"INTERFILTRA - INTERMEMBRANE - 94"

Conference, 15 - 17, November, 1994

Paris, France

CROSSFLOW MICROFILTRATION APPLICATION FOR ALGAE REMOVAL

C Visvanathan*, Gemunu B B Herath* and R Ben Aim**

* Environmental Engineering Program, Asian Institute of Technology, G.P.O. Box 2754, Bangkok 10501, Thailand.

** Departement Genie Chimique, UTC, 60206 Compiegne, France.

Summary

The objective of this research was to investigate the possibility of coupling conventional Crossflow Microfiltration (CFMF) and Dissolved Air Flotation (DAF) for the algae separation. Oxidation pond effluent containing multi culture algae with total concentration of 65 to 105 mg/L was used as feed solution. The following operational parameters were examined for the process efficiency: crossflow velocity (2.0 - 5.5 m/s) and membrane pore size (0.2 to 2.0 μm), with and without flocculent addition.

The study showed that the optimum permeate flux was obtained at a crossflow velocity of 3.5 m/s and 0.8 μm pore size. The addition of alum as flocculent improved the flux up to 3.7 times while coupling of DAF further improved it to 6.3 times. This shows an increment of flux by 71% with the introduction of DAF for 0.2 micron membrane. Increase in pore size showed a decreasing trend in improvement of flux with coupled DAF. It was noted that the filtration flux during coupled DAF operation was found to reach a steady state after 2 hours and 90-95% of algae was removed from the floating algae mat. Whereas in CFMF mode, the flux continue to decrease rapidly even after 3 hours of filter run. The quality of permeate was below 0.2 NTU in all the tests, indicating possible reuse of the effluent.

Introduction

The treatment of municipal, industrial, and agricultural wastes employing stabilization pond or lagoons has found increasing application during the last two decades. Regardless of whether the lagoon is an oxidation pond, anaerobic cell followed by an aerobic polishing pond, or a facultative lagoon, the effluent from these units is likely to contain a significant concentration of algae.

In these ponds, algae is one main component in assisting aerobic waste stabilization. The algae generates oxygen in their photosynthesis reaction that is essential for aerobic bacteria in oxidizing organic pollutants. Nevertheless, oxidation pond effluent still contain a high amount of suspended solids and biochemical oxygen demand (BOD) in the form of algae. Hence, it becomes imperative to design the oxidation pond facilities, with the means for separating the algae in order to meet the required effluent standards. In practice due to algae's small size and low specific gravity, physical unit operations used for their removal encounters enormous difficulties.

Crossflow Microfiltration (CFMF) is a physical solid/liquid separation technique which involves the separation of particles from suspension using membranes of pore sizes ranging from 0.01 to 10 μm. In CFMF process, a suspension containing particles and colloids is pumped over a porous membrane under a moderate pressure. Here the membrane retains particles, while allowing colloids and ions to pass through. But it has been established that colloids cause a significant fouling in CFMF by being absorbed inside the membrane or on its surface leading to rapid flux reductions [1,2]. The main influential parameters on the degree of clogging is the feed concentration and particle size distribution.

Dissolved Air Flotation (DAF) is an alternative clarification process for sedimentation that is more efficient for the separation of low density particles such as algae [3,4]. Major parameters effecting DAF efficiency can be classified as the bubble/particle size, recycle ratio (bubble volume concentration) and the over flow rate. For an efficient flotation removal particle size should be above 32 μm [5]. The unflocculated algae are of much smaller size than this value causing poor algal removal in flotation plants without pre-treatment [3,4,6,7]. One of the pre-treatment method used in destabilization and agglomeration of particles is the use of a flocculent, which modifies the physico-chemical behavior of the constituents. This coagulation flocculation not only improve the flotation efficiency, it is also used as a de-clogging technique in microfiltration process [8,9].

Although DAF process is technically suitable in separation of low density algae, it does not produce high quality effluent. On the other hand, CFMF provides high quality effluent, the rapid membrane clogging makes it uneconomical for large scale applications. Therefore a system consisting the coupling of DAF and CFMF would enhance both the effluent quality and quantity.

Experimental Investigation

The main schematic diagram of the experimental set up used is shown in fig. 1. The main components of the set up can be described as follows.

The storage tanks were used as storage for raw feed and to maintain a constant water level in the flotation tank. The flotation tank is of 120mm diameter which feed water to the CFMF unit and act as the contact and separation tank for the DAF process. The pipe network which is of 13mm stainless steel is installed with membrane housings for both CFMF and DAF processes. A single channel tubular ceramic membranes (MEMBRALOX) with a pore size range of 0.2 to 2.0 μm were used. The filtering and backflushing was regulated with an automatic timing device together with solenoid valves. Air backflushing was used as the declogging techniques with a frequency of 2 seconds backflushing for 60 seconds filtering.

By regulating valve 'B' the pressure in the pipe section AB was elevated to 4.0 to 5.2 bar for the generation of dissolved air. The compressed air was injected in to this high pressure AB pipe section through a 0.2 μm membrane which acted as a diffucer. The pressure and flow of air to the system was controlled by the fine adjustment 'Harris' type pressure valve and solenoid valve S4. The section BC was under a pressure required for CFMF with the help of valve 'C'. An oxidation pond effluent was used as the raw wastewater. The concentration of algae ranged between 64 to 105 mg/L during the investigation period. Flocculation of algae was carried out with alum and a very short flocculation period was allowed since it was not necessary to have longer flocculation durations for algae removal [10]. Regular jar tests were carried out to obtain the optimum alum content [4,8] (refer Fig. 2). The consumption of alum was very high when compared with normal water turbidity removal (optimum alum dosage was between 650 to 800 mg/L). This may be due to the irregular shape of the type of algae found in the pond wastewater which, requires large amount of aluminum hydroxide flocs, for an efficient flocculation [11].

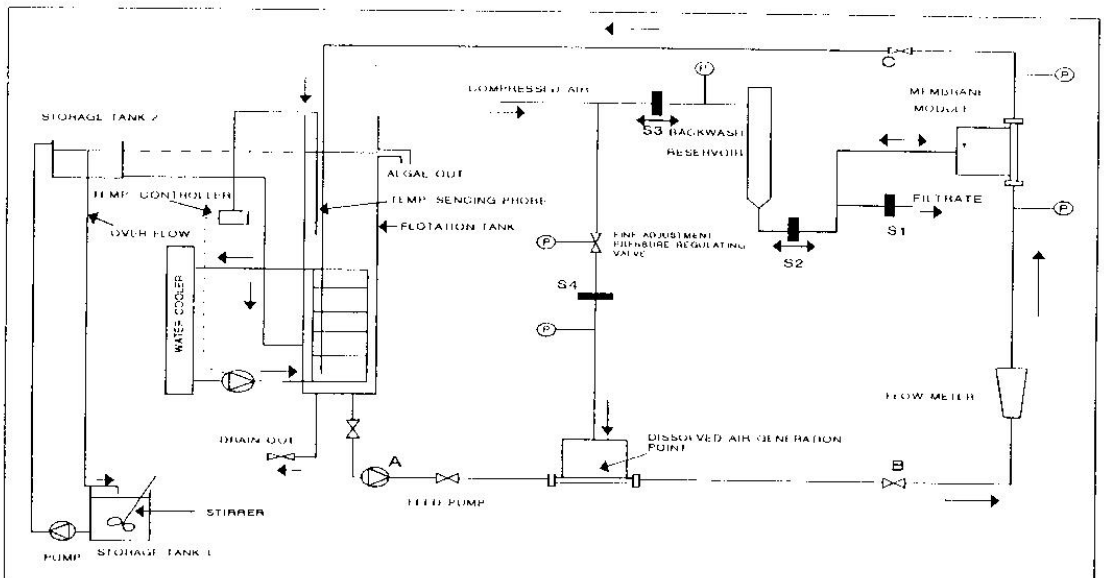

Fig.1 Experimental setup

Investigations were carried out with and without flocculent addition varying the crossflow velocity and membrane pore size. The other characteristics of the module and experimented optimum operating parameters [12] used are presented in Table.1.

Table 1. Characteristics of experimental parameters

Parameter	Selection
Applied pressure	1.5 bar
Temperature	28 ± 1°C
DAF system pressure	4.35-5.20 bar
Backflushing	
Medium	Air
Frequency	2 sec for 60 sec
Membrane	
Made	MEMBRALOX (SCS France)
Material	Ceramic
Dimensions	Inner Diameter - 7mm Outer Diameter - 10mm Total Length - 250mm Effective Area - 4550 mm^2

Results and Discussion

The experimental series was mainly directed at studying the effect of coupling the DAF process in CFMF in removing the algae from oxidation pond effluent. The experiments were carried mainly focussing on algae pre-treatment, crossflow velocity and membrane pore size.

The flux variation with time for flocculated and unflocculated samples are presented in figure 3. The figure reveals that, without pretreatment, the flux was very low compared to flocculated samples. This phenomena can be explained by the fact that, the raw pond effluent contain wide range of particles/algae and colloids and a significant potion of them smaller than the membrane pore size. Thus, they could penetrate into the membrane pore walls and create a rapid internal clogging. When, the pond effluent was flocculated, most of the colloids and fine algae fraction are retained as flocs on the membrane surface, thus the flux was improved by 370%.

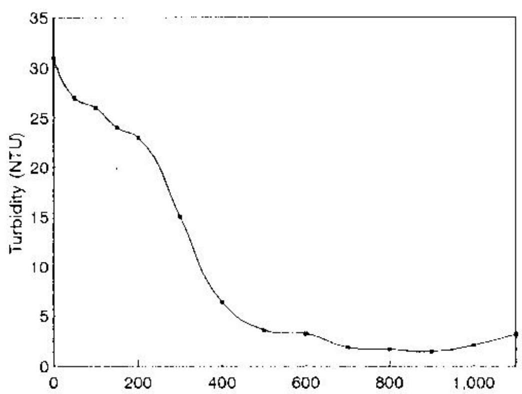

Fig. 2 Results of the Jar test for oxidation pond effluent concentration 64 mg/L.

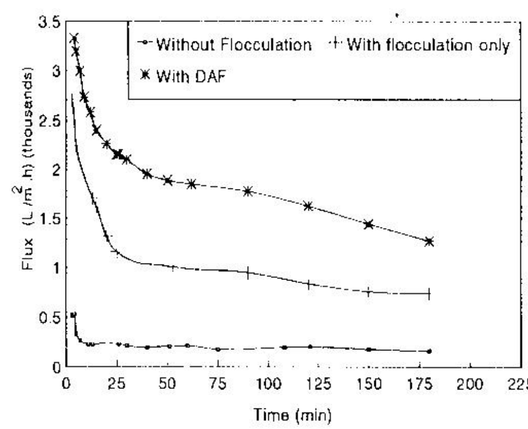

Fig 3 Flux variation with time pressure 1 5 bar, concentration 64 - 80 mg/L. C\F velocity 3.5 m/s, 0 2 μm membrane

Whereas the DAF was coupled with CFMF, the flux was further improved by 260%. This is mainly due to the fact that:

a) The flocculation process assist agglomeration of fine colloids and algae, thus preventing significant internal fouling and,

b) The flotation process, assist creating a thick floating algae mat on the tank surface, which was continuously removed. This process led to reduction of algae concentration in the feed water from 80 to 8.2 mg/L (fig 4a & b), i.e. almost about 90 - 95% of the algae were removed through floating mat.

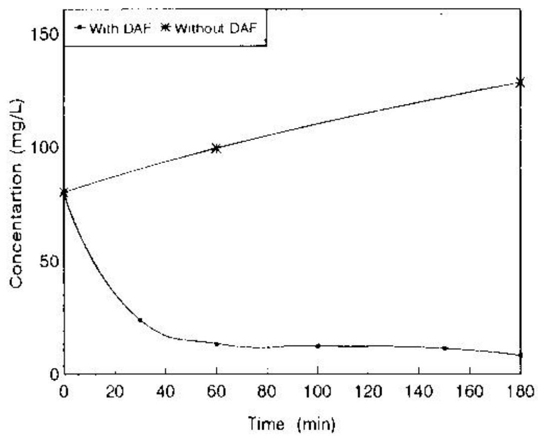

Fig. 4a Flotation tank algae concentration 0.2 μm membrane, pressure 1.5 bar concentration 80 mg/L, C\F velocity 3.5 m/s

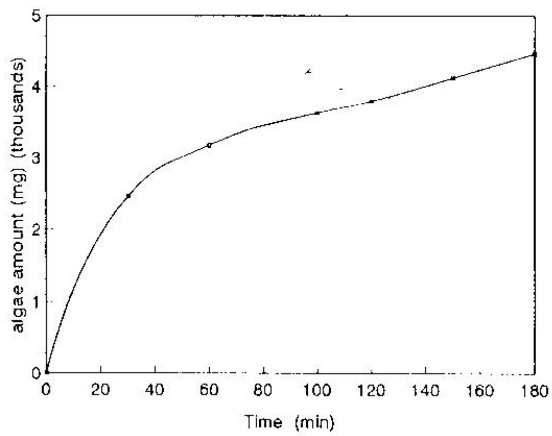

Fig. 4b Total Floted Algae, 0.2 μm membrane, pressure 1.5 bar, concentration 80 mg/L C\F velocity 3.5 m/s

Effect of crossflow velocity

The effect of crossflow velocity from 2.0 - 5.5m/s on flux is graphically presented in figure 5. For both uncoupled and coupled processes it appears there is a clear optimum flux at a moderate crossflow velocity of 3.5 m/s. The effect of low bubble volume concentration is clearly visible with the poor results at low crossflow velocities. The low velocity reduces the recycle ratio leading to a poor flotation removal (fig 6) where, the flotation tank algae concentration for 2 m/s shows a slower reduction compared to the other velocities. On the other hand, a very high crossflow velocity, create high turbulence and shear forces on the formed flocs. These forces could lead to floc breakage and destabilization, forming a larger fraction of smaller particles in solution causing rapid clogging.

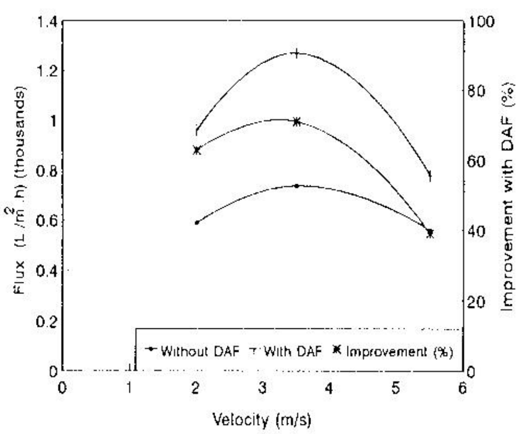

Fig. 5 Flux change and % improvement with C\F velocity, 0.2 μm membrane, concentration 64 - 105 mg/L, pressure 1.5 bar,

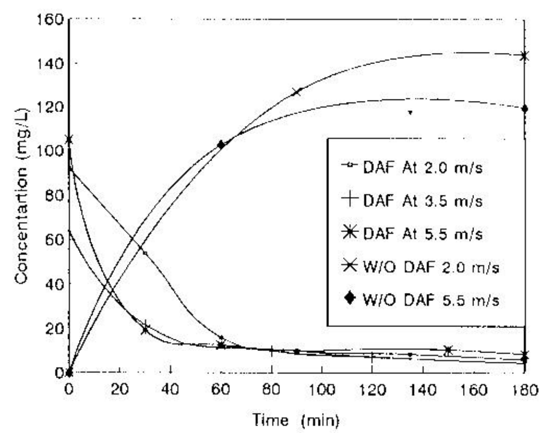

Fig. 6 Flotation tank algae concentration, 0.2 μm membrane, pressure 1.5 bar

The improvement in flux with coupled DAF were 62.8%, 71% and 36% for 2.0, 3.5 and 5.5m/s respectively. The flux at the above three velocities (with DAF) were 800, 1270 & 760 L/m^2.h respectively showing the flux optimum and the improvement optimum was achieved with the same crossflow velocity of 3.5 m/s.

Effect of pore size

The flux profiles obtained for the four pore sizes 0.2, 0.8, 1.4 and 2.0 μm, with and without flotation are presented in fig 7a and b. The figure 7a shows the variation of flux during the total 3hour process run with DAF, while figure 7b shows similar variation without DAF. The comparison of flux and the total throughput shows, the 0.8 μm membrane provides the optimum flux for both coupled and uncoupled runs (Fig 8). Though the optimum flux was obtained with the 0.8 μm membrane, percentage-wise flux improvement for coupled DAF are 71%, 23%, 29% and 23% for 0.2, 0.8, 1.4 and 2.0 μm membranes respectively. The results reveals that the increase in pore size were less beneficial in improving the process efficiencies (fig 8).

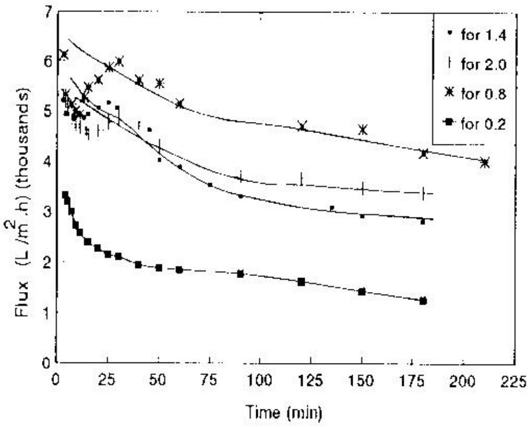

Fig 7a Flux change with time for diffrent pore sizes with DAF, pressure 1.5 bar concentration 64 - 105 mg/L, C\F velocity 3.5 m/s,

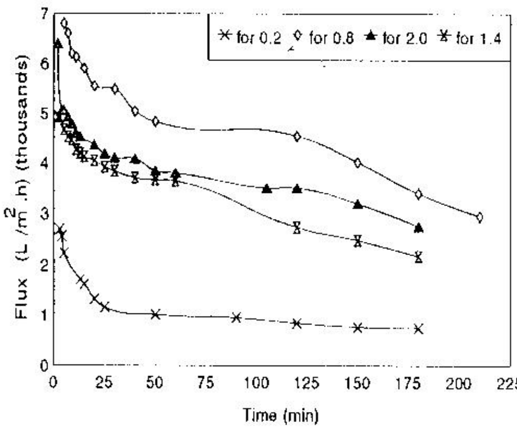

Fig 7b Flux change with time for differrent pore size, pressure 1.5 bar, concentration 64 - 105 mg/L, C/F velocity 3.5 m/s,

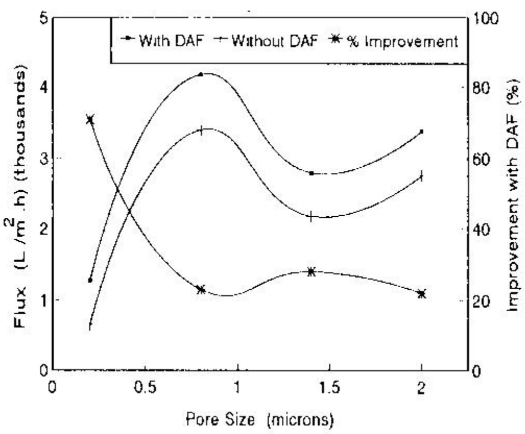

Fig 8 Flux change with pore size for pond wastewater, pressure 1.5 bar, C\F velocity 3.5 m/s, concentration 64 105 mg/L,

There may be many possible reasons for this flux reduction with increased pore size. The oxidation pond effluent is expected to have a wide range of particles and colloids. The flocculation assist the agglomeration of major portion of algae in the form of flocs, which are easily retained in the membrane surface. But it is expected that there exists a reasonable amount of unflocculated particles much smaller than the pore sizes hence, when they pass through the pores, with a fraction been attached to the inner surface of pores resulting in plugging of pores [1]. Once these pores are clogged it is difficult to clean them even with high pressure backflushing, causing a high resistance to flux. The percentage improvement results shows this fine particle interference on 0.2 μm membrane was minimum showing the best improvement (three times flux improvement compared to other larger pore size membranes).

However still even with this draw back in flotation, the uncoupled filter runs does not achieve a steady state conditions after 180 minute filtration run whilst the coupled flotation runs achieves the steady state. This can be illustrated with the figures 7a and 7b. The percentage flux reduction between 150 and 180 minutes for 0.8, 1.4 and 2.0 μm membranes were 15.4, 12.2, 13.6 and 4.1, 4.5, 2.9 respectively for uncoupled and coupled DAF experimental runs.

These values shows the continuing rapid flux decrease for the uncoupled case (fig 7b), while the coupled case had almost reached a quasi steady state.

Conclusions

The following conclusions could be drawn from this initial experimental investigation conducted to couple crossflow microfiltration and dissolved air flotation to remove algae from oxidation pond water. The coupling of DAF with CFMF in treating oxidation pond water, produce significant improvements in algae separation efficiencies. A pre-treatment with a flocculent such as alum was essential.

At a moderate crossflow velocity of 3.5 m/s, the coupled system achieved optimum efficiencies in both DAF and CFMF processes. The improvement in flux with coupled DAF was more than 70% in the case of 0.2 μm membrane. This moderate value for optimum velocity shows the interrelated influence of turbulence and shear force on floc size and boundary layer which controls the rate of flux. At higher velocities the positive influence generated with decreased boundary layer(i.e. surface deposit layer thickness) is over dominated by the breakage of floc causing severe clogging.

The increase of pore size shows a deteriorating degree of improvement in flux for coupled system. The 0.8 μm membrane had the optimum product volume though its improvement with coupled DAF was only 22%. The coupled system flux achieves a steady state values within the 3 h operation time while, uncoupled runs continued its declining phase for higher pore sizes.

In all value ranges the flotation process obtained a concentration reduction of about 85-95% as a floated algae mat. The quality of the final product out of CFMF unit was never over 0.2 NTU turbidity. When comparing the 0.2μm membrane with the 0.8 μm membrane the 0.2 μm membrane has the following advantages though flux was higher with 0.8 μm :

a) Improvement with coupled system was more than three times higher for 0.2
b) The final product is very high since bacterial separation also achieved and
c) The 0.2 μm membrane has a longer service life due to lower pore clogging.

REFERENCES

1. **VISVANATHAN C. and BEN AIM R. (1989)**, Studies on colloidal membrane fouling mechanisms in crossflow microfiltration, Journal of membrane science, Vol. 45, PP. 3 - 15.

2. **TARLETON E.S. and WAKEMAN R.J. (1993)**, Understanding Flux Decline in Crossflow Microfiltration, Part 1, Effect of particle size and pore size, Journal Trans IChemE, Vol. 71, Part A, July, PP. 399 - 408.

3. **EDZWALD J.K. and MALLEY Jr J.P. (1990)**, Removal of humic substances and algae by dissolved air flotation, U.S. Environmental Protection Agency, Risk reduction engineering laboratory, Cincinnati.

4. **ZABEL T. (1985)**, The advantages of Dissolved air flotation for water treatment, Journal AWWA, May, PP. 42 - 46.

5. **SCHERS G.J. and DIJK J.C. VAN. (1992)**, Dissolved air flotation theory and practice, Graduation Thesis, Dept. of Civil Engineering, Technical University, Delft, Netherlands.

6. **EDZWALD J.K. and WINGLER B.J. (1990)**, Chemical and Physical aspects of dissolved - air flotation for the removal of algae, Journal Aqua, Vol. 39, PP. 24 - 35.

7. **BOTES V. and VUUREN L.R.J. (1991)**, Dissolved air flotation for the removal of algae and inorganic turbidity on a large scale, Water Supply, Vol. 9, PP. 133 - 139.

8. **PEUCHOT M.M. and BEN AIM R. (1992)**, Improvement of crossflow microfiltration performances with flocculation, Journal of Membrane Science, Elsevier Science publishers B.V, Amsterdam. PP. 241 - 248.

9. **VIGNESWARAN S. and BOONTHANON S. (1992)**. Crossflow microfiltration with in line flocculation, Water, February, PP. 29 - 31.

10. **EDZWALD J.K., MALLEY Jr J.P and YU.C (1991)**, A conceptual model for dissolved air flotation in water treatment, Journal of Water Supply, Vol. 9, PP. 141 - 150.

11. **BERNHARDT H. and CLASEN J. (1991)**, Flocculation of micro-organisms, Journal Water Aqua, Vol. 40, No. 2, PP. 76 - 87.

12. **HERATH G. B. B (1994)**, Coupling of Crossflow Microfiltration and Dissolved Air Flotation for Algae Removal, Masters Thesis EV, AIT