WEDC 12th Conference: Water and sanitation at mid-Decade: Calcutta 1986

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High turbidity direct filtration by contact flocculation

1.0 INTRODUCTION

Sand filters have been used for clarification of dilute liquid suspensions in municipal water supply for over a century. Due to the advancement in the design of coagulation and sedimentation processes, conventional treatment plants have been able to considerably reduce the suspended solids load in the filter influent. Thus, the filters are operated solely to polish the water.

In recent years a lot of attention has been turned towards filtration research. It has been found that the process of direct filtration possesses a few disadvantages, primarily its inability to handle raw water of high turbidity and its incapability to effectively perform under high operating flow rates.

One fairly recent development in the area of porous media filtration is the utilization of the bed for the purpose of coagulation, flocculation and floc removal. The new process is called "Contact flocculation" due to the occurrence of flocculation of particles while they are in contact with the bed.

In this study, the performance of the contact flocculation system, comprised of a flocculator bed followed by a standard dual media filter was compared with that of the direct filtration system.

2.0 LITERATURE REVIEW

2.1 Direct Filtration

Past research efforts on direct filtration have shown that the process is incapable of handling water of high turbidity. Roebeck et al (1964) "(ref. 1)" concluded that with relatively clear water (turbidity $<$ 25 NTU) the flocculation and sedimentation steps of conventional treatment plant design could be omitted if dual media filters were being used. Culp (1977) "(ref.2)" has also recognised the possibility of applying direct filtration to municipal plants with good results if the raw water turbidity and color are each less than 25 units.

2.2 Contact Flocculation

Contact flocculation is a process whereby a water containing a dilute suspension of suspended solids is passed through a granular medium in such a manner that they form larger particles that are either more settleable or more filterable than in the original suspension.

Electrokinetic effects exist simultaneously between the filter bed and the particles themselves. Smith (1967) "(ref. 3)" found that only particle bed interactions take place when particles were filtered without any coagulant. He also noticed that interactions between particles (flocculation) play a great part when coagulants were added. Ghosh (1958) "(ref. 4)" and Borchardt - O'Melia (1961) "(ref. 5)" concluded that adding certain ions causes flocculation and formation of larger particles which can be subjected to sedimentation.

It was seen that the available information on contact flocculation is relatively meager. This study was undertaken to provide a better understanding of the contact flocculation process and to compare its performance with the direct filtration process.

3.0 MATERIALS AND METHODS

A pilot scale water treatment plant was fabricated to collect the data necessary for evaluating the parameters involved in the study. A schematic diagram of the experimental set up is shown in figure 1.

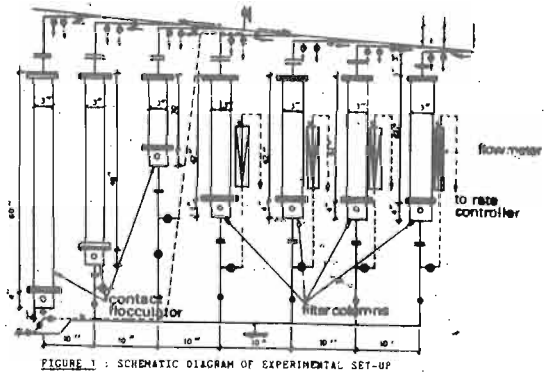

FIGURE 1 : SCHEMATIC DIAGRAM OF EXPERIMENTAL SET-UP

Raw water from the storage tank was fed to the contact flocculators by a centrifugal pump. Three contact flocculators of 14", 38", 51" bed depths were each followed by a standard dual media filter consisting of 12" of sand overlaid by 18" of anthracite coal. Another standard dual media bed was operated independently to evaluate the performance of direct filtration. The three contact flocculation units will be referred to as system 1, 2 and 3 respectively and the single dual media filter as system 4 in the following sections. In this manner the contact flocculation process was compared with that of the direct filtration method.

The flow rates of effluent from the filter columns into the rate control chambers were adjusted by the rate control valves and measured by the flow meters. Samples of the influent raw water and effluents of the dual media filters were collected at the inlet to the rate control chamber. Head losses through the contact flocculators as well as the head loss across the dual media filter were measured by either pressure gauges or by mercury manometers.

The media specifications for the contact flocculator beds and the specifications of the sand and the anthracite coal used for the dual media filter beds are presented in tables 1 & 2 respectively.

For all filtration runs, a liquid cationic polymer (Purifloc C-31, Dow Chemicals Corporation) was used. A dosage of 9.0 mg/l for the above coagulant was used for all experimental runs. This polymer dose was selected after performing a trial run at varying dosages of 1-12 mg/l to determine the dosage for best filter effluent. The raw water turbidity for this particular run was maintained at 100 NTU and the filters were operated at a flow rate of 5.0 gpm/sq.ft. The lowest polymer dose that produced an effluent turbidity of less than 0.5 NTU in all the four filters was chosen as the optimum polymer dose. This value was 9.0 mg/l.

All the systems were operated until break through was observed. The final break through of a particular run could happen due to either the turbidity of the effluent water or the head loss through the filters being too high. A turbidity level of 0.50 NTU was adopted for the break through point in turbidity. A system was shut down when the head loss built up reached a value of 12 psi corresponding to 27.7 feet of water. This value was used as the break through point with respect to head loss.

Table - 1

Media Specifications for Contact Flocculator Bed

Range (mm)	Geometric Mean (mm)	Porosity	Shape Factor
2.80 - 4.75	3.65	0.388	1.21

Table - 2

Media Specifications for Dual Media Filter Beds

Media Type	Effective Size (mm)	Uniformity coefficient
Sand	0.60 ± 0.05	1.60
Anthracite Coal	0.912	1.63

4.0 RESULTS AND DISCUSSION

The contact flocculation systems and the single dual media filter were operated simultaneously to compare the performance of the two systems. Different filtration runs with influent turbidity of 100 and 200 units and flow rates varying from 2.5 - 10.00 gpm/sq.ft. were carried out to evaluate the performance of each system. The run times and filtrate volumes produced by the systems are summarized in tables 3 and 4.

The single dual media filter (system 4) was found to be inadequate in handling high turbidity water. A run time of 24.0 hours could never be obtained by the single filter. Consequently the filtrate volumes produced by the dual filter was very small compared to the contact flocculation system for each filtration run (refer to table 4). The deepest flocculator produced run times of 2.5 to 3 times that of the single filter and correspondingly a lot greater removal than the dual filter. As observed by

Table - 3

RUN TIMES (Hours)

Description of Run	System - 1	System - 2	System - 3	System - 4
100 NTU and 2.5 gpm/sq.ft.	46.0	26.0	-	14.0
100 NTU and 5.0 gpm/sq.ft.	29.0	23.0	15.50	13.0
100 NTU and 7.5 gpm/sq.ft.	10.0	8.0	4.50	2.80
100 NTU and 10.0 gpm/sq.ft.	4.25	3.25	1.25	-
200 NTU and 2.5 gpm/sq.ft.	19.0	13.0	7.0	7.0
200 NTU and 5.0 gpm/sq.ft.	4.0	2.0	1.0	1.0
200 NTU and 7.5 gpm/sq.ft.	0.75	0.0	0.0	0.0
200 NTU and 10.0 gpm/sq.ft.	0.50	0.50	0.0	0.0

Table - 4

Volume of Filtrate (Gallons)

Description of Run	System - 1	System - 2	System - 3	System - 4
100 NTU and 2.5 gpm/sq.ft.	338.70	191.44	-	103.08
100 NTU and 5.0 gpm/sq.ft.	427.0	338.70	228.26	191.44
100 NTU and 7.5 gpm/sq.ft.	220.89	176.71	99.40	61.85
100 NTU and 10.0 gpm/sq.ft.	125.17	95.72	36.82	0.0
200 NTU and 2.5 gpm/sq.ft.	139.90	95.72	51.54	51.54
200 NTU and 5.0 gpm/sq.ft.	58.90	29.45	14.73	14.73
200 NTU and 7.5 gpm/sq.ft.	16.57	0.0	0.0	0.0
200 NTU and 10.0 gpm/sq.ft.	14.73	14.73	0.0	0.0

previous researches, this study also proves that the dual media filter can operate efficiently only if the influent solids concentration is low.

The most important criteria determining the efficiency of a filter is the quality of the flocs produced. The influent suspension that is fed into the dual filter directly is a cloudy, turbid suspension which shows no floc formation. No flocculation takes place in the bed. In direct filtration, the particles were removed by straining or sedimentation inside the media voids. The clay particles quickly fill up the void spaces and the filter is seen to get clogged up very rapidly. This causes the head loss to build up very quickly.

On the other hand, the contact flocculation system is seen to adequately handle raw water turbidity upto 100 NTU. The experimental results show that the contact flocculators could be successfully operated upto a flow rate of 5.0 gpm/sq. ft. The contact flocculators use larger size media than the dual filter. When using the larger media and high operating flow rates, the filter bed acts as a contact media that promotes flocculation of the suspension into larger particles that pass through the bed to be removed by filtration. Agglomeration of the particles into larger suspended matter and the production of filterable flocs inside the contact flocculator bed cause the system to operate efficiently. The dual filter bed is incapable of producing any in-bed flocculation. Floc formation in the filter is regarded as a major removal mechanism by other researchers.

Culp (1977) "(ref. 2)" had stated that the direct filtration process may not be applicable to raw water having turbidity greater than 100 units. Because of the short time between application of the coagulant and filtration, more operator vigilance is required.

5.0 SUMMARY AND CONCLUSIONS

The performance of the contact flocculation unit comprising of a contact flocculator followed by a dual media filter was compared to that of the direct filtration system. The results of the contact flocculation system was observed to be far superior to that of direct filtration. The filter run times and filtrate volumes produced by the contact flocculation system was 2.5 to 3 times more than that of the direct filter. The direct filtration process did not promote in-bed flocculation and was incapable of handling high turbidity water.

6.0 REFERENCES

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