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Comprehensive Analysis of Jet Flocculator in Square and Circular Basin

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Abstract: ***The demand for better quality drinking water gives inspiration for advancement in the functioning of water treatment processes. Jet mixing technology, widely adopted in Flocculation process is unique due to its advantages over mechanical stirrer or vanes. Jet flocculator take primacy, as it do not have any moving parts inside the reactor. The present experimental investigation focuses on the examination of jets in flocculation. Comprehensive study of various parameters such as nozzle diameter, angle of inclination, flow pattern and jet position in two geometrical shapes of flocculation chamber: Square and Circular. Effect of tank shapes on flocculation process is analysed and compared.***

Keywords: ***Flocculation, Jet mixing, turbidity, velocity Gradient.***

I. INTRODUCTION

Coagulation and Flocculation processes are very inherent in all water treatment schemes. [9] gives cursory information about the important units (Coagulation, Flocculation, Clarification) of water treatment plant and explains about the basic things required to understand what customer wish to monitor in the units of WTP. Diverse techniques with their own merits and demerits, are available to effectuate flocculation. Amongst all Jet mixing in flocculation has become optimal alternative to conventional impeller mixing. Jet mixing in flocculation process plays crucial role in determining the final quality of water, affects the subsequent processes of flocculation and ultimately cost of water treatment plant hence it has become a key area of research. Lack of effective supervision and most importantly managerial control are the major problem encountered by operating units of most of the WTP.

Therefore it is necessary to search a technique which can overcome the mentioned problems.

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The limitations associated with the conventional techniques can be overcome by minimizing the moving parts and by designing simple robust technique. [7] & [11] in his experimentation studied the efficiency of free jets and recommended the usage of Jet flocculator by removing turbidity of raw water which was observed as good as that of conventional flocculators fitted with mechanical stirrers with negligible maintenance cost. [8] worked on the design of (below & above 5 MLD) and [12] on 3 MLD capacity units and found efficient.

Hence it can be concluded that jet flocculator seems to be a viable alternative and system may be advantageously used for sustained satisfactory service.

Researchers undertook diverse modifications in the jet techniques and compare the performance with conventional flocculation process. [6] studied the principle of tapered flocculation and concluded that a tapered jet flocculator is as efficient as a mechanical flocculator. [2] conducted an experimental study on a gravel-packed channel flocculator. [5] studied the performance of a jet mixed separator (JMS) which has a series of porous plates inserted in the channel perpendicular to a flow which passes water creating a jets effect by mixing the water gently. The turbidity obtained from JMS effluent was constantly below I NTU at the hydraulic retention time of about 1 hour. [10] developed simulation technique and model, for solving problems related to Environmental Engineering and clearly mentioned the benefits which can be gained from the use of CFD in flocculation chamber. In view of this [13] provides a comprehensive review of flocculation mechanism from empirical and theoretical perspective, which discuss its practical applications with its future need. [1] has stated the Camp- Stein equation for the root-mean- square velocity gradient G, leading to the conclusion that G is only a valid parameter for flocculation. Various aspects of Jet flocculators were studied by researchers. Jet flocculator takes advantage of all the factors which includes easy installation, low maintainance cost, no requirement of any structural reinforcement of the tank & cheaper in cost as compared to conventional mixing devices. Even though guidelines for the design of jet flocculator are not available.

In view of the aims and objectives of this study, a comprehensive review of literature related to previous research efforts have been carried out. On the basis of this review effort was carried out for synthesizing and gaining a new perspective of the issues concerning use of Jet Flocculators in Water Treatment Process in general and research related to their design aspect in particular.

Experimentation emphasis on various combinations and conditions of position of jet, tank geometry, various heads, angle of jet and various diameter of jet was considered in two geometrical shapes: Square & Circular.

II. EXPERIMENTAL SETUP & PROCEDURE

The tests were conducted considering for two geometrical shapes: Square & Circular. In both the flocculation chambers flocculation process is carried out which was placed at the height of 1.4m from the ground level. The foremost setup consist of a circular overhead tank of 500 lit capacity. In a overhead tank Required turbidity of 100 NTU is attained by addition of 96 gm of artificial clay, kaolin clay.

Preparation of the turbid water & to prolong required turbidity was quite crucial since the artificially generated turbidity settles down quickly in the tank. Stirrer arrangement is installed in the tank which revolves persistently throughout the experiment which avoids the settlement of clay at bottom of the tank and to sustain the required turbidity . Comparing the chemical coagulants for various aspects [14] Concluded that for floc removal, Aluminum Sulphate (Alum) coagulant is more efficient than that of Ferric Chloride. Alum Coagulant dose of 23 gm is added in the tank. The ultimate performance of flocculator depends upon both coagulation and flocculation processes. Therefore it is meaningful to give importance to flash mixing of water sample after addition of coagulant prior going to flocculation chamber. Flash mixing gives dissipation of chemicals in the water which assist the slow mixing process for better floc growth. Arrangement is significant in maintaining the requisite turbidity. The turbidity of water sample is checked by drawing water time to time. Turbidity is constantly supervised so that at any instant it should not surpass or lower down the required limit. Flocculation is a hydrodynamic process of slow mixing. It results in the formation of large and readily settleable flocs by bringing the finely divided matters into contact, resorted to agglomerate the flocs to grow which can be achieved by flowing water through a jet of various diameters in the chamber under the gravity from the overhead tank. Head of 0.79m is maintained throuout the procedure.

Flocculation process lasts for about 30-60 mins. For all experimental readings retention time of 30 mins is considered for flocculation process in chamber. Jet mixers are simple and reliable having no moving parts and hardly subject to any wear. Once the Steady state is achieved in flocculation chamber the outlet point is fixed upto the depth of water filled in the tank. The outlet is adjusted and fixed by screw at that position and the readings are noted. Experimentation is carried out considering 900 & 450 angle of jet in the flocculation tank at various points in the chamber for radial and straight flow pattern. The setup is flexible for changing diameter of jet and number of jets throughout the experimentation. The jets of desired angles are fabricated. It can be easily fixed, removed and also can change the position as required in flocculation chamber. Pressure gauge is attached to every point of jet which is examined for all the readings. Water was discharged through a jet of various diameter into the tank under gravity. Proper plumbing and water drainage arrangement promotes no water accumulation in any part of the setup. The discharge nozzle was located at the various positions of the tank. Jet is applied for one set of reading keeping others point of nozzle closed which produced three dimensional flow in the tank which mixes all of the contents homogenously. For each of the location readings are taken and compared.

Experiments were conducted with a square and circular flocculation chamber for twelve different jet diameters 2, 2.5, 3, 3.57, 3.97, 4.75, 5.5, 6, 7, 8, 9 and 10mm. Detention time of 30 minutes was considered for flocculation. Nephelo turbidity meter is used to check the turbidity. Turbidity was measured for each sample for the retention time of 30 mins and 1 hr. Optimum dose of coagulant is obtained using Jar test apparatus. The temperature of raw water was in the range of 240C to 280C in the experiments. For 450 and 900 jet inclinations considering radial and straight flow pattern an average of three samples tested is reported.

III. RESULT AND DISCUSSION

A. Effect of Retention Time on Straight flow

Retention time is necessary for the formation of floc. Figure 1 & 2 shows the effect Retention time on straight flow condition for 90^0 and 45^0 angle of Jet on turbidity removal for retention time of 30 mins and 1 hr. Experimentation was supervised on twelve diameters 2, 2.5, 3, 3.57, 3.97, 4.75, 5.5, 6, 7, 8, 9 and 10mm of jets diffusing in Square & circular tank.

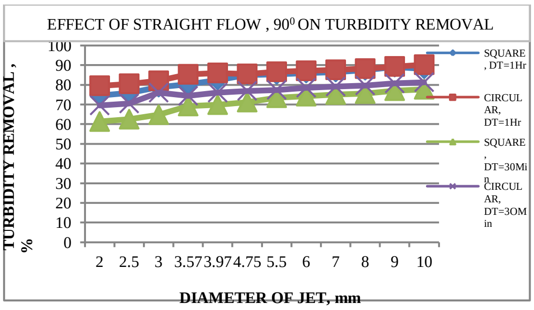

Fig.1 . Effect of Retention time for straight flow at 90^0

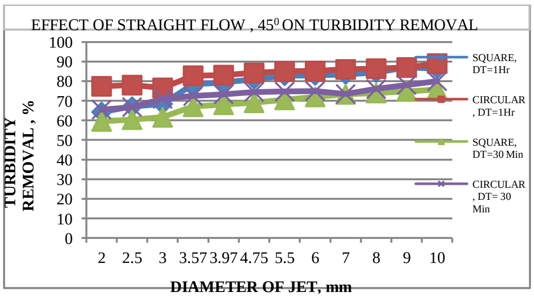

Fig.2. Effect of Retention time for straight flow at 45^0

The variation in residual turbidity as a function of retention time is examined for retention time of 30 mins & 1 hr. Percentage turbidity removal for 90 & 45 degree jet is observed for straight flow condition in Fig 1 & 2 respectively. Experimental study shows that larger diameters of jets performs marginally better than smaller diameters of jet. Results does not shows remarkable variations in the values of turbidity removal for both 45^0 & 90^0, still 90^0 jet performs marginally better than that of 45^0 jet.

Tank geometry is crucial in determining the effective turbidity removal rate. It is observed that circular tank shows turbidity removal is in the range of 80% to 90% considering all jet diameters which is notable. Increase in retention time increases turbidity removal. Observations contemplates 60 mins of detention time is necessitate for both the geometry when flocculation supported for 30 minutes. Retention time suggested was more as compare to, 30 mins of retention time as reported by [3] for static flocculators and [4] for clariflocculators.

B. Effect of Retention Time on Radial flow

Figure 3 & 4 shows the effect Retention time on radial flow condition for 90^0 and 45^0 angle of Jet for radial flow on turbidity removal.

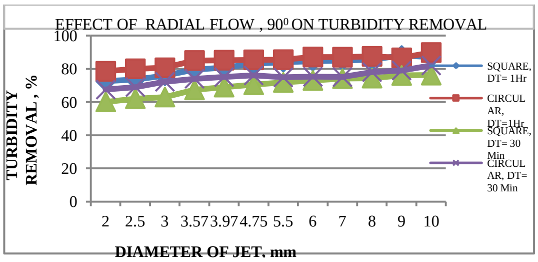

Fig.3. Effect of Retention time for straight flow at 90^0

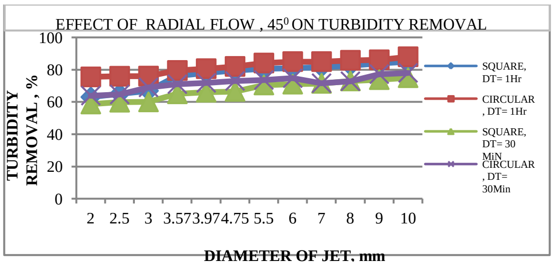

Fig. 4. Effect of Retention time for straight flow at 45^0

From the above figure 3 & 4 it can be noticed that the larger jet diameters performs significantly better than that of smaller jet diameters in radial flow condition. Increase in retention time definitely promotes maximum turbidity removal. In radial flow condition 90^0 performs marginally better than that of 45^0 jet as that of straight flow condition. In comparison of straight and radial flow condition straight flow hold up superior results for all twelve mentioned diameter of jet.

C. Effect of Jet Angle for Straight flow on Velocity Gradient

Figure 5 and 6 shows the effect of angle of Jet for straight flow on Velocity Gradient considering 45^0 & 90^0 angle of inclination.

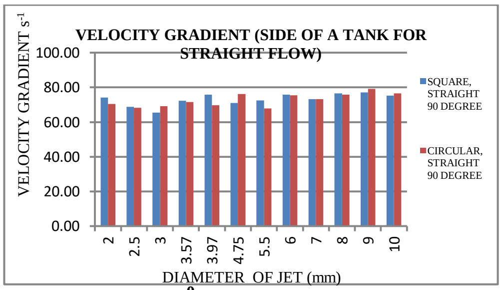

Fig. 6. Effect of 45^0 for straight flow on Velocity Gradient

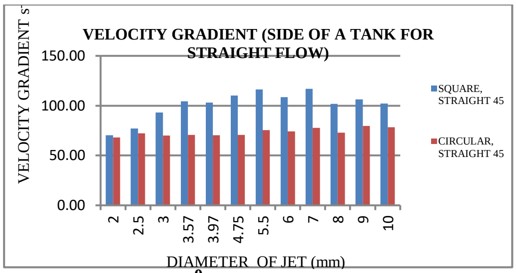

Fig. 6. Effect of 45^0 for straight flow on Velocity Gradient

Figure 5 & 6 shows the Velocity gradient (G) values for mentioned sizes of twelve number of jets dispersing in both square and circular tank for straight flow condition. Turbidity removal shows increasing tendency with the increase of diameter of jet. But it has been noticed smaller jet diameter shows smaller 'G' values. Circular tanks performs marginally better for 90^0 jet if it is compared with conventional G value of upto $70s^{-1}$ for flocculation process. The value observed for 10 mm jet was $102s^{-1}$ for 45^0 in square chamber whereas $78s^{-1}$ in circular tank, and it is observed that radical variation in results for 45^0 jet in square chamber as that of circular. Looking towards the consequential turbidity results which highlighted the fact that when G value ranges in between 65 to $102s^{-1}$ the performance of Jet flocculator is not sensitive of G values which was interesting to notice.

D. Effect of Angle of Jet for Radial flow on Velocity Gradient

Figure 7 and 8 shows the effect of angle of Jet for Radial flow on Velocity Gradient considering 45^0 & 90^0 angle of inclination for radial flow pattern.

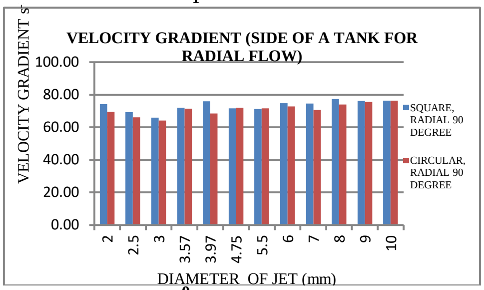

Fig. 7. Effect of 90^0 for straight flow on Velocity Gradient

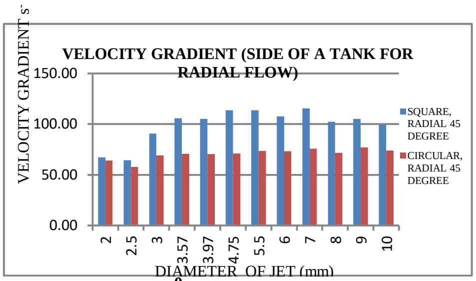

Fig. 8. Effect of 45^0 for straight flow on Velocity Gradient

Figure 7 & 8 shows efficient flocculation at 3mm dia of jet with the minimum Velocity gradient (G) values in both square and circular tank for radial flow condition amongst all sizes of jet.

Comparison shows the substantial variation in results for 45^0 jet in square tank as of circular. Results concluded that 90 degree jet initiate better mixing when initiated at straight flow condition in circular tank rather than other combinations of radial flow condition.

E. Effect of position of jet on Velocity Gradient

Figure 9 shows the effect of angle of Jet for straight flow on Velocity Gradient considering 900 angle of inclination.

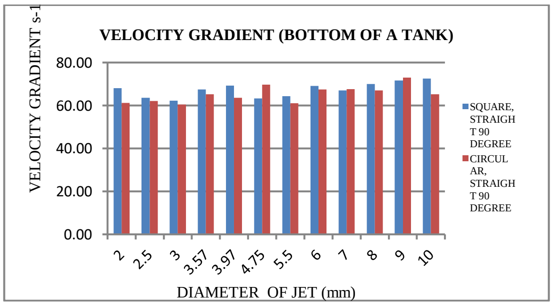

Fig. 9. Effect of position of Jet on Velocity Gradient

When jet is positioned submerged, at the centre of bottom of the tank performs effectively (from the fig 9). The velocity gradient ranges in between 68 to 72 s-1 for all twelve jet diameters in square basin whereas 61 to 72 s-1 in circular basin which is significantly less as compare when jet is attached at side of a tank. Moreover 3mm jet shows suitable results in both the basins with turbidity removal of 78 % & 82% in square & circular flocculation chamber respectively.

IV. CONCLUSIONS

The outcomes of the current experiment of jet flocculation in square and circular, both the geometrical basins are summarized as follows:

1. Circular basins shows maximum turbidity removal efficiency in the range of 79 to 90% which is more as compare to square basin. Larger diameter nozzle can enhance the turbidity removal efficiency.
2. The results show the 30 minutes of detention time for preferable flocculation which is same as that of the recommended value for mechanical flocculator.
3. Retention time of one hour after completion of flocculation process indicates enhanced turbidity removal than that of 30 minutes retention time.
4. Jet positioned at bottom of the flocculation chamber with 3mm jet diameter proves superior in flocculation process for both tank geometry.
5. Straight flow patterns are prominent in the promoting flocculation process than that of radial flow pattern.
6. Jet angle of 90^0 with straight flow encourage proper mixing in circular flocculation chamber for nearly all twelve jet diameters.

REFERENCES

1. Cleasby J.L., (1984) Is Velocity Gradient A Valid Turbulent Flocculation Parameter?, J. Environ. Eng., 110, pp.875-897.
2. Bhole A.G., and Viraraghavan T.,(1990) Gravel Packed Baffled Channel Flocculator', J. Environ. Eng. 116, pp.795-796.
3. Bhole A.G., (1993), Performance of static flocculator. Water Science and Technology, IAWQ 27 (10), 181-194.
4. Armal S.D., (1997). Peripheral inlet tapered velocity gradient flocculatot, Journal of IWWA 29 (1), 43-51.
5. Watanabe Y., Kasahara S and Iwasaki Y. (1998). Enhanced flocculation/sedimentation process by a jet mixed separator, Water Science and Technology,37(10), pp.55-67.
6. Kumar, N and Pani, B.S. (2003).'Tapered flocculation with hydraulic jets', Journal of Indian Water Works Association, Bombay, 35(3), pp.167 to 172.
7. Pani, B. S and Patil, L.G.(2007). Single-basin jet flocculators, Journal of Hydro-environment Research, 1(1), pp. 20-29.
8. Dhabadgaonkar S.M., (2008). Jet Floccu-Clarifiers: Appropriate Technology for Water Treatment in India, Journal of Indian Water Works Assiciation, January- March 2008.
9. Engelhardt, T. L. (2010). Coagulation, Flocculation and Clarification of Drinking Water.
10. Bridgeman, J., Jefferson, B and Parsons, S.A.(2010). The development and application of CFD models for water treatment flocculators, Advances in Engineering Software, 41(1), pp. 99-109.
11. Kumar, N. S., Pani, B. S and Joshi, S. G.(2012). Residual Turbidity In Hydraulic Jet Flocculators, ISH Journal of Hydraulic Engineering,15(2), pp.108-117.
12. Subramani, T and Nair, S. (2012). Experimental And Numerical Analysis On Horizontal Jet Flocculates For Small Water Supply Schemes, International Journal of Modern Engineering Research (IJMER), 2(4), pp-1534-1539.
13. Oyegbile, B., Ay, P and Satyanarayana, N. (2016). Flocculation kinetics and hydrodynamic interactions in natural and engineered flow systems: A review, Environ. Eng. Res., pp. 1-47, http://dx.doi.org/10.4491/eer.2015.086.
14. P.S. Randive, D.P.Singh, A.G.Bhole, V.P.Varghese, A.M.Badar (2019). Experimental Study of Floc Growth Characteristics, International Conference on Recent Advancement in Civil Engineering and Infrastructural Developments, 5-6 July 2019. (Under process for Springer Publication)

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