APPLICATION OF EXTENDED BIOLOGICAL TREATMENT TRAIN (ANAEROBIC-AEROBIC) FOR HEAVY METALS AND ORGANIC REMOVAL

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Abstract

A previous laboratory works have been carried out for the determination of the behaviour of sulfte reducing bacteria in an upflow anaerobic fixed film reactor, UAFFR, for heavy metals and organic removal. Full description of the reactor, sizing and design requirements have been precisely identified. That reactor ws capable biologically to remove heavy metals to high concentrtions up to 100% and to reduce organic up to 60% of its concentration. For the design of the complete tretment train, that reactor should be followed by an aerobic treatment system. In this paper, a pilot unit representing activted sludge was used after that reactor. The objective of this paper was to examine the effect of the effluent wastes out of the UAFFR, which is charcterized by high concentration of soluble sulfides (may up to 120 mg/l), on suppress of the following aeration system. It was found that aeration system should have a minimum of 20 hours retention time to reach adequte removal. The suppression of aerobic activity lasted for about 4 hours before the system get aquinted with the environment and sulfides toxicity is eleminated.

Background

A previous work was conducted by one of the authors in the University of Windsor, Ontario, Canada (El Bayoumy et al., 1997) to investigate the performance of sulfate reducing bacteria, SRB, in removal of organic and heavy metals. The previous laboratory works were conducted totally depending on growth of SRB in a fixed film reactor. This work has identified the design equations of the reactor to determine its hight necessary for full removal of heavy metals concentrations, which were found to depend on the metal toxicity. Also, it was observed that the SRB behaviour was responsible about the metals removal, not only by precipitation but also by biosorption on the bacterial biomass.

The objective of this research work is to study and to define a full scheme train of treatment which might be needed not only to achieve the full removal of heavy metals but also to possible highest removal of organic loading. This covers the possible need for industrial waste treatment characterized by high concentration of organic along with high concentration of metals. The work done in this research was carried out to investigate the recommended treatment consists of UAFFR followed by an activted

sludge process. The goal of this work is to study the effect of the effluent of the UAFFR which has high concentration of sulfides and other toxics on the aerobic activity of the activted sludge process and its performance.

The literatures show that previous researches have examined the usage of packing materials such as polypropylene pall rings 15.9 mm in fixed film reactors, (Lappan, 1987) and Wijaya (1993). Elbayoumy et al. (1997) has also examined and compared growth of sulfate reducing bacteria in fixed film reactors with polypropylene 15.9, 25.4 mm and porcelain saddles 25.4 mm. The growth of sulfate reducing bacteria with all of these three packing materials was almost the same without any effect of packing material type on growth activity.

Also, previous researches have shown that the sulfate reducing bacteria can effectively precipitate heavy metals in fixed film reactors (Tsezos, 1985). Sulfate reducing bacteria make excellent biosorpents because of their high surface to volume ratio (Beveridge, 1989). Metal binding behavior has been evaluated on the basis of bacterial cell Gram reaction for viable cells (Mullen et al. 1989) and cell walls and envelopes (Flemming et al. 1990). Gram-positive bacteria are particularly suitable for metal binding (Damal et al. 1986; Ross and Townsley 1986).

Materials and Methods

The reactor of the UAFFR was set for the experiment, where it was fed with metals and substrate of up to about 5000 mg/L as Total Organic Carbon (TOC). This substrate composition was chosen to match the recommendations and findings of previous work for optimum environment for SRB growth (Elbayoumy, 1997). Also, an additional 500 mL of old active biomass of SRB strain was fed to the reactor for the start up of the system.

The reactor was filled with packing material as specified in the literature works. The substrate was pumped from the feed container to the bottom inlet of the anaerobic reactors by means of a variable speed peristaltic pump. These pumps were continuously calibarated. The reactor was construced from a grey dark polyvinyl chloride pipe with the following dimensions:

- Overall height	:	1300 mm
- Effective Depth	:	1220 mm
- Internal diameter	:	102 mm
- Net empty working volume	:	9.8 L

The reactor was filled with 15.9 mm polypropylene pall rings with a porosity of 90% to provide a working volume of 8.9 L. The reactor was kept air tight by using rubber stoppers and screws to control and close all openings. All connecting piping were made of plastics. The experiment was conducted at room temperature which varied between 20 degrees to 25 degrees. This UAFFR reactor was followed with a

basin to treat the effluent aerobically up to 24 hours, the basin is totally aerated to present the aerobic environment of activated sludge needed to remove remaining organic concentration.

All experiments were done in the laboratory in the university of windsor, and the results were determined in accordance to the *Standard Methods* (APHA, 1992). Oxidation Reduction Potential, ORP, and pH were run and tested using proper electrodes, while the sulfide concentration was measured as per the iodometric method 4500-S B,C,E of the standard method. A rapid test kit was used to determine the bacterial count.

Results

The experiment was operated and the results of sulfides concentrations were principaly measured to represent its presence in the effluent of the UAFFR to the aerobic reactor. Also, organic removal measured as total organic carbon, TOC, was recorded to indicate any suppress of the aeration basin due to the sulfides and toxicity exists in the UAFFR effluent.

Sulfate Reducing Bacteria Rapid Test Count

A rapid test kit was used to determine the concentrations of the biomass cells of the sulfate reducing bacteria in the reactor. The importance of that count was to indicate and assure the existance and growth of the sulfate reducing bacteria inside the UAFFR reactor. This test count were done on a daily basis to monitor changes in the concentrations of the SRB biomass. The counts show an existance and growth of bacteria in the reactor. The count indicated growth rate in the bacterial count (cells/mL/days). The rapid test count, only, give indicative values with accpetable range of accuracy of the bacterial growth rate. The count showed a value of about 1000 cells/mL in the begining of the continuous flow conditions and increased to about 1000000 cells/Ml. This result assures existance of SRB in the reactor and confirms the growth of the bacterial cells, during the whole experiment period.

Sulfides

Figure 1 shows the concentration of sulfides measured from the effluent of the reactor versus time. Results show that this concentration drops significantly down to almost zero mg/l through the length of the batch regime aerobic reactor. This length was calculated according to the flow applied to the reactor and found to resemble a retention time of about 2.0 hour. Afterwards, the aerobic activity took about 4.0 hours to launch its activity for organic removal.

pH and ORP

All results collected show that pH was maintained ranged in the reactor from 6 to 8, which represents optimum conditions for sulfate reducing bacteria growth according to previous literature. Also, oxidation reduction potential, ORP was tested to indicate the anaerobic conditions and confirm the environment of the SRB. Postgate (1984) has illustrated that proper ORP for SRB growth is about –150 mV to about –250 mV. The ORP results of this research from the reactor matched the above range. Values ranging between –195 mV to –220 mV were recorded.

TOC

TOC ws measured at the influent and effluent of the UAFFR respectively, and a removal of about 50 – 60% was monitored. Also, TOC was measured in the aerobic basin and it was found that aerobic activity took about 4.0 hours at the beginning of the aerobic reactor as an adoption time needed to accomodate the UAFFR anaerobic effluent to the aerobic condition. Afterwards, the aerobic activity could perform the biodegredation of the organic loading of the wastes. A removal ratio up to 97% was achieved in both anaerobic and aerobic reactors. To reach such removal, a retention of about 16 hours is needed after the 4.0 hours at the beginning. A total retention time not less than 20 hours is required.

Conclusions

The results of this study have shown that the bacterial count indicated the existance of the SRB in the UAFFR with proper growth pattern. pH and ORP were maintained to indicate adequate environment for SRB growth. Sulfides concentration at effluent has dropped through the aerobic reactor length, representing a period of about 2.0 hour with effluent sulfides concentrtion exists. After that period the aerobic reactor was capble to sustain the anaerobic environment of the UAFFR effluent and the existance of the anerobic bacteri, SRB.

The toxicity effect lasted for 2.0 hours nd afterwards, the aerobic reactor was capable to perform properly in a 4 hours retention time. TOC results assured that UAFFR can maintain organic removal of about 60%, while the aerobic reactor after these 4.0 hours, has achieved a removal of up to 97% of the main influent to the system in a minimum of 16 hours retention under the working condition described in this research. A minimum of 20 hours retention time is needed to achieve the removal ratio targeted as described above.

The following conclusions can be summarized:

1- Extended treatment train consists of an UAFFR (retention time of 6 – 12 hours) and followed by extended aeration of about 20 hours.

2- UAFFR will be capable to perform orgnic reduction of 60% and 100% of the heavy metals.

3- Extended aeration will be capable to maintain a removal 97%, after overcome the inhibition and toxicity effect of the anaerobic effluent in 4.0 hours.

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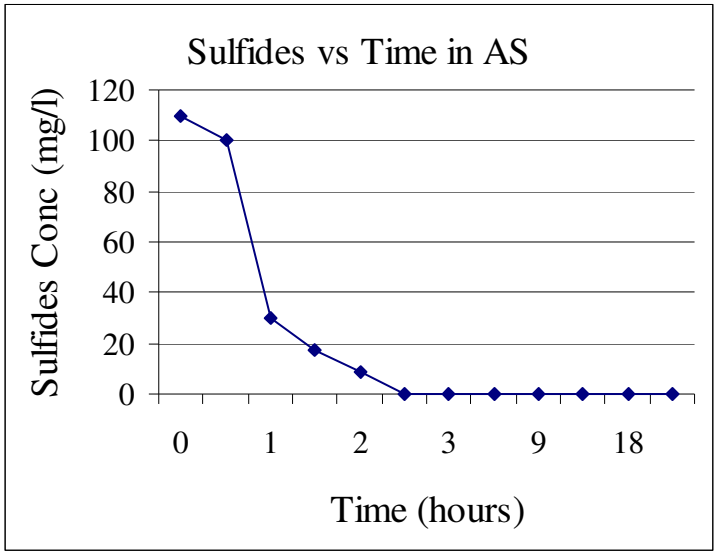
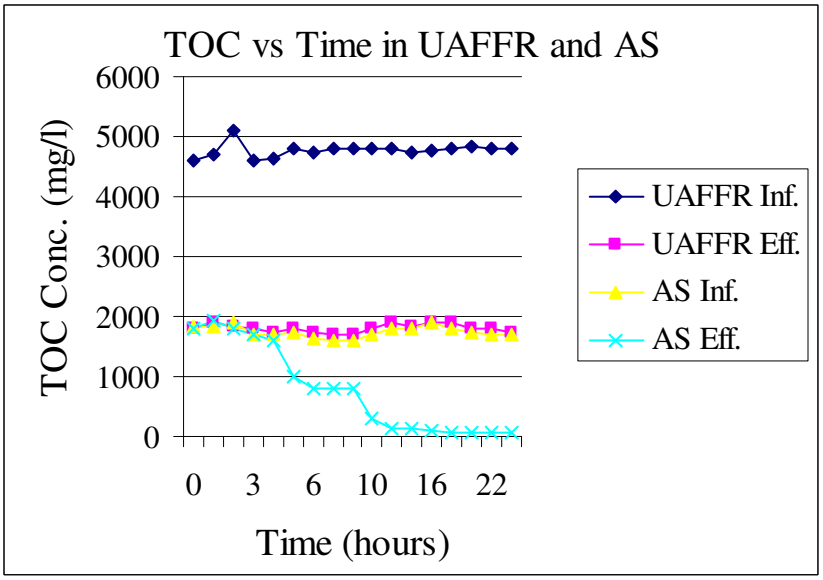
Table-1 : Substrate Composition

Acetic Acid, g/L	4.67
SO4, g/L	2.5
MgSO4.7H2O, g/L	6.4
NH4Cl, g/L	0.94
KH2PO4, g/L	0.05
K2HPO4, g/L	0.2
Th.O.D./SO4	2
OLR, Kg/m3/d	6
TOC, g/L	5


Sulfides vs Time in AS
Sulfides Conc (mg/l)
120
100
80
60
40
20
0
0
1
2
3
9
18
Time (hours)


TOC vs Time in UAFFR and AS
TOC Conc. (mg/l)
6000
5000
4000
3000
2000
1000
0
0
3
6
10
16
22
Time (hours)
UAFFR Inf.
UAFFR Eff.
AS Inf.
AS Eff.