the design philosophy from the book " Water Supply Engineering" (Punima, 1995). The filters model was setup in premises of Pulchowk Campus, IOE, Lalitpur, Nepal as shown in figure:

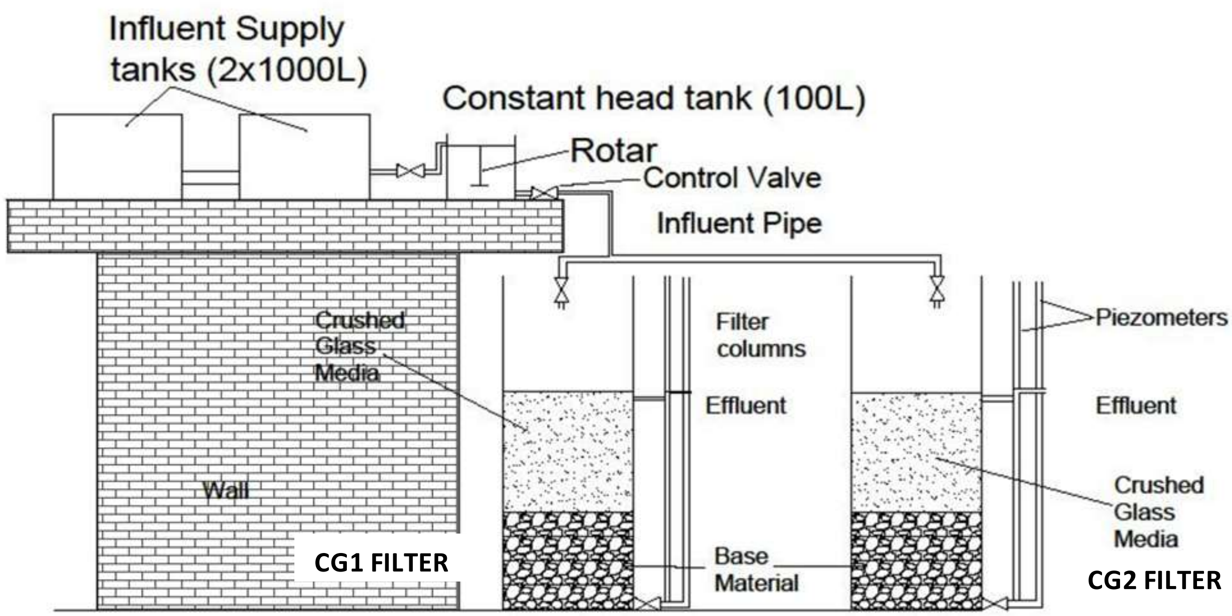

Fig1: Schematic Diagram of Crushed Glass Rapid Filter

A constant head water tank of 100 liters capacity was provided for constant supply of influent water to the filters which was connected to a two storage tanks with total capacity of 2,000 liters. Filters were connected with constant head water tank by 20 mm diameter pipes. Each model consists of altogether six ports, three at 5 cm above the base of filter on three different faces for outlet, piezometer and backwashing purposes, fourth at height of 115 cm from base of piezometer, fifth at height of 135 cm from base for backwashing effluent and sixth at height of 285 cm from base for influent overflow. Ball valve of 20 mm diameter was fitted to each port, except for the influent overflow port. The effluent level was kept 5 cm above the filter media to keep minimum of 5 cm water level above the filter media to keep media wet and to avoid development of negative head loss in the filter media

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IV. SAMPLE COLLECTION

Water samples were collected from inlet and outlet of the rapid filter for the experimental analysis. In the first phase, natural water from the well situated at water treatment plant premises of IOE was used while synthetic water was used in secondary phase of the study. Synthetic water was prepared by adding silt in natural water. The silt was brought from Lahan Nepal Water Supply Corporation branch office's sedimentation tank. Hit and trial method was used to calculate the amount of silt required to prepare the artificial suspension. The mixing tank was stirred continuously using mechanical rotor. As certain amounts of particles of silt settled quickly, wood stick was also used simultaneously so that the quickly settled particles are also agitated nicely to produce the desired turbidity range of synthetic water.

Filters were run for five filter run with turbidity range 10-25 NTU, 25-80 NTU, 80-150 NTU, 150-250 NTU and 250-350 NTU. Samples of influent and effluent water from the both filters were run were collected at interval of one hour in the sampling bottles of capacity of 120 ml and development of head loss was measured from measuring tape attached with filter over piezometer.

V. TUBIDITY and HEAD LOSS ANALYSIS:

The turbidity removal efficiency is greater of filter having higher Cu with constant effective size i.e., for comparing CG2 and CG3 filter having same effective size of filter media and different Cu, 1.70 and 1.30 respectively, CG2 filter have greater turbidity removal efficiency in all five-turbidity range filter run and also the rate of head loss is greater in CG2 filter than CG3 filter due to lower porosity of filter media, the pores are clogged faster than CG3 filter. The UFRV of CG3 filter is greater than CG2 filter comparing on varied C_u filter with constant effective size. Higher value of uniformity coefficient of filter media will get greater voids, that increases flow rate of filtration. But with decrease of effective size with constant uniformity coefficient the porose becomes smaller and filter run volume of filter goes on decreasing. Here also on observation we get CG1 filter has less UFRV than CG2 filter.

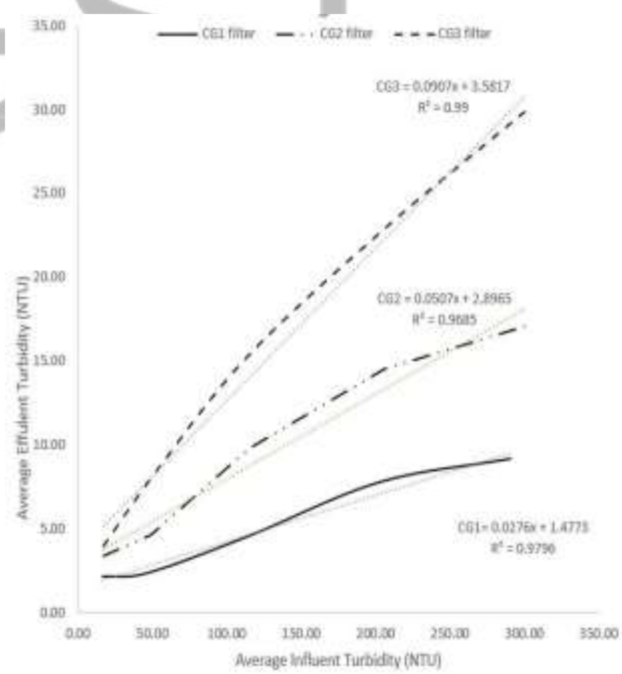

Fig2: Influent Vs Effluent Turbidity of Filters

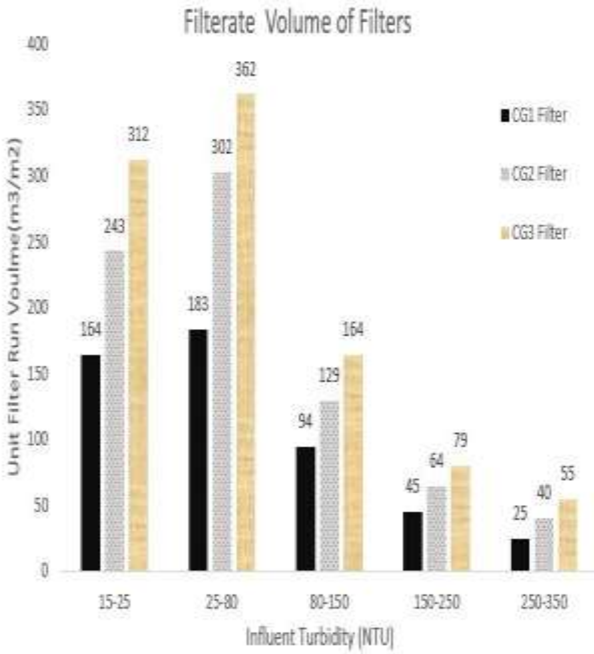

Fig3: UFRV of Filters for Different Turbidity Range

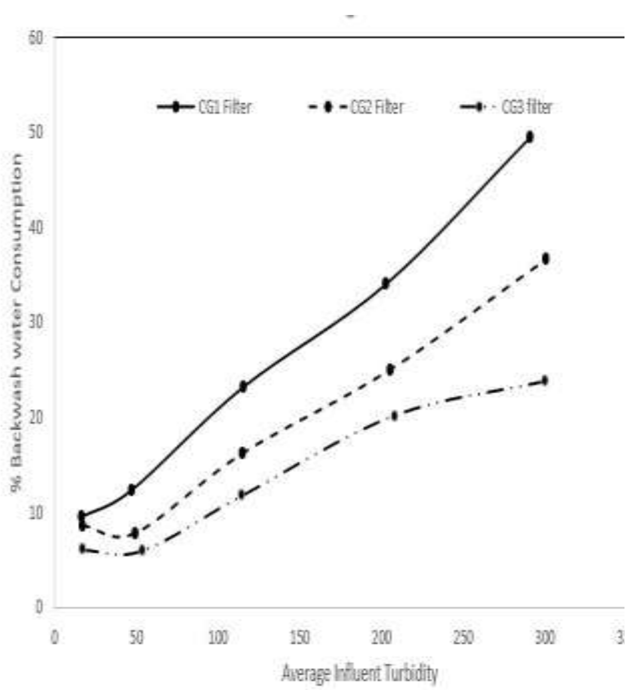

Fig 5: Backwash Water Consumption % out of Total Filtrate Volume by filters for different turbidity range filter run.

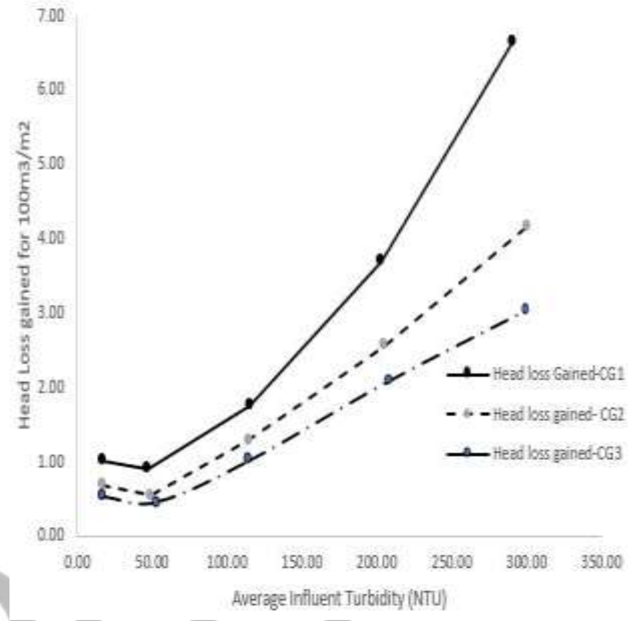

Fig4: Head Loss Generation of Filters for Different Influent Turbidity Range

Table1: Summary Table of Filters

S.N.	Filter	Filter Run	Turbidity Range (NTU)	Average Influent Turbidity (NTU)	Average Effulent Turbidity (NTU)	Filter Run Time (Hr.)	UFRV m3/m2	Head Loss gained for 100	Filter Backwashing	
									Time, mins	% Water Consumptio n
1	CG2 Filter (Cu=1.70, D10=0.60 mm)	1	15-25	17.03	3.37	49	243	0.68	33	8.60
		2	25-80	49.22	4.59	61	302	0.55	42	7.78
		3	80-150	114.76	9.79	26	129	1.28	30	16.17
		4	150-250	205.38	14.49	13	64	2.56	27	24.99
		5	250-350	300.75	17.07	8	40	4.16	22	36.60
2	CG3 Filter (Cu=1.33, D10=0.60 mm)	1	15-25	17.35	3.98	63	312	0.53	36	6.07
		2	25-80	53.70	8.54	73	362	0.46	40	5.99
		3	80-150	114.69	15.35	33	164	1.01	33	11.76
		4	150-250	207.89	23.06	16	79	2.08	29	20.16
		5	250-350	299.87	29.88	11	55	3.03	24	23.76
3	CG1 Filter (Cu=1.33, D10=0.45 mm)	1	15-25	16.74	2.16	33	164	1.01	27	9.49
		2	25-80	47.01	2.37	37	183	0.90	36	12.26
		3	80-150	115.32	4.57	19	94	1.75	25	23.13
		4	150-250	202.89	7.76	9	45	3.70	22	34.01
		5	250-350	291.00	9.14	5	25	6.66	16	49.48

VI. CONCLUSION

Our research shows that turbidity removal efficiency goes on increasing with increase of uniformity coefficient on comparing filters with constant effective sizes of crushed glass filter media and turbidity removal efficiency decrease on increase of effective size for constant C_u. The maximum average turbidity removal efficiency is 94.30%, and 90.01% for CG2 and CG3 filter respectively for turbidity range 250-350 NTU on comparing the filters with different C_u and same D_{10} size. The maximum average turbidity removal efficiency for CG1 filter is 96.84% for same turbidity range. Filters with minimum effective size of filter media and Cu gives higher removal efficiency but clogs at faster rate. Highest filter run time for was 73 hours, 61 hours and 37 hours for CG2, CG3 and CG1 filters respectively.

For higher rate of filtration volume, filters of lower uniformity coefficient with greater effective size of filter media should be used but for achieving maximum level of turbidity removal efficiency, filter media with greater uniformity coefficient (C_u) and lower effective size(D_{10}) should be used as porosity decreases with well graded filter media.

VII. ACKNOWLEDGEMENT

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