

Optimisation of Flocculation Process Using Jet Flocculators

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Abstract: -- Flocculation is the second stage wherein the formation of readily settleable-flocs from destabilized colloidal particle is achieved by bringing particles into close proximity by gentle and prolonged mixing. In the present study, the jet flocculation aspect is considered since small towns in developing countries need water treatment plants which should be simple to operate, have the least number of moving parts, need no skilled labor for maintenance and are economical. It is very likely that the raw water pumping station may be located at a far away distance and the flocculator may not have the electricity available simultaneously at all time periods. Hence flocculators requiring regular maintenance and continuous power supply for the mechanical stirrers provided usually fail to give good results. These facts may compel the public health personnel engaged in water treatment to compromise on the quality of water being supplied to the community. Under these adverse conditions, it is therefore, necessary to improve and modify the design of flocculator to obviate these problems. The jet flocculator is a viable alternative for small water treatment plants (1000cum. /day) which needs to be thoroughly investigated. The jet action in a jet flocculator produces the required velocity gradient essential for the formation of flocs without assistance from any moving mechanical parts. In this study, various experiments are performed on 3 jet model set i.e horizontal spiral set up, vertical setup and central helical path setup with varying pipe diameters to check the efficiency of the jet flocculation using jet flow. Slow mixing which is usually done with the help of rotating paddles in any conventional flocculator, was done using a water jet which creates turbulence in water as required for slow mixing. Result obtained inferred that the jet can be effectively used for the purpose of flocculation with an increase in the duration of sedimentation.

I. INTRODUCTION

Water treatment process generally consist of various unit operation such as screening, aeration, coagulation, flocculation, sedimentation, filtration and disinfection. One of the important stages in this procedure is "Flocculation". It is the second stage wherein the formation of readily settleable flocs from destabilized colloidal particle is achieved by bringing particles into close proximity by gentle and prolonged mixing. Small towns in developing countries need water treatment plants which should be simple to operate, have least number of moving parts, need no skilled labour for maintenance and are economical. It is very likely that the raw water pumping station may be located at a far way distance and the flocculator may not have the electricity available simultaneously at all time periods. Hence flocculators requiring regular maintenance and continuous power supply for the mechanical stirrers provided usually fail to give good results. These facts may compel the public health personnel engaged in water treatment to compromise

on the quality of water being supplied to the community. Under these adverse conditions, it is therefore necessary to improve and modify the design of flocculator to obviate these problems. The jet flocculator is a viable alternative for small water treatment plants (1000cum. /day) which needs to be thoroughly investigated. The jet action in a jet flocculator produces the required velocity gradient essential for the formation of flocs without assistance from any moving mechanical parts.

II. EXPERIMENTATION

A. Preparation of Standard Solution:

Calibration of turbidity meter is done using formazine standard solution. The stock standard of 4000 NTU is prepared as per the following procedure:

1. 5 grams of reagent grade 'hydrazine sulphate' is taken and dissolved in 400 ml of distilled water. This solution is termed as A

2. 50 grams of pure ‘HexamethyleneTetramine’ is dissolved in 400 ml of distilled water. This solution is termed as B
 3. Solutions A and B are mixed and made up to 1 litre by adding distilled water. This mixture is allowed to settle for 48 hours at normal room temperature.
 4. The solution obtained is stock solution of 4000NTU strength of formazine. This solution is usually stable for a period of 6-8 weeks and working can be prepared as required.

B. Preparation of known turbidity sample using kaoline light

For checking the efficiency of flocculation the known turbidity sample of kaoline light is prepared wherein 1gm of kaoline light sample is taken and mixed with 1 litre of tap water. The mixture is mixed well for a minute and subsequently kept at rest for half an hour of settling. The supernatant turbidity is measured and recorded. For this measured turbidity of the given sample the amount of kaoline light required to be added for the range of 70 NTU to 80 NTU is calculated.

Table 1 Kaoline light used for raw water

Kaoline Light	Volume of water	Turbidity after half hour settlement
1 gram	1 litre	84 NTU

C. Optimum Dose of Coagulant using Jar Test:

A graph of coagulant dose in X axis and residual turbidity on Y axis is plotted after performing jar test. The optimum coagulant dose for a sample is the one in which the residual turbidity remaining is 20 NTU. The jar test is conducted for kaoline light sample. For kaoline light the initial turbidity was 84 NTU.

III. EXPERIMENTAL SET UP

The experimental set up consist of one storage/mixing tank and one bucket type flocculation tank. The kaoline light/fullers earth of appropriate quantity i.e the quantity which was obtained from the previous experiment was mixed with raw water and the same was allowed to settle for 30 minutes to obtain the required turbidity.

The calculated alum dose obtained from jar test was rapidly mixed from the above solution for a period of 2 -3 minutes. The mixed water is passed from mixing tank to flocculation tank through pipes of different diameters through different mechanisms viz. symphonic and submersible pumps. The set up was arranged with jet and pipes fixed at desired positions in the following ways:

1. Horizontal Spiral Set up

2. Vertical Set up
3. Central Helical path set up

3.1 Horizontal spiral set up

In horizontal spiral set up pipes of different diameters are placed along the inner periphery of bucket type flocculation tank through different number of turns at certain depth from bottom.

The symphonic action was used in this setup to transfer water from storage tank to flocculation tank which was created with the help of a pipe. The constant head of water was maintained so as to form slow mixing inflocculation tank through jet.

No. of Turns	Diameter of pipe	Position of jet from bottom of tank (cm)
1	9	5
		10
3	7	12
		16
		18
		18

Table 2 Details of Horizontal spiral setup

3.2 Vertical jet setup

Vertical jet setup consist of a bucket type flocculation tank provided with a vertical pipe and a circular disc at a suitable height to spread the jet evenly coming out of the vertical pipe. The symphonic action and pump was used to transfer water from storage tank to flocculation tank through pipes. The constant head of water was maintained for proper mixing in flocculation tank through jet.

3.3 Central Helical channel setup

The central helical channel setup consists of flocculation tank provided with a central helical channel of suitable width. The water from the storage tank was allowed to flocculation tank through the helical channel from as well as from bottom using a suitable pipe. The constant head of water was maintained for proper mixing in flocculation tank through jet.

IV. OBSERVATIONS

Sr. No	Location of Jet	Diameter of Jet	No. of Turns	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	5 cm from Bottom	9 mm	1	7	78	75	10.25
2				10		70	21.5
3				13		61.5	26.8
4				15		57.5	26.28
5				18		35.4	54.61
6				21		20.1	74.23
7				24		15.1	80.64
8				30		7.4	90.5
9				35		5.7	92.7

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Table 3 observations for horizontal spiral setup

Sr. No	Location of Jet	Diameter of Jet	No. of turns	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	10 cm from Bottom	9 mm	1	11	72.3	47.8	33.88
2				14		35.4	51.03
3				17		31	57.12
4				20		23.3	67.77
5				23		19.5	73.03
6				26		11.8	83.68
7				29		10.2	85.59
8				35		8.3	88.52
9				40		6.1	91.56

Table 4 observations for horizontal spiral setup

Sr. No	Location of Jet	Diameter of Jet	No. of turns	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	12 cm from Bottom	7 mm	3	10	75.26	50	33.33
2				13		30	60
3				16		24	68
4				19		23.6	68.53
5				22		19.3	74.26
6				25		16.8	77.6
7				28		15	80
8				31		14.8	80.3
9				34		13	82.67
10				37		12	84
11				40		11.5	84.67
12				45		8.8	88.27

Table 5 observations for horizontal spiral setup

Sr. No	Location of Jet	Diameter of Jet	No. of turns	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	18 cm from Bottom	7 mm	3	10	78	51	34.61
2				13		41.8	46.41
3				16		34.5	55.77
4				19		26.3	66.28
5				22		22.7	70.9
6				25		21.1	73
7				28		19	75.64
8				31		18	77
9				34		17	78.2
10				37		15.2	80.77
11				40		12.4	84.1
12				43		9.6	87.7

Table 6 observations for horizontal spiral setup

Sr. No	Location of Jet	Diameter of Jet	No. of turns	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	16 cm from Bottom	7 mm	3	10	76.3	62.4	18.22
2				15		41.8	45.21
3				20		34.5	54.7
4				23		26.3	65.53
5				26		20.5	73.13
6				29		17.3	77.32
7				32		14.8	80.6
8				35		13	82.96
9				38		10.3	86.5
10				41	7.1	90.7	

Table 7 observations for horizontal spiral setup

Sr. No	Location of Jet	Diameter of Jet	Position of plate	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	15 cm from bottom pump	7 mm	21 cm from bottom	5	74.1	42.5	42.64
2				8		31.3	57.76
3				11		25.5	65.58
4				14		18.5	75.03
5				17		15.5	79.1
6				20		13.5	81.78
7				23		11.7	84.21
8				28		10.5	85.83
9				31		7.7	89.6

Table 8 observations for vertical spiral setup

Sr. No	Location of Jet	Diameter of Jet	Position of plate	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	15 cm from bottom syphon	7 mm	21 cm from bottom	10	76	41.5	45.4
2				13		30.7	59.6
3				16		21.3	71.97
4				19		15.4	79.74
5				22		13.5	82.23
6				25		10.5	86.18
7				28		3.7	95.13

Table 9 observations for vertical spiral setup

Table 10 observations for vertical spiral setup

Sr. No	Location of Jet	Diameter of Jet	Position of plate	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	15 cm from bottom pump	7 mm	21 cm from bottom	15	74	58	21.62
2				18		46	37.84
3				21		36	51.35
4				24		29.3	60.4
5				27		27.5	62.83
6				30		25	66.22
7				33		18.4	75.14
8				36		15	79.73
9				39		14.5	80.4
10				42		10.2	86.22
11				45		8	89.19

Sr. No	Location of Jet	Diameter of Jet	Position of plate	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	15 cm from bottom syphonic	7 mm	16 cm from bottom	12	79	60	24
2				15		43	45.56
3				20		32	59.49
4				23		26	67.1
5				26		24	69.6
6				29		22.4	71.64
7				32		17.6	77.7
8				35		14.9	81.14
9				38		11	86.1
10				41		7.1	91.01

Table 11 observations for vertical spiral setup

Sr. No	Location of Jet	Diameter of Jet	Position of plate	Time (Min.)	Initial Turbidity (NTU)	Final Turbidity (NTU)	% Turbidity Removal
1	5 cm from bottom pump	7 mm	21 cm from bottom	7	72	70	2.8
2				10		45	37.5
3				13		38	47.22
4				16		29	59.7
5				19		20	72.2
6				22		14	80.6
7				25		10	86.1
8				28		6.5	91

Table 12 observations for vertical spiral setup

V. RESULTS AND DISCUSSIONS

The experimental investigations of jet flocculator yielded the following results:

5.1 HORIZONTAL SPIRAL SETUP:

Sr. No.	No. of turns	Diameter of pipe (mm)	Position of jet (cm from bottom)	Type of action	Average % Turbidity Removal
1	1	9	5	syphonic	92.7
2	1	9	10	syphonic	91.56
3	3	7	12	syphonic	88.27
4	3	7	16	syphonic	90.7
5	3	7	18	syphonic	87.7

5.2 VERTICAL SPIRAL SETUP:

Sr. No.	position of jet	position of plate	Type of action	Average % Turbidity Removal
1	15	21	syphonic	95.13
2		16	syphonic	91.01
3		21	with pump	89.6
4		16	with pump	89.19

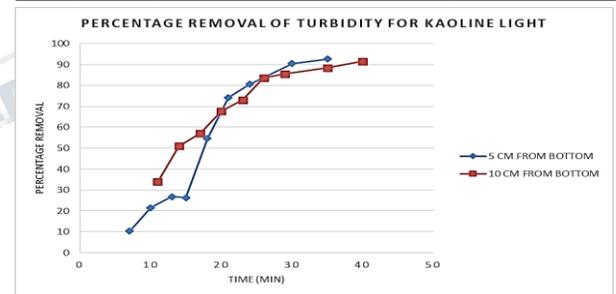


Fig.1 Horizontal Action of jet through siphon of 9mm diameter jet

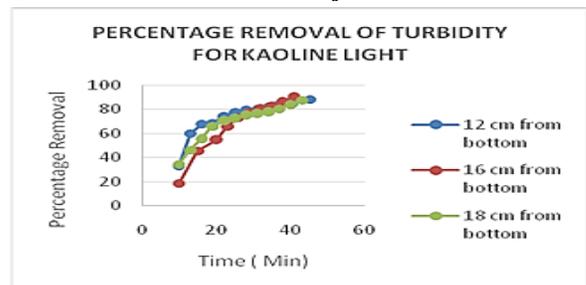


Fig.2 Horizontal Action of jet through siphon of 7mm diameter jet

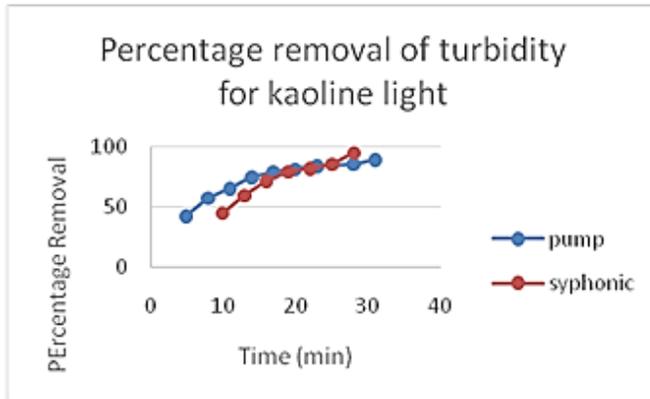


Fig.3 Vertical action of jet with pump and symphonic action for positon of plate of 21 cm

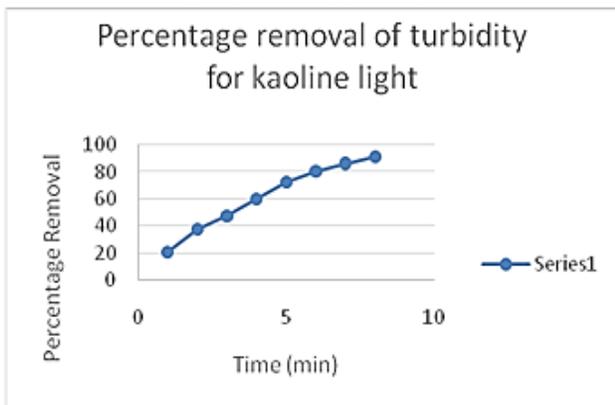


Fig.4 Central helical action of jet

The following are the general conclusions are drawn based on present study:

1. Jet flocculators are robust and perform with reasonable efficiency over a range of detention time.
2. They are easy to operate and maintenance free.
3. More elaborate experimental investigations are required to arrive at optimal value of detention time.
4. The single basin jet flocculator is a very simple, robust, low cost device which is capable of removing turbidity from the raw water in a efficient way. The efficiency of turbidity removal for the raw water turbidity of 100 NTU was in the range 80 – 90, which is as good as that of a flocculator fitted with mechanical stirrers.
5. By adopting larger diameter nozzles the efficiency of the turbidity removal can be enhanced.
6. It can be noted that the 9mm diameter perform marginally better than 7 mm diameter jet even though it has smaller G and Gt.

7. Central helical path setup performs better than other two set upsi.e average percentage turbidity removal is 91 %.

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