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Ammonia Removal from Aquaculture Waste Water using Ccoconut Coir Media in Lab-Scale Batch Reactors

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Abstract—*The advent of aquaculture as an industry worldwide, and especially in India, is responsible for the negative impact on the environment. The huge volume of wastewater generated from the aquaculture farms has remained a cause of concern for the natural water bodies. The biological treatment is one of the most economical processes for nitrogen removal. Coconut coir is one of the readily available materials, which can be used for bioremediation due to its large surface area and pore spaces. So, in the present study, series of laboratory experiments were carried out using waste water with ammonia concentrations of 10, 20, 30, 40 and 50 mg/L (designated as reactors R_1, R_2, R_3, R_4 and R_5, respectively) for two set of treatment conditions at 20 and 30cm depth of coconut coir attachment media (designated as Treatment A and Treatment B, respectively). From the study, it was observed that the rate of ammonia removal increases with the increase in the initial concentration of ammonia. The removal rate increases from 0.083 mg/L/hr in case of R_1 to 0.67 mg/L/hr in case of R_5 for the treatment A. Similarly for Treatment B, the removal rate increases from 0.27 mg/L/hr in case of R1 to 0.70 mg/L/hr in case of R_5. It was also observed that at the same concentration, the removal rate and removal efficiency in treatment B is better than treatment A because of higher depth of attachment media results in higher surface area for biofilm growth. Thus, this study suggested that the coconut coir depth of 30 cm with 50 mg/L concentration could be used as an attachment media in the biological nitrogen removal processes from aquaculture waste water.*

1. INTRODUCTION

Nutrients are substances that are required for the growth of living plants and animals. In any aquatic body the major nutrients are nitrogen and phosphorous. Both are found in wastewater in various forms. Nitrogen is typically present in the effluent discharges in the form of ammonia (NH_3), nitrite (NO_2) and nitrate (NO_3) and organically bound nitrogen. When large amounts of nutrient rich water are allowed to enter the rivers and lakes, they can cause problem by increasing the growth of autotrophs, such as algae. If improperly managed, aquaculture operations can have severe impacts on aquatic ecosystems as nutrient wastes are discharged directly into the surrounding waters. For every ton of fish, aquaculture operations produce between 42 and 66 kilograms of nitrogen waste [1].

The main source of ammonia in aquaculture water is fish excretion and uneaten fish feed. The rate at which fish excrete ammonia is directly related to the feeding rate and the protein level in feed. Ammonia is the major end product of protein catabolism, which remains in the form of unionized ammonia (NH_3^-) and ionized ammonia (NH_4^+).Unionized ammonia is a critical water quality parameter and toxic to aquatic life, but the ammonium ion is harmless except in extremely high concentrations.

If the ammonia concentration gets high enough, the fish will become lethargic and eventually fall into a coma and die. Therefore, the reduction of the impact of total ammonia and nitrite on the receiving environment may be essentially obtained upstream by optimizing shrimp/fish farming management practices regarding feeding and water quality [3].

Biological treatment is the use of bacteria to convert dissolved wastes to cell mass and other stable end products. Biofilm treatment is one of the most important biological treatment processes used in water and wastewater treatment. In aquaculture wastewater treatment, it is used to purify the water for potable use whereas in aquaculture wastewater treatment, the main purpose of treatment is to produce that it can be reused for various purposes. Although it is necessary for water treatment systems to be engineered due to the amount of pollution contaminating wastewater, natural ways of cleaning wastewater through the use of microorganisms can also be incorporated into the process. For example, biofilm treatment systems employ the use of bacteria, fungi, algae, and protozoa to remove organic and inorganic materials from the surrounding liquid.

There has been extensive research on the structure of microbial biofilms, which are used in aquatic biosystems for water treatment [1]. The oxidation of organic matter by heterotrophic bacteria and oxidation of ammonia by nitrifying bacteria occur simultaneously in microbial biofilms. This may lead to competition for oxygen among these bacterial groups. Biofilms, which oxidize simultaneously organic matter and ammonia, consist of a microbial colony embedded in slime attached to a carrier surface [2]. So, in the present study was carried out to evaluate the performance of coconut coir as an attachment media for ammonia removal from the treatment of aquaculture waste water.

2. MATERIALS AND METHODS

2.1 Bioremediation experimental setup

The experimental was carried out in the laboratory of Department of Agriculture Engineering, Assam University, Silchar. The experiment set-up consists of a submerged biological reactor tanks (SBRT), attachment media, synthetic aquaculture waste water, biofilm and data sonde. In this study, five number of lab scale variety of submerged biofilm reactor tank were fabricated to investigate the removal of ammonia from the synthetic formulated aquaculture wastewaters. Effect of temperature, nitrate and values of pH from the SBRT were also monitored.

The SBRT fabricated was a submerged fixed film reactor biofilm based technology that uses aquaculture treatment for the ammonia removal through biofilm. Each reactor contains natural media to support the growth of biofilm. The reactors which are cylindrical in shape and fabricated for static submerged mode for batch operation process, were filled with different depths of coconut fibre to act as an attachment media for biofilm.

In the present study, five tanks were maintained as reactors and labelled serially from R_1 to R_5, Which consist of coconut coir as attachment media for ammonia bioremediation. The experiment was carried out by taking 20 cm and 30 cm height of the coir from the bottom of the tank to study the bioremediation in different ammonia concentration. The five numbers of controls in addition to 5 numbers of reactors were also maintained as control and labelled serially from C1 to C5. In these control reactors no coconut coir was added as attachment media. However, waste water is added with ammonia concentration in values of 10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L and 50 mg/L respectively in each of the control tanks. The mixtures of different dilutions of ammonia concentration of the aquaculture waste water were then prepared by filling the reactor tanks with ammonium chloride ($NH_4^+Cl^-$) and sulphuric acid ($H_2SO_4^-$) (Table 1).

Table 1: Standard solution for ammonia concentration in tanks of 50 L.

Concentration (mg/L)	Weight of $NH_4^+Cl^-$ (g)	Volume of conc. $H_2SO_4^-$ (ml)	Volume of water to be mixed in salt (L)
10	1.910	0.5	1
20	3.819	1.0	1
30	5.729	1.5	1
40	7.638	2.0	1
50	9.548	2.5	1

Coconut fibre is a good attachment media for biofilm development in wastewater treatment [4] studied and found that coconut husk fibre could be applied as an alternative medium to gravel bed for packed bed filters for the treatment of domestic wastewater since areca fibre filter could achieve highly stable BOD_5, COD and NH_3-N removal. Naturally available coconut media coir was used as the biofilm support structure. The developed biofilm in the natural condition of coconut coir where density of coconut coir was 0.900 kg/m^3 were then introduced in the SBRT.

2.2. Performance evaluation of attachment media

In order to evaluate the performance of coconut coir as an attachment media for ammonia removal, experiments were carried out by studying the ammonia removal efficiency at different concentrations of ammonia in the wastewater. The different concentrations of ammonia at the start of the experiment were 10, 20, 30, 40 and 50 mg/L and they were designated as Reactor 1 (R_1), Reactor 2 (R_2), Reactor 3 (R_3), Reactor 4 (R_4) and Reactor 5 (R_5), respectively. The media was kept submerged in the said water and the decrease in ammonia concentration was monitored at an interval of 4 hrs. For each of the reactor, a control (C) without any media was maintained where the same water quality parameters were monitored simultaneously. The ammonium concentration test was performed and monitored on daily basis for a week four times on the reactor tanks. These tests gave a sense of the rate and efficiency at which the biofilms converted ammonium to nitrites and nitrates. The experiment was continued for a total period of 156 hrs with two depths of 20 cm and 30 cm coconut coir media designated as Treatment A and Treatment B, respectively.

The water quality parameters were monitored using a water quality meter sonde of Hatch industries. With the use of this instrument 15 different types of water monitoring parameters can be measured. Different parameters of data were monitored as ammonia, nitrate, temperature, dissolved oxygen and pH. The temporal variations and efficiency of ammonia removal are presented in the results and discussion sections.

3. RESULTS AND DISCUSSION

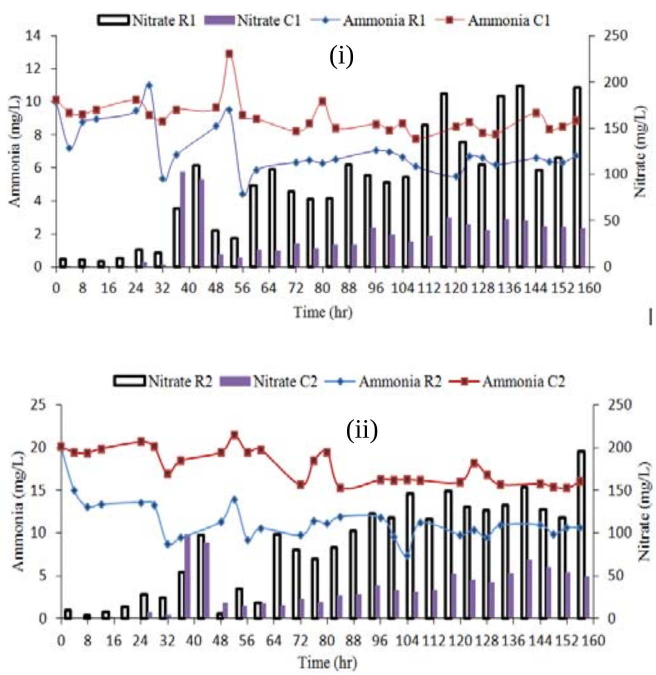
3.1. Trends of ammonia removal for treatment A

The temporal variation of nitrate and ammonia removal in each reactors (R_1 to R_5) and corresponding controls (C_1 to C_5) under the treatment for 20 cm depth of coconut coir attachment media are presented in Figure 1(i to v).

It was observed from the Figure 1 (i) to (v) that there is no appreciable variation of ammonia or nitrate in controls (C_1 to C_5) with different concentrations (10, 20, 30, 40 and 50 mg/L). In different controls, the ammonia attained a maximum value of 12.89 mg/L at 52 hr, 21.45 mg/L at 52 hr, 32.68 mg/L at 56 hr, 40.16 mg/L at 124 hr and 50.95 mg/L at 124 hr, respectively after the start of the experiment. However, the minimum value was reached at 108 hr with a value of 7.75 mg/L, 152 hr with a value of 15.25 mg/L, 156 hr with a value of 24.1 mg/L, 72 hr with a value of 31 mg/L, 144 hr with a value of 41.76 mg/L, respectively.

For reactors R_1, R_2, R_3, R_4, and R_5 the highest value of ammonia was observed as 11.01 mg/L at 28 hrs, 14.94 mg/L 4 hrs, 30.07 mg/L 84 hrs, 40.16 mg/L 76 hrs and 46.54 mg/L 4 hr after the start of the experiment, respectively. However, the minimum value was observed at 56 hr with a value of 4.44 mg/L, 104 hr with a value of 7.32 mg/L, at 72 hr with a value of 21.78 mg/L, 128 hr with a value of 32.5 mg/L and128 hr with a value of 31.37 mg/L, respectively.

In case of nitrate the maximum value was observed in the controls were 49.54 mg/L at 144 hr, 68.23 mg/L at 144 hr, 70.65 mg/L at 144 hr, 78.45 mg/L at 144 hr and 81.45 mg/L at 144 hr, respectively.



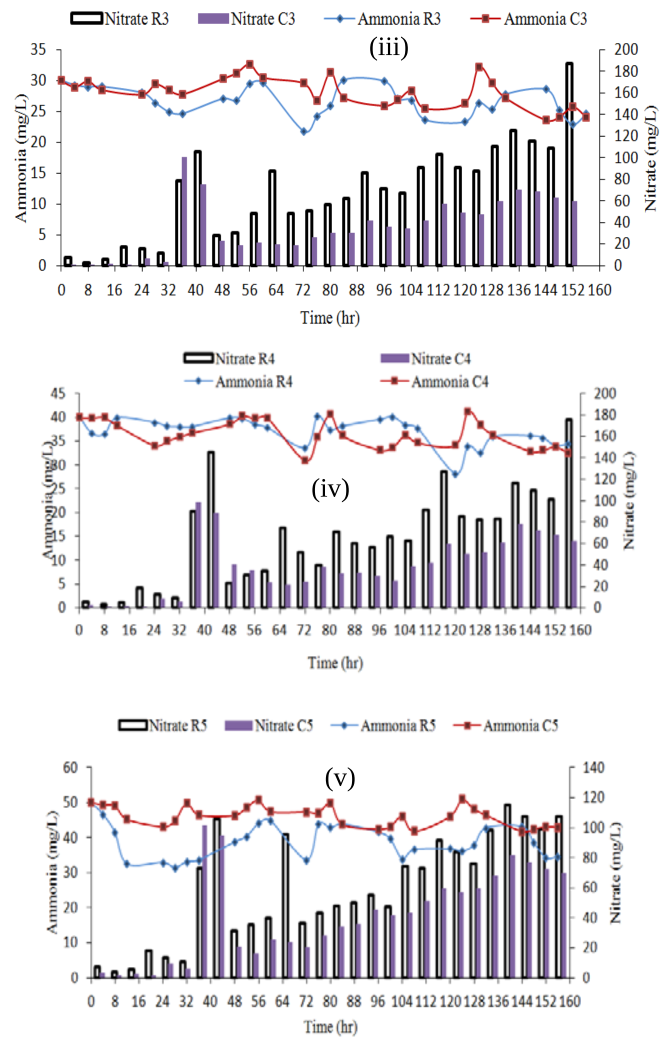


Fig. 1: Variation of ammonia removal with time in different reactors and controls for the treatment A

However, the minimum was observed at 4 hr with a value of 0.32 mg/L, 4 hr with a value of 0.41 mg/L, at 4 hr with a value of 0.86 mg/L, 4 hr with a value of 1.33 mg/L, 4 hr with a value of 1.81 mg/L, respectively.

The variation in nitrate in case of reactors was more pronounced than that of control. Hence, from the figure it can be inferred that the drop in the value of the harmful ammonia, is attributed to the increase in the value of the less harmful nitrate in the system.

3.2. Trends of ammonia removal for treatment B

Similarly, the temporal variation of ammonia removal in each reactors and corresponding controls under the treatment for 20 cm depth of coconut coir attachment media are presented in Figure 2. The Figure 2 (i to v) represents the temporal variation of nitrate, ammonia in the reactors R_1 to R_5 and controls C_1 to C_5 with the 30 cm depth of coconut coir attachment media. It can be observed from the figures that with time there is an appreciable decrease in both the ammonia and nitrate concentrations in all the five initial concentrations.

For reactors R_1, R_2, R_3, R_4, and R_5 for the B treatment, the highest value of ammonia was observed as 6.73 mg/L 36 hrs, 12.64 mg/L 12 hrs, 24.34 mg/L 4 hrs, 37.03 mg/L 104 hrs and 46.9 mg/L 96 hrs after the start of the experiment, respectively. However, the minimum value was observed at at 132 hr with a value of 3.32 mg/L, 96 hr with a value of 7.03 mg/L, at 80 hr with a value of 13.38 mg/L, at 148 hr with a value of 24.36 mg/L 24 hr with a value of 33.12 mg/L, respectively.

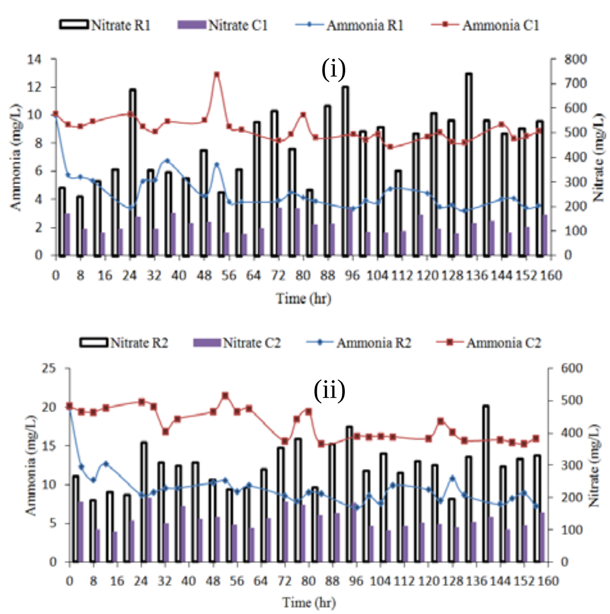
In case of nitrate the maximum value was observed in the controls were 739.75 mg/L at 132 hr, 380.07 mg/L at 76 hr, 322.98 mg/L at 0 hr, 243.75 mg/L at 24 hr and 285.37 mg/L at 24 hr, respectively.

However, the minimum was observed at 238.81 mg/L at 4 hr, 194.59 mg/L at 128 hr, 107.81 mg/L at 128 hr, 133.21 mg/L at 100 hr, 155.62 mg/L at 128 hr, respectively.

The variation in nitrate in case of reactors was more pronounced than that of control. Hence, from the figure it can be inferred that the drop in the value of the harmful ammonia, is attributed to the increase in the value of the less harmful nitrate in the system.

3.2. Performance evaluation of attachment media

The comparative evaluations of the performance of ammonia removal for the two treatments are shown in Figure 3 and also in Table 2 and 3 for ammonia removal with attachment media depth of 20 cm (Table 2), it can be observed that the rate of removal increases with the



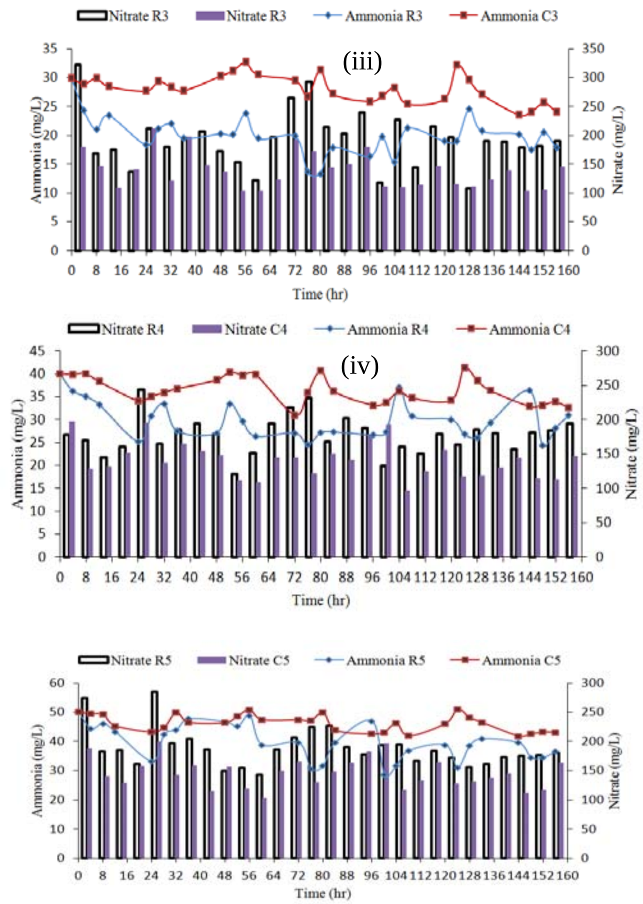


Fig. 2: Variation of ammonia removal with time in different reactors and controls for the treatment B.

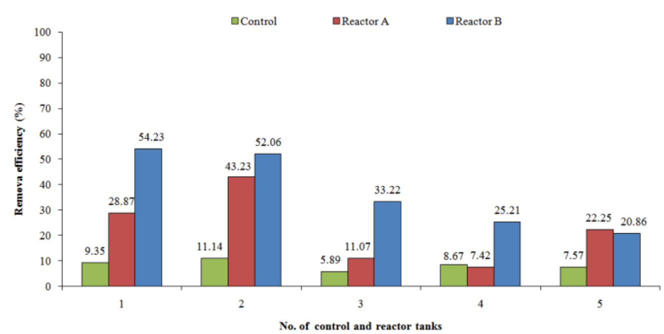


Fig. 3: Ammonia removal efficiency of attachment media.

Table 2: Performance evaluation of ammonia removal with different concentrations of initial ammonia concentration for treatment A.

Reactor	Ammonia Concentration (mg/L)	Time (hr)	Removal Rate (mg/L/hr)	Removal (%)
R1	5.36	56	0.083	46.4
R2	8.68	32	0.35	56.6
R3	21.78	72	0.11	27.4
R4	36.45	8	0.44	8.87
R5	31.37	28	0.67	37.26

Table 3: Performance evaluation of ammonia removal with different concentrations of initial ammonia concentration for treatment B.

Reactor	Ammonia Concentration (mg/L)	Time (hr)	Removal Rate (mg/L/hr)	Removal (%)
R1	3.42	24	0.27	65.8
R2	8.69	24	0.47	56.55
R3	18.4	24	0.48	38.67
R4	25.23	24	0.66	36.93
R5	33.12	24	0.70	33.76

increase in the initial concentration of ammonia. The removal rate increases from 0.083 mg/L/hr in case of R_1 to 0.67 mg/L/hr in case of R_5. It may be due to the fact that at higher concentration of ammonia the concentration gradient is higher which results in higher removal rate. However, the percentage removal of ammonia decreases with increase in ammonia concentration.

Similarly for attachment media depth of 30 cm (Table 3), it can be observed that the rate of removal increases with the increase in the initial concentration of ammonia. The removal rate increases from 0.27 mg/L/hr in case of R_1 to 0.70 mg/L/hr in case of R_5. However, as like treatment A, the percentage removal of ammonia in treatment B decreases with increase in ammonia concentration.

The increase in removal rate with the increase in concentration in both the treatments may be due to the fact that at higher concentration of ammonia the concentration gradient is higher which results in higher removal rate. It can also be observed from table 4 and table 5 that at the same concentration, the removal rate and percentage removal in treatment B is better than treatment A. It may be due to the fact higher depth of attachment media results in higher surface area for biofilm growth resulting in higher removal efficiency and removal rate. Since ammonium is a main component of wastewater, an upward trend can be noticed in the blue bars showing the efficiency of ammonia removal in 20 cm depth of attachment media in different reactor tanks and the other blue bar is showing the ammonia removal efficiency of the 30cm depth of attachment media of the five different ammonia concentration tanks.

The reactor tanks with 10mg/L, 20 mg/L, 30 mg/L, 40 mg/L and 50 mg/L ammonia concentration, the ammonia removal efficiency of attachment media depth 30cm was 46.4%, 56.6%, 27.4%, 8.87% and 37.26%. And attachment media depth 20cm for ammonia removal was found 65.8%, 56.55%, 38.67%, 36.93% and 33.76%, respectively.

Average ammonia removal rate (mg/L/hr) for attachment media of 30cm depth with 10mg/L, 20 mg/L, 30 mg/L, 40 mg/L and 50 mg/L ammonia concentration was found 0.083, 0.35, 0.11, 0.44 and 0.67, respectively. And the corresponding average ammonia removal rate (mg/L/hr) for attachment media depth 20cm was found 0.27, 0.47, 0.48, 0.66 and 0.70, respectively. This led to improved conditions for ammonia oxidation during in depth 20 cm.

4. CONCLUSIONS

In the present study, the performance of the 20 cm and 30 cm depths coconut coir attachment media was used for removal of ammonia from aquaculture wastewater with different concentration levels. Among the coconut coir media, depths 30 cm reactor having lower concentration (R_1 and R_2) performed best in the ammonia removal process. Since, ammonia removal efficiency increases with the depth of attachment media at lower concentration because of higher surface area for biofilm growth, so, the more depth of coconut coir attachment media could be used in the bioremediation process with the aeration system for the aquaculture waste water treatment.

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