Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **2(10),** 38-42, October **(2012)** *Res.J.Chem. Sci.*

Effect of Filter Backwash Water when blends with Raw Water on Total Organic Carbon and Dissolve Organic Carbon Removal

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Available online at: www.isca.in
Received 28th May 2012, revised 2nd June 2012, accepted 7th June 2012

Abstract

Clogging of sand-granular-gravel media filters due to increased passage of particles and microorganism is a common problem of the water treatment plants (WTP). To prevent from this problem, there is need of back washing and this results loss of water. In most of the drinking WTP filter backwash water (FBWW) and clarified sludge water (CSW) are generated. Reuse of FBWW is of great interest. Recycling of FBWW and its suitable treatment is possible in order to provide guarantee of water quality. Experiments were performed with RW and FBWW from full scale surface water Bhagirathi water treatment plant (BWTP). Impact of removal of total organic carbon (TOC) and dissolve organic carbon (DOC) was examined by blending of FBWW 5, 7 and 10% respectively with RW. Significantly higher removal of TOC and DOC was showed by 7% blending of FBWW with RW as compared to RW. Jar test results indicated that the improvements in RW quality could be achieved by recycling of FBWW with RW. Other parameters such as turbidity, colour, total aluminum, total iron, and total suspended solids were recorded for RW, FBWW and blends of both and found significant differences.

Key words: FBWW water, raw water, alum dose, coagulant, turbidity

Introduction

During purification of water in drinking water treatment plant, waste residuals volumes FBWW and CSW are generated according to the nature of the unit operations involved in treatment of raw source water. These residuals can include organic and inorganic compounds in solid, liquid and gaseous forms[1]. Reclamation of FBWW can be adopted in areas of water scarcity. Simultaneously this reduces the disposal problem of the waste. A case study has been conducted to evaluate the process of treatment and to find out the problems of drinking water treatment process in the unit situated at Bank Note Press Dewas MP, India. In general, conventional treatment is provided having a sequence of alum addition, coagulation, flocculation, sedimentation, filtration and disinfection by chlorination[2].

Removal of natural organic matter (NOM) in drinking water plant for a variety of source water has been extensively investigated. Optimum coagulant dosage along with strict pH control selected for the treatment of low alkalinity water that augmented coagulation based on minimizes UV absorbance gave excellent treatment for turbidity, pathogen and organic removal [3,4]. In a laboratory-scale study of treated FBWW from a water treatment plant by using cross-flow microfiltration (MF) ceramic tubular membranes removed turbidity, bacteria, and aluminum significantly[5,6]. The physico-chemical parameters such as nitrates, phosphate, temperature and alkalinity are favourable for the growth of phytoplankton. Arora focused on the presence of protozoa, such as, *Cryptosporidium* and *Giardia*, in FBWW, examined the use of back washable depth filter technology in the place of conventional filtration and the use of polymers resulted in excellent removal of turbidity, particles and microorganisms[7,8]. Series of publications noted that the quality of water recycled from FBWW was temporally variable for plants with only flow equalization (without solids removal), exhibiting significant peaks in solid levels that led to short-term increases in influent turbidity[9,10,11]. There is no need of additional coagulant demand when FBWW recycles as it has already low density particles of aluminium hydroxide[12,13]. Previous research showed that recycling of FBWW with raw water brought changes in process of coagulation, flocculation, and biotic factors removals[8,12,14].

Jar test experiments were conducted to investigate treatment processes for a combined residuals stream of FBWW and clarified sludge water (CSW). The results of these studies showed that the removal of FBWW contaminants from the main treatment plant were more efficient than contaminants present in the raw water as FBWW solids have already been stabilized, settled and filtered[12]. The study demonstrated that by mixing of FBWW to the RW it increased number of attachment sites[15]. Bench-scale recycle experiments that used a combined waste residuals such as FBWW and CSW on a low-turbidity source water demonstrated that recycling of 5 and 10% of the CSW resulted in improved sedimentation in terms of total organic carbon (TOC) as compare to control jar test that had only RW[16].

The overall purpose of this research work was to evaluate the impacts of FBWW recycle with raw water on organic removal. Samples of raw water and FBWW collected from the Bhagirathi

WTP that used alum as the primary coagulant were used in this study. Different blends of FBWW and raw water were used to gain better understanding of how main treatment plant effected by recycling. Jar test experiments were conducted using a standard jar-test apparatus. Effect of different percentage of FBWW on organic removal of RW was evaluated. Standard water quality parameters were analyzed to calculate organic removal during coagulation–sedimentation processes under different recycle blending.

Material and Methods

RW and FBWW water samples collected from surface water treatment plant (BWTP) were used in the experiments. Plant's treatment consists of pre and post chlorination, Alum mixing, vertical paddle flocculator, clarified tanks, dissolved air flotation (DAF) and sand –gravel dual media filters. The plant uses ferric alum as the primary coagulant at an average dosage of 22 mgL^{-1}. The BWTP uses chlorine at an average dosage of 1.2 mgL^{-1} to the raw water. Chlorine demand of raw water depends on the concentration of organic matter. Chlorine reacts with biogenic organic matter. The DAF is operated between 6 and 8 cycle with clarified water. The filters are backwashed generally after 24 hrs and it takes about 20 minutes with approximately 45m^3 of water. FBWW is generated during the process of cleaning of filter beds. Representative FBWW sample from the dual-media filters collected after one complete backwash cycle so that the recycled water represented a homogeneous mixture of the waste residuals. The Jar test experiments used homogenized samples of RW and different blends of FBWW and RW to evaluate applications applying in FBWW recycle rule[17].

Analytical Methods: The jar test is used to determine the optimum operating conditions for water or waste water treatment. This method allows adjustments in PH, variations in coagulant of polymer dose, alternating mixing speeds or testing of different coagulant or polymer types, on small scale in order to predict the functioning of a large scale treatment operation.

The following jar test procedure uses alum (aluminum sulfate) as a chemical for coagulation/flocculation in water treatment, and a typical six-gang jar tester. The results of this procedure can help to optimize the performance of the plant. The jar test experiment was conducted using a Phipps and Bird standard jar-test unit. Raw water and backwash water were collected from the Bhagirathi WTP during summer.

The jar testing apparatus consists of six paddles which stir the contents of six 1 liter containers. One container acts as a control while the operating conditions can be varied among the remaining five containers. An rpm gage at the top-center of the device allows for the uniform control of the mixing speed in all of the containers. 1000 milliliter of raw water was added to each of the jar test beaker and recorded the temperature, pH, turbidity and alkalinity of the raw water before beginning. After that a stock solution was prepared by dissolving 100 grams alum into 1000 (ML) distilled water. 1.0 ml of this stock solution was equal to 10 mgL^{-1} when added to 1000 (ML) of water tested. Then each beaker was dosed with increased amounts of stock solution by graduated syringe. After dosing, the stirrer was turned on. This part of the procedure reflects the actual conditions of the plant. Chemical in static mixer in a plant was allowed for 30 min. in flocculator then kept for 30 min. to settle down before the filters. The Jar test was performed by operating the stirrers at a high 100 rpm for 10 minutes. The rapid mix stage helps to disperse the coagulant throughout each container. The stirrer speed was slow down to 30 rpm to promote the floc formation and continued mixing for further 20 minutes for larger flocs due to particle collision. After that mixture was allowed to settle for 30 to 45 minutes. Then the final turbidity of each container supernatant was measured.

The supernatant of jar test was analyzed for water quality parameters such as colour, turbidity, TOC, DOC, total aluminum, total iron according to standard testing procedure as recommended as per Indian standard for drinking water specification.

To determine, TOC, water sample sparging under slightly acidic condition to remove inorganic carbon. Water sample digested with persulfate acid to form carbon di oxide. During digestion the carbon di oxide diffused into pH indicator formed carbonic acid which changed the colour of pH indicator solution. The amount of colour changes represents the original amount of TOC in the sample. Test results were measured at 598 and 430 nm by DR5000 spectrophotometer. True colour was measured using an HACH DR5000 spectrophotometer. Turbidity was measured using a HACH 2100p turbidity meter. Total suspended solids were measured as per Standard methods[18]. Field and laboratory temperatures and pH values were measured using an Orion model 210A pH meter with combination electrode. The pH meter was calibrated before each analysis using 4.02, 7.01, or 10.00 pH standards.

Results and Discussion

A list of water quality analyses of RW and FBWW collected from the BWTP during summer season is presented in table 1. Colour of RW and FBWW was recorded in the range of 5-10 Hazen and 250-400 Hazen respectively. It could be reduced to <5 Hazen when FBWW blended with RW. The iron concentration in RW was found in the range of 0.08 to 0.15 mgL^{-1} and in FBWW from 0.8 to 1.5 mgL^{-1} which was decreased up to 0.12 to 0.15 mgL^{-1} after recycling. Aluminum was not found in the RW. In FBWW, it was found in the range of 1.0 to 2.0 mgL^{-1}. The presence of aluminum in FBWW was primarily attributed to the use of alum as the coagulant. Turbidity of RW varied 25 to 200 NTU and in FBWW from 200 to 500 NTU. Rapid fluctuation in turbidity was observed in both samples. The FBWW quality of WTP was varied accordingly RW. Turbidity found much higher in FBWW than RW. This high turbidity due to aluminum hydroxide ($Al(OH)_3$) which comes from alum solution added to the RW. This alum solution required to remove the turbidity of RW.

Table-1
Water quality of RW and FBWW

Parameters	Units	Raw water (Average)	FBWW (Average)
Temperature	^0C	27	29
Turbidity	NTU	20-40	300
pH	mgL^{-1}	7.7-8.0	7.5-7.7
Alkalinity	mgL^{-1}	140	150
Total Suspended solid (TSS)	mgL^{-1}	80	200
Colour	Hazen	1-5	1-5
Total organic carbon (TOC)	mgL^{-1}	1.3-2.5	4.5
Dissolve organic Carbon (DOC)	mgL^{-1}	2.0	2.5
Total Aluminum	mgL^{-1}	Nil	1.0
Total Iron	mgL^{-1}	0.12	1.0

The suitable alum dose for RW was observed 20 to 22 mgL^{-1} as per turbidity whereas suitable alum dose of FBWW 16 mgL^{-1} table 2. This alum dose was also found equivalent to coagulant sedimentation treatment range used in main plant operation for RW treatment. For the blend of FBWW and RW, the suitable alum dose was recorded 16 mgL^{-1} table 2. This study suggests that when RW added with FBWW having already high turbidity, less alum required for treatment. According to result shown in table 1, the FBWW turbidity and aluminium concentration found with high level. DOC level increased slightly as compare to RW. Figure 1 represents the TOC and DOC measurement of supernatant of jar test. Jar test results showed 89% reduction in TOC at an alum dose of 20 mgL^{-1} at controlled pH. DOC concentration also showed decrease trends as TOC, with the marks of 60% reduction in DOC as dose increased from 10 to 20 mgL^{-1} at controlled pH. Beyond this alum dose minimal improvement of 20% in reduction of both TOC and DOC was found. Above results reflects that the best alum dose of 20 mgL^{-1} could be recommended for DOC and TOC removal.

Table-2
Applied dose for Raw Water and FBWW water

Parameter	Unit	Raw water	FBWW with RW
Alum Dose	mgL^{-1}	20	16

Table-3
TOC and DOC removal at variable alum doses

ALUM DOSE mgL^{-1}	TOC mgL^{-1}	DOC mgL^{-1}
0	4.25	3
10	3.64	2.3
20	2.75	1.69
30	2.31	1.23
40	2.03	1.03
50	2	1

TOC and DOC were determined for blends-5, 7, and 10% FBWW with RW separately. Reduction of 20, 40 and 30% TOC were recorded with 5, 7, and 10% FBWW with RW respectively, whereas reduction of DOC was recorded 20, 80 and 50%. By using analysis data from table 4, mass balance calculation proved that 7% blend would result maximum removal of DOC and TOC as compare to RW in main treatment plant. Thus, this was most suitable blend for the recycling figure 2. Jar test experiment results suggest that there is a mechanism that responsible for removal of DOC and TOC.

Table-4
Settled water TOC and DOC of RW and RW with different blends of FBWW

Source water	TOC mgL^{-1}	DOC mgL^{-1}
RW	3.2	2.8
5% blends	3	2.6
7% blends	2.75	2.0
10% blends	2.84	2.3

Due to low density particles of FBWW, flocs size was found increase in flocculation, which improves sedimentation process. These processes lead to removal of turbidity and pathogen[6,10,11,12].

In present study high turbidity FBWW used with low turbidity raw water, that increased the reduction of DOC because of large number of flocs mixed by FBWW recycling. When destabilized particles of FBWW mixed with RW, it increased the number of collision sites. Increased collision sites improved floc aggregation in the flocculation and decreased the settling rate. This could explain the improvements in DOC removal found in RW.

Other studies suggested the theory that both chemical and physical mechanisms are responsible for improved floc aggregation and organic removal. According to the theory when destabilized solids from the FBWW were mixed with the raw source water, both an increase in the number of collision sites (e.g., physical) and new charge neutralization sites (e.g., chemical) were available for the coagulation–flocculation process[14]. The result of the current study is also support the theory that, introduction of destabilized FBWW solids to the main treatment plant during coagulation process brings changes in flocculation. Recycling of FBWW to the main treatment plant achieved organic removals by simply increasing the turbidity (i.e., number of collision sites) during the coagulation and flocculation stages without increasing the coagulation dosages.

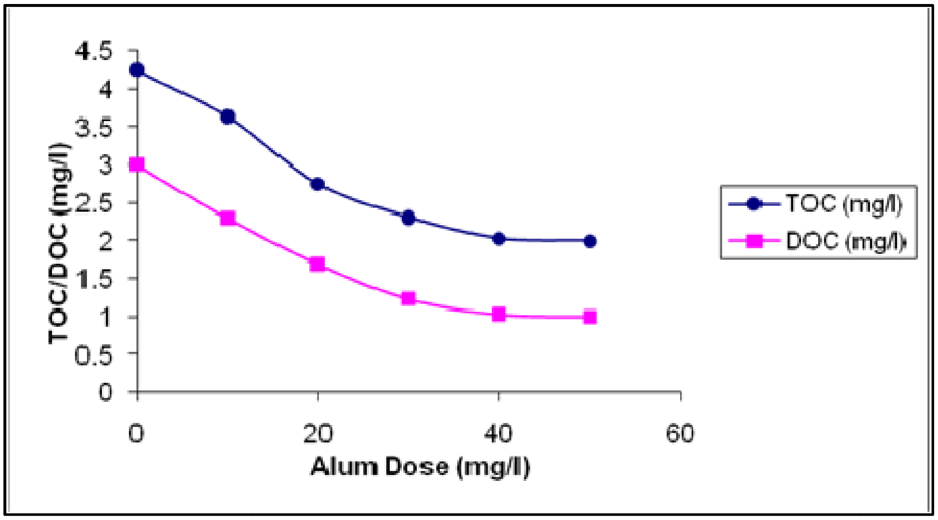

Figure-1
TOC and DOC removal at variable alum dose

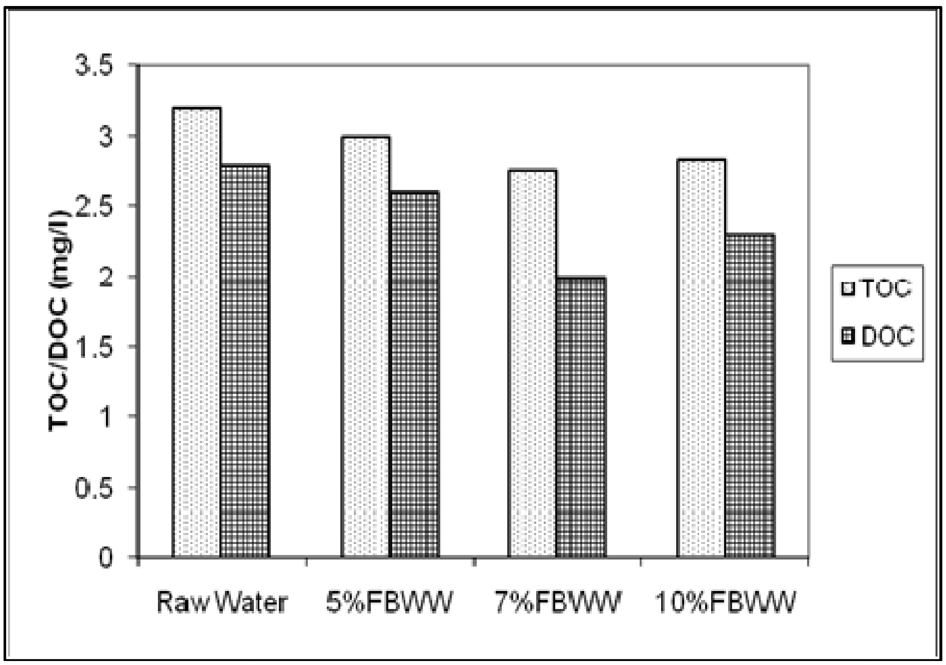

Figure-2
Settled water TOC and DOC of RW and RW with different blends of FBWW

Conclusion

Studies concluded that FBWW recycle affected the coagulation, flocculation, and sedimentation processes. In jar test study the low-turbidity raw water evaluated and showed significant decrease in organic removal when FBWW was recycled prior to coagulation–flocculation–sedimentation processes. When FBWW blended with raw water having already low density floc particles of aluminum hydroxide, less alum required for treatment. The jar test study demonstrated that if FBWW mixed with low turbidity RW before coagulation process it significantly increased the size of flocs and decreased in settling rate. The results of this research suggest that instead of increasing coagulant dosages to maximum removal of turbidity and organics, recycling of FBWW that containing destabilized particles could be used to get the same results. Jar test also demonstrated that the presence of aluminum hydroxide precipitates in the FBWW samples increased the number of bonding sites. These collision sites increased removal of raw water DOC and TOC through sweep coagulation mechanisms. The focus of this study was directed to use FBWW with RW by which less cost on treatment, preventing of going water level low and use of treated water could be achieved.

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