

REFLUX : IT'S IMPACT ON THE REMOVAL OF NITROGEN AND PHOSPHORUS FROM SEWAGE WATER USING ENHANCED AO BAF SYSTEM

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Abstract

A/O BAF system has been used in the treatment of nitrogen and phosphorus and other nutrients present in wastewater, This economical and effective way of nutrients removal uses different parameters in the actualization of desired objectives, one of them is the Reflux ratio, this research focuses on the influence and roles of Reflux, Sponge Iron and Manganese sand on the removal of nitrogen and phosphorus from wastewater. The following experimental operational parameters was set up for the purpose of this experiment, Hydraulic load of $0.5 \text{ m}^3 / \text{m}^2 \cdot \text{h}$., Air/Water ratio of 10:1 (0.42L/min) and reflux ratio of 100 and 200 percent.

The experiment is divided into two main areas: The effects of reflux ratio presence and absences on removal efficiency of the BAF system. The reflux water was introduced into the anaerobic column and sometimes in aerobic column. The results were examined to note the extent to which reflux plays a part on the removal rate of the nutrients when introduced into the aerobic column instead of the anaerobic column and vice versa. sponge iron and manganese sand column were also introduced, and the results of the nitrifying bacteria shown it supports the removal efficiency observed in the BAF system. The results were all investigated, compared and the analysis showed that reflux helped more in the removal of nitrogen and ammonia, while sponge iron and manganese sand increased the removal efficiency of phosphorus from waste water

Key Word: BAF: Biological Aeration Filter; Total Phosphorus; Total Nitrogen; Chemical Oxygen Demand (COD); Removal Efficiency;

1. INTRODUCTION

Sewage water contains various pathogens, organic and inorganic compounds, heavy metals, etc. This water body if not carefully treated can lead to a major problem known as eutrophication, which invariably will affect public health and cause million of US dollars during clean up. In this study, Biological Aerated filter will be used for the removal of nitrogen and phosphorus from sewage water. While the main objectives is to investigate nitrification in BAF using different reflux ratio comparing the findings with results from without reflux.

Biological Aerated Filters (BAF) have been know as a fixed-film system on which the biofilm support media are stationary during normal operations, The primary purpose of BAF technology is to simultaneously accomplish the biological oxidation of organic compounds and physical filtration of suspended solids, (J.G Peladan, et al, 1996, P.W. Westerman et al, 2000). it is also known as a powerful system to treat a stream having variations of PH and high organic content [J.M . Montgomery, 1990]. BAF, as well as the other fixed-film processes, is advantageous in comparison to the activated sludge systems due to the higher volumetric loads, increase process stability, and compactness of the reactors, caused by higher biomass concentration and higher specific removal rate [H.P Kallabo

1997].Furthermore, organic materials removal and nitrification can be carried out in a single unit [Fdz. Polano et al, 2000].

In achieving desirable results in a BAF system, the selection of packing media plays an important role in maintaining a high amount of active biomass and a variety of microbial populations [Wong-Seok Chang]. Natural materials, involved such as sand, shale and expanded clays have been frequently applied [R.Moore et al, 1999,2001, S.B. He, et al 2007]. In addition, synthetic materials have also been used , e.g. polystyrene, polyethylene, however, the production of these materials are costly, and synthetic materials may not be significantly more effective than natural materials [T.D. Kent, 1996].however, in this study natural ceramic and zeolite were used as the packing media, while the enhanced column had sponge iron and manganese sand used in various ways.

In this work, AO BAF system is used as a means for remediating the sewage water with emphasis at how reflux water, sponge iron and manganese sand plays a part in the removal efficiency of the nutrients. With the objective of finding a better parameters to support the removal rate of COD, NH₃-N, TP and TN pollutants from sewage water.

2. MATERIALS AND METHODS

2.1. Experimental Set-up

The experimental setup was composed of two unit, the AO BAF unit which is composed of the anaerobic and the aerobic column and the sponge iron/ manganese sand unit which was composed of the sponge iron/ manganese sand column. The height of the anaerobic and aerobic column is at 3m and 2m respectively with a column diameter of 8cm for both. The sponge iron/manganese sand column has a total height of 1m and a diameter of 8cm. The anaerobic filter was divided into two layers, upper and lowers layers.

The upper layer served mainly for the filtration of suspended solids coming from the influent tank, while the lower layer was where denitrification mainly took place. The filter packing materials in the upper layer stood at 0.75m in height inside the column, while the lower layer filter packing materials was at a total height of 1m inside the column.

The Aerobic filter column served mainly for nitrification and partial absorption reaction of phosphorus, the packing materials stood at a total height if 0.70m inside the column. The pool of microorganisms were gotten from Qilihe district sewage plant, it was pumped into the anaerobic and aerobic column simultaneously for a total period of 7 days, and then left to grow for a total period of one month before the start of the experiment.

The treated effluent were used periodically for the backwashing of both columns to remove the suspended solids, hence allowing the proper flow of water through the

filter materials. The backwashed was carried out three times weekly. During backwashing, the air flow rate was raised to allow an increase in the column's liquid volume which enables the outflow of the suspended solids from the column through the backwash outflow chamber. The experimental air flow into the aerobic column was set at 0.42 L/min.

Reflux water was introduced into the anaerobic column and aerobic column, and the results were used to compared to the experiments were reflux water was absent. this was to enable us determine the effectiveness of reflux in the removal efficiency of the various targeted nutrients from the influent wastewaters.

2.2. Packing Materials

The packing materials used for the purpose of this experiment were made of the following:

Ceramic, Zeolite, Sponge iron and Manganese sand.

Pebbles were laid inside all the column up to 15cm in height. The anaerobic column upper layer had a ceramic filter packing materials size ranging from 8-12mm, while the lower layer had a ceramic filter packing materials size of 5-8mm.

The aerobic column had a zeolite filter packing materials size ranging from 3-5mm, and the sponge iron and manganese sand materials had a size of 1-3mm.

Table 1: Packing materials and sizes

Project	Filter materials diameter (mm)	Packing materials height (m)	Column total height (m)
Anaerobic filter column (Upper Unit)	8-12	1	2
Anaerobic filter column (Lower Unit)	5-8	0.75	1
Aerobic filter Column	3-5	1.2	2
Sponge Iron and Manganese Sand Column	1-3	0.75	1

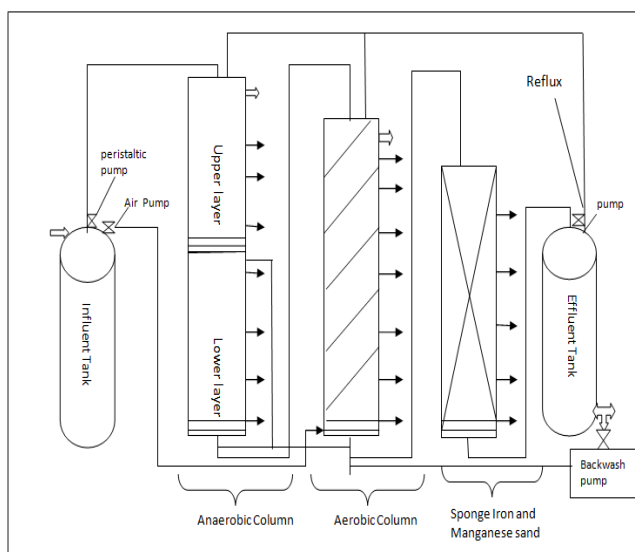


Fig 1. Diagrammatic representation of an enhanced A/O BAF system

2.3. The Waste water

The waste water was obtained from the Lanzhou Jiaotong University's sewage system by a pump. The concentration of the nutrients in the wastewater was characterized depending on weather the school was in session or not. The school has a centralized sewage network that collects the water runoff from all areas of the university. Wastewater was collected into a secondary sedimentary tank to enable the removal of some suspended solids before it was discharged by a pump into the influent tank, it was thereafter pumped into the anaerobic column with a peristaltic pump. The sewage water was tested for organic and inorganic nutrients, (COD, TN, TP and Ammonia), and suspended solids.

3. RESULTS AND DISCUSSION

The results of this experiment was analyzed in two different categories, Firstly, results from the use of reflux under different operational parameters and results from without the

use of reflux. The various results was compared and the removal efficiency of the four indexes investigated.

3.1 Effects of reflux ratio presence on removal efficiency.

Under this categories the following condition/types results was examined.

3.1.1. Ceramic and Zeolite packing stage (Experiment/Type A) : The operational parameters conditions are as follows: hydraulic load $q = 0.5 \text{ m}^3 / \text{m}^2 \cdot \text{h}$, the waste water flow rate was set at 42ml/min, Air/water ratio at 10:1 (0.42L/m), while the reflux ratio was set at 100% going into the anaerobic columns.

3.1.2. Ceramic and Zeolite packing stage (Experiment/Type B) : Here the parameters conditions are as follows: hydraulic load $q = 0.5 \text{ m}^3 / \text{m}^2 \cdot \text{h}$, the waste water flow rate set at 42ml/min, Air/water ratio at 10:1 (0.42L/m), The reflux ratio was set at 100% going into the aerobic columns.

3.1.3. Sponge Iron and Manganese Sand packing stage (Experiment/Type C): The operational parameters are as follows: hydraulic load $q = 0.5 \text{ m}^3 / \text{m}^2 \cdot \text{h}$, the waste water flow rate set at 42ml/min, Air/water ratio at 10:1 (0.42L/m), The reflux ratio was set at 100% with the reflux going into the anaerobic columns. The difference between this experiment and experiment A is the installation of the sponge iron and manganese sand column which was otherwise absent in the stage A.

3.2 Effects of reflux ratio absence on removal efficiency.

In this category, we investigated the results of the various conditions without the presence of reflux, and the data's was compared to the conditions with reflux, The results showed the impact and effect of reflux ratio on the removal efficiency in a A/O BAF system. The following are the different Experiment/types.

3.2.1. Ceramic and Zeolite packing stage (Experiment/Type D) : The operational conditions are as follows: hydraulic load $q = 1 \text{ m}^3 / \text{m}^2 \cdot \text{h}$, the waste water flow rate set at 84ml/min, Air/water ratio at 10:1 (0.42L/m).

3.2.2.Sponge Iron and Manganese Sand packing stage (Experiment E): Here the operational conditions are as follows: hydraulic load $q = 1 \text{ m}^3 / \text{m}^2 \cdot \text{h}$, waste water flow rate set at 84ml/min, and the Air/water ratio at 10:1 (0.42L/m). The difference between this experiment and experiment C was the increase in hydraulic loading rate of this stage from $0.5 \text{ m}^3 / \text{m}^2 \cdot \text{h}$ in experiment C to $1 \text{ m}^3 / \text{m}^2 \cdot \text{h}$ in experiment E.

Chemical Oxygen Demand (COD) Results

Results from the all types were investigated and there was only a slight variation in the removal efficiency of COD across all stages. It shown a removal efficiency of 89,83.7,87.5,85.3 and 81.7% from stage A to E respectively, with type A having the best removal efficiency. The graph below illustrates further the removal efficiency.

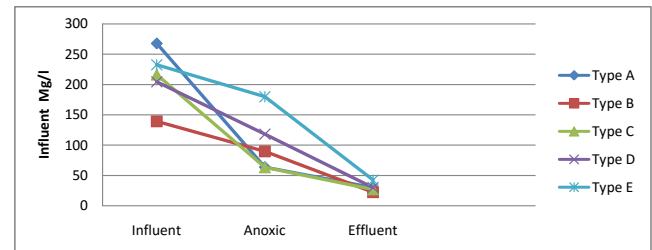


Fig 2. COD removal rate

Analyzed with Potassium dichromate colorimetric DR5000 Water Quality Analyzer

It could be seen that for type D and E there was a lesser removal efficiency when compared to those types with reflux presence. Type A,B,C,D and E shown a removal efficiency of 89,83.7,87.5,85.3 and 81.7% respectively.

Total Nitrogen Results: The total nitrogen removal efficiency in the reflux presence experiments were shown to having type A as having the highest rate of removal. While type B was shown to have the lowest. But, the results of type D and E shown lots of variation; Notably in type D were the nitrogen concentration in the effluent were more than in the influent. This however was attributed to the presences of large amount of suspended solids in the aerobic column. The results is present in Fig 3. below.

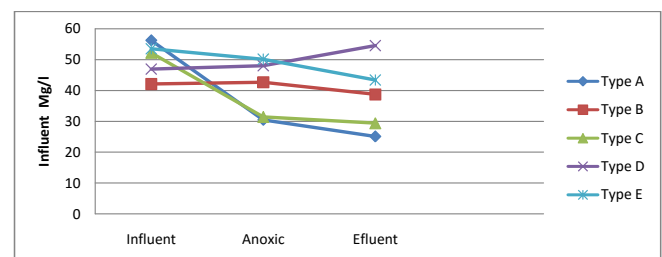


Fig 3. Total nitrogen removal rate results.

Total Nitrogen was analyzed with Per sulfate oxidation - molybdenum, antimony spectrophotometer, 721 Vis

From the results it shows conditions with reflux presence had higher removal rate when compared with the conditions without reflux. In type D, possible research should be carried out to ascertain other explanation in regards to why there was an increase in the concentration of nitrogen in the effluent more than the influent. A.

Total phosphorus Results: The total phosphorus removal efficiency recorded in the all categories found that the removal efficiency of total phosphorus in the sponge iron

mixed with manganese sand packing conditions (Type C) and (Type E) were at the highest, meeting the effluent discharge standard when compared to the zeolite packing phase in types A,B, and D. It further shows that reflux have little impact on the removal efficiency of total phosphorus unlike the sponge iron and manganese sand. Fig 4. further explains the removal rate.

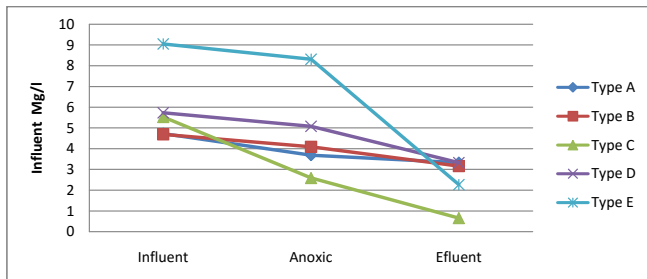


Fig 4. Total phosphorus removal rate results

Analyzed with Per sulfate oxidation - molybdenum, antimony spectrophotometer, 721 Vis

The influence of sponge iron and manganese sand on the removal of total phosphorus can be seen to have a percentage increase when compared with the lowest removal rate in type A. The removal efficiency varies significantly across the different types of the conditions. For example, Type A,B,C,D, and E was shown to have had a removal efficiency of 30,32.3,82.3,41.8 and 74.9%. Showing that the addition of sponge iron, manganese sand or the combination of both directly increase the removal rate of phosphorus.

Ammonia Results:

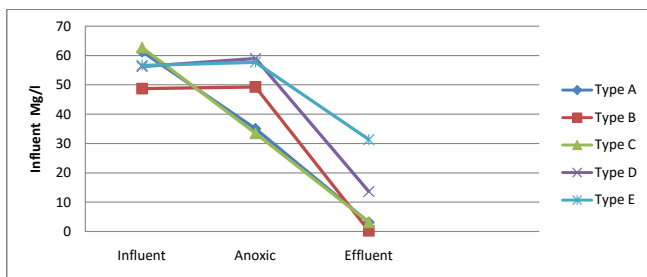


Fig 5. Ammonia removal rate results

Analyzed with Nessler - spectrophotometer:721 Vis

Reflux water played a major impact on the removal of ammonia, This can be seen in fig 5. the positioning of the reflux water in the aerobic column showed no significant difference from when positioned in the anaerobic column. This is because the presence of reflux in the aerobic and anaerobic column both support ammonia removal effect on an A/O BAF system.

Dissolved Oxygen

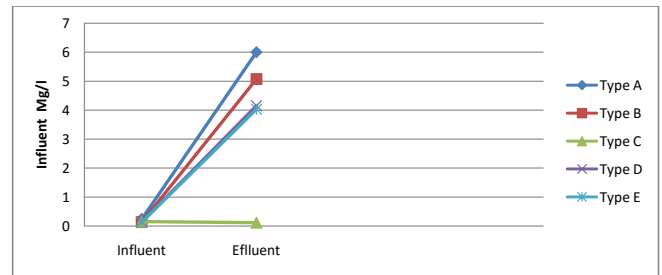


Fig 6. dissolved oxygen results

Analyzed by Direct Reading Instruments: HQ -10 LDO dissolved oxygen analyzer

The dissolved oxygen in all conditions had different effects on the microorganism, the appearance of the filter column, and subsequently the removal efficiency of the nutrients from the wastewater. The presence of fungi mould were observed in the anaerobic column were there was absences of reflux water. All the experimental Types except C shows the removal of dissolved oxygen in the effluent of the system. Type C however, shows little or no significant difference in the dissolved oxygen between the influent and effluent , This is as a result of the action of the sponge iron and manganese sand, which helps reduce the dissolved oxygen coming from the aerobic column. This is further illustrated in Fig.6.

MEASUREMENT OF NITRIFYING BACTERIA

Table 2 and 3 shows the results of nitrite and nitro bacteria culture conducted from the 5th to 26th June 2015.

Table 2. Nitrite Bacteria measurement data table

Test-tube Number	1	2	3	4	5
Concentration gradient					
10 ⁻³	-	+	+	+	+
10 ⁻⁴	+	+	+	+	+
10 ⁻⁵	+	+	+	+	+
10 ⁻⁶	+	+	+	+	+
10 ⁻⁷	+	+	+	+	+

Nitrification bacteria measured by the number of indicators are: 455

MPN tables cannot be detected by checking the nitrification bacteria in the number of indicators measured, therefore it cannot be counted.

Table 3. Nitro bacteria measurement data table

Test-tube Number	1	2	3	4	5
Concentration gradient					
10 ⁻³	+	+	+	+	+
10 ⁻⁴	+	+	+	+	+
10 ⁻⁵	+	+	+	+	+
10 ⁻⁶	+	+	+	+	+
10 ⁻⁷	+	+	+	+	+

Nitrobacteria measured by the number of indicators are: 555
By search drawn MPN table Nitrification bacteria approximation is: 180.0

According to the formula: the number of samples per milliliter of bacteria = bacteria approximation \times number of indicators of the first digit of the dilution factor.

Results per ml mixture of nitrifying bacteria of Number of bacteria: $180.0 \times 10^4 = 1.8 \times 10^6$ therefore: the amount of nitrifying bacteria is consistent to the good removal of ammonia.

CONCLUSION

In this study, reflux presence in an A/O BAF system have proven to be effective in increasing the removal rate of the nutrients when compared to without reflux. it was shown that reflux presence contributed to the removal rate increase in ammonia and nitrogen. It should be noted, that reflux rate affected the removal of nitrogen and ammonia more than any other pollutants observed.

As regards to phosphorus removal efficiency, sponge iron and manganese sand when mixed together increase the removal rate of total phosphorus when compared to without it, In this case, there was a percentage increase in the removal efficiency of phosphorus with the presences of sponge iron and manganese sand.

The nitrifying bacteria count in table 2 and 3 above supports good removal rate observed in ammonia

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