TUTA/IOE/PCU

Journal of the Institute of Engineering, Vol. 8, No. 1, pp. 119–125

Fax: 977-1-5525830

Role of pH on biological Nitrification Process

Iswar Man Amatya[1], Bhagwan Ratna Kansakar[2], Vinod Tare[3], Liv Fiksdal[4]

[1]Pulchowk Campus, Institrute of Engineering, Tribhuvan University, Nepal
[2]Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal
[3]Indian Institute of Technology, Kanpur, India
[4]Norwegian University of Science and Technology, Trondheim, Norway

Abstract: It is important to determine the effect of changing environmental conditions on the microbial kinetics for design and modeling of biological treatment processes. In this research, the kinetics of ammonia oxidation by nitrifying process bacteria under varying pH and temperature conditions are studied.

Ammonia oxidation in groundwater was carried out by biological method of nitrification process. The nitrification was performed in one set of reactors. The reactor consists of two columns connected in series packed with over burnt bricks as media. The filtration rate varied from 10.5 to 210.4 m/day for nitrification process respectively. The ammonia, nitrate and nitrite nitrogen concentrations were measured at inlet, intermediate ports and outlet. The temperature varied from 10 to 30°C at 2°C intervals.

The results demonstrated that high amounts of ammonia nitrogen nitrified in groundwater at nitrification process. The average ammonia nitrogen oxidation efficiency of 77.27% was achieved from pH 7.3 to 8.0 in the reactor packed with OBB media at 20°C, for the flow rate 500ml/min due to biological nitrification. The total amount of ammonia nitrogen removed by nitrification varied from 0.76 to 17.80 gm/m^3/h at influent concentration from 2.84 to 149.28 gm/m^3/h.

Key words: Over burnt brick, Filtration rate, Temperature, Nitrification and Nitrifying bacteria

1. Introduction

One of the major factors affecting nitrification in treatment is pH. Nitrification systems are sensitive to pH variation. Optimum pH has been found to be approximately 7.8 to 9.0. Reductions in nitrification have been found outside this range. [1] Alkalinity is also destroyed during nitrification. However, this is especially important when nitrification processes [2] are of concern. Nitrification is considered to be a surface-based process in water and wastewater systems [3], [4]. It has been widely used for nitrifying ammonia to nitrate and nitrite. The previous studies indicated that nitrifying bacteria tended to grow by attaching on the surface of sediment solids; consequently, effect of sediment on the nitrification process is significant [5], [6].

The major concern affecting human health pertains to infants less than six months of age. In sufficient quantities, at ammonia concentrations exceeding 1.5 mg/l., the possibility of health hazard is significant towards infants. [7] The primary health hazard from drinking water with nitrate-N occurs when nitrate is transformed to nitrite in the digestive system due to ammonia present in source water. The nitrite oxidizes iron in the hemoglobin of the red blood cells to form methemoglobin, which lacks the oxygen carrying ability of hemoglobin. This creates the condition known as methemoglobinemia. This is also known as blue baby syndrome causing the veins and skins to appear blue.

2. Theoretical Consideration

Nitrification: the process by which nitrogen in ammonia and organic compounds is oxidized to nitrites and nitrates by soil bacteria of the family *Nitrobacteraceae*. Biological nitrification may be used to prevent oxygen depletion from nitrogenous oxygen demand (NOD) in the receiving waters. Much of the nitrogen is found in the form of ammonia. When secondary treatment is used, a great deal of this ammonia is discharged in the effluent. Bacteria can utilize this ammonia as an energy source and convert ammonia to nitrite and nitrate as shown in Eq. (1) [8].

$$NH_3 + O_2 + Bacteria \rightarrow NO_2^- + O_2 + Bacteria \rightarrow NO_3^- \quad ..Eq.(1)$$

Bacterial nitrification is a biological process which can be applied to recirculation systems in order to control ammonium level. Two groups of beneficial bacteria are involved, *Nitrosomonas* and *Nitrobacter* species. The process is efficient and reliable when water temperatures are above 10˚C. This seemingly simple process involves a complex series of reactions that can be summarized as in Eqs. (2), (3), (4) and (5) [1].

For Nitrosomonas:

$$55\ NH_4^+ + 76\ O_2 + 109\ HCO_3^- \rightarrow C_5H_7O_2N + 54\ NO_2^- + 57\ H_2O + 104\ H_2CO_3 \quad ...\ Eq.\ (2)$$

For Nitrobacter:

$$400NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3^- + 195\ O_2 \rightarrow C_5H_7O_2N + 3H_2O + 400\ NO_3^- \quad ...\ Eq.\ (3)$$

The stoichiometric equations for nitrification are

$$NH_4^+ + 1.5O_2 \rightarrow 2H^+ + H_2O + NO_2^- \quad \cdots\ Eq.\ (4)$$

$$NO_2^- + 0.5O_2 \rightarrow NO_3 \quad \ldots Eq.\ (5)$$

Theoretically, 7.2 pounds of alkalinity are destroyed in converting 1 pound of ammonia to nitrate. In low alkalinity wastewater, Quick lime (CaO) or Ca $(OH)_2$ is often used to provide alkalinity and pH control. [1] Below a pH of 8.5, almost all of the ammonia in solution will exist as the ammonium ion. The conversion of ammonium to nitrite results in the formation of hydrogen ions (Eq. 6). If the pH of the water is less than 8.3, the hydrogen ions produced are neutralized by bicarbonate ions in the water.

$$H^- + HCO_3^- \rightarrow CO_2 + H_2O \quad \ldots Eq.\ (6)$$

Approximately 4.3 mg O_2 are consumed for every mg of ammonia-nitrogen oxidized to nitrate-nitrogen. About 8.64 mg of alkalinity in the form of HCO_3^- are consumed per mg of ammonia-nitrogen oxidized. This is quite a substantial amount of alkalinity and will over a period of time dramatically change the character of the water, affecting both hardness and pH stability. It is also an acidifying process, producing a gradual build up of nitric acid. It should also be noted that the process does not remove any nitrogen from the system; merely changing it from one form to another. [1].

3. Materials and Methods

A. Experimental setup

The reactors were constructed by using two high-density polythene (HDPE) pipe columns in series (132 mm internal diameter and 3m height) for both nitrification reactors. Two meters of filter media was used in each column with a total depth of four meters. The oxygen was provided by injecting compressed air into the reactors from the bottom of the nitrification unit. The six numbered sampling ports were provided at 1 m intervals in each set of reactors. The schematic flow diagram of experimental setup is presented in Figure 1.

B. Biofilter media and column packing

The media was selected by considering the physical, chemical and biological parameters of the raw water. The media sizes of 10 to 15mm were packed in the columns. A perforated HDPE sheet was used for supporting media in each column. The over burnt bricks (OBBs) were chosen as the media since they have shown significant nitrification in the preliminary test. The media OBBs were first moistened and gently placed into each column from top. The columns were slightly agitated to achieve a stable pack and eliminate unwanted voids. The characteristics of OBBs which were used as filter media are presented in Table 1.

C. Reactor startup and operation

The media OBBs were fully exhausted first with ammonia water in reactors so as not to take intrusion by adsorption phenomena in the nitrification columns. The seed nitrifying culture was originally obtained from the experimental scale activated sludge plant that has been successfully performing nitrification. The one liter of nitrifying seed culture obtained was mixed with four liters of ammonia water in nitrification reactors. The inoculants thus prepared was poured into the submerged filters, retained and aerated for 1 week in nitrifying column maintaining pH 7.5 using sodium hydro-oxide. After this, the start-up time was considered complete and the experiment was started.

The nitrification has been carried out in down flow submerged granular OBBs media. For nitrification, the filtration rate varied from 10.5 m/day to 210 m/day. The influent ammonia nitrogen concentration varies from 26 to 100 mg/l. Compressed air was used as an oxygen source for nitrification. The air was injected into the submerged filters at the bottom of the filter media with a tube having many small nozzles of 1 mm diameter in order to have uniform distribution of air in the filter and prevent short-circuiting of air. The air was supplied from the compressor at a constant rate so as to maintain dissolved oxygen more than 4 mg/l at all times. Then influent water was varied in pH from 7.1 to 9.1 at an interval of 0.1

4. Result and Discussion

D. Characteristics of groundwater and flow rate

A set of nitrification reactor with the OBBs as the media was used for the study. The natural groundwater with the characteristics as shown in Table 2 was used. Concentration of ammonia-N in groundwater varied from 23 to 123mg/l. The water flowed in plug flow characteristics in the reactors. The study was made at pH which varied from 7.1 to 9.1 in 0.1 intervals at 20°C and was operated at flow rates of 10.5, 26.3, 52.6, 105.2, 157.8 and 210.4 m/day (100, 250, 500, 1000, 1500 and 2000ml/min) respectively.

The total ammonia removal by nitrification in the reactor was observed 5 mg/l at 10˚C and 79.1 mg/l at 30˚C at the filtration rate of 500ml/min for the influent ammonia –N concentrations of 26 and 100 mg/l respectively. As evident from Figure 2, the ammonia-N reductions at low temperatures were considerably lower in comparison to reductions at higher temperatures.

When the temperature varied 10˚C to 30˚C, the ammonia removal efficiency of 26.9 to 89.9 %, 23.0 to 84.6 %, 19.2 to 79.5%, 15.3 to 42.1%, 11.54 to 27.64% and 8.1 to 10.3% were observed in nitrification reactor at the filtration rates of 100, 250, 250, 1000, 1500 and 2000 ml/min respectively. In general, the ammonia removal increased as the temperature increased in the reactor.

At 10˚C, the ammonia-N removal was observed as 0.76, 1.64, 2.73, 4.38, 4.93 and 4.65 gm/m^{3}h in the reactor at the filtration rates of 100, 250, 250, 1000, 1500 and 2000ml/min respectively. The ammonia removals in the reactor are significantly higher at 30˚C in comparison to the removal rate at 10˚C is presented in Figure 3. Similarly, total ammonia-N reduction due to nitrification was observed as 9.80, 23.07, 43.34, 46.56, 45.19 and 22.46 gm/m^{3}h for the same flow rates at 30˚C. The ammonia removals by the nitrification process were observed insignificant at a flow rate above 1500 ml/min and less significant above 24˚C.

E. Effect of pH in nitrification

Nitrification was observed at different pH values ranging from 7.1 to 9.0 at temperatures ranging from 10~30°C at 2˚C intervals for the flow rates 100ml/min and 2000 ml/min respectively. A typical pH effect in nitrification at 20°C for the flow rate 500ml/min in presented in Figure 4. Nitrification process was found more efficient above 7.3 to 8.0 pH at 20°C for the flow rate 500ml/min. Stable nitrification process was found within that range.

Conclusion

It can be deduced from the study that pH has a strong direct impact on the nitrification process. The average ammonia nitrogen oxidation efficiency of 77.27 % was achieved in the reactor packed with OBBs media at 20˚C due to biological nitrification. As the pH increased, nitrate nitrogen removal was found higher in biological nitrification process with less significant.

Acknowledgement

The authors are grateful to the Centre for Research and Development (CARD), IOE, TU, Nepal and the Norwegian University of Science and Technology (NTNU), Norway for providing the part of financial support necessary for this study.

REFERENCES

[1] Koi (2001) report on "Koi Nitrification, http://www.coloradokoi.com/filtrati.htm", Dec

[2] Focht D.D. and Verstraete W. (1977), Biochemical ecology of nitrification and denitrification. Adv. Microbial. Ecol., 135–214

[3] Rittmann, B.E., McCarty, P.L., (1981), Substrate flux into biofilm of any thickness. J. Environ. Eng. 107, 889–897

[4] Garland, J.H.N., (1978), Nitrification in the River Trent. In: James, A. (Ed.), Mathematical Models in Water Pollution Control. Wiley, Chichester

[5] Belser, L.W., (1979), Population ecology of nitrifying bacteria. Ann. Rev. Microbial., 33, 309–333

[6] Hall, G.H., (1986), Nitrification. In: Prosser, J.I. (Ed.), Special Publication in the Society for General Microbiology, vol. 20. IRL Press, Oxford, pp. 127–156

[7] WHO, (2004), "Guidelines for drinking-water quality", third edition, pp 191,213 304

[8] ENV149, (2003), A publication by ietech: distance learning courses on water and wastewater in "Advance Wastewater Treatment". http://www.vccs.edu/dept/ietech /distance learning/cources/ENV149 /sampling.htm

Table 2: Influent groundwater characteristics

S.N.	Parameters	Unit	Observed Value
1	Appearance	-	Hazy
2	Turbidity	NTU	25-87
3	Color	ºH	27-94
4	Temperature	ºC	7-28
5	pH	-	7.1-9.3
6	Electrical conductivity	µS/mS/cm	135-981
7	Total alkalinity as $CaCO_3$	mg/l	312-524
8	Total hardness as $CaCO_3$	mg/l	164-208
9	Total ammonia-N	mg/l	23-123
10	Nitrate-N	mg/l	0.1-3
11	Nitrite-N	mg/l	ND
12	Magnesium	mg/l	ND
13	Total Iron	mg/l	1.17- 4.07
14	Manganese	mg/l	0.1-0.17
15	Silica	mg/l	21- 48.54
16	Sulphate	mg/l	1.7-3.5
17	Orthophosphate	mg/l	0.1-0.5
18	Chloride	mg/l	3.1- 4.7
19	Cadmium	mg/l	ND
20	Total Coliform	CFU/100ml	1
21	E. coli	CFU/100ml	ND

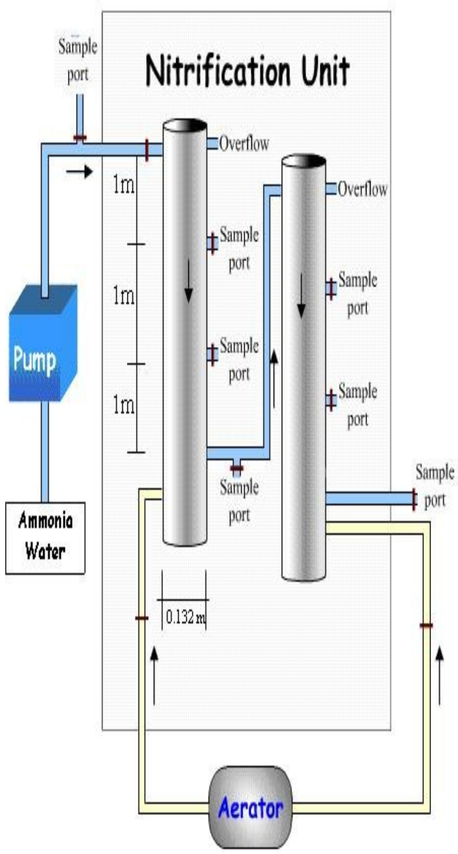

Figure 1. Schematic flow diagram of experimental setup

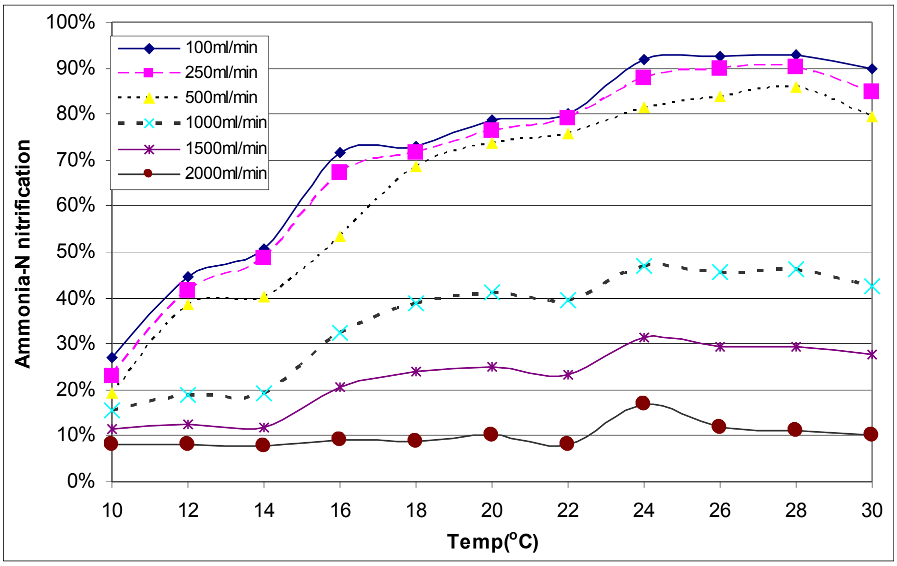

Figure 2. Ammonia-N nitrification efficiency at various flows

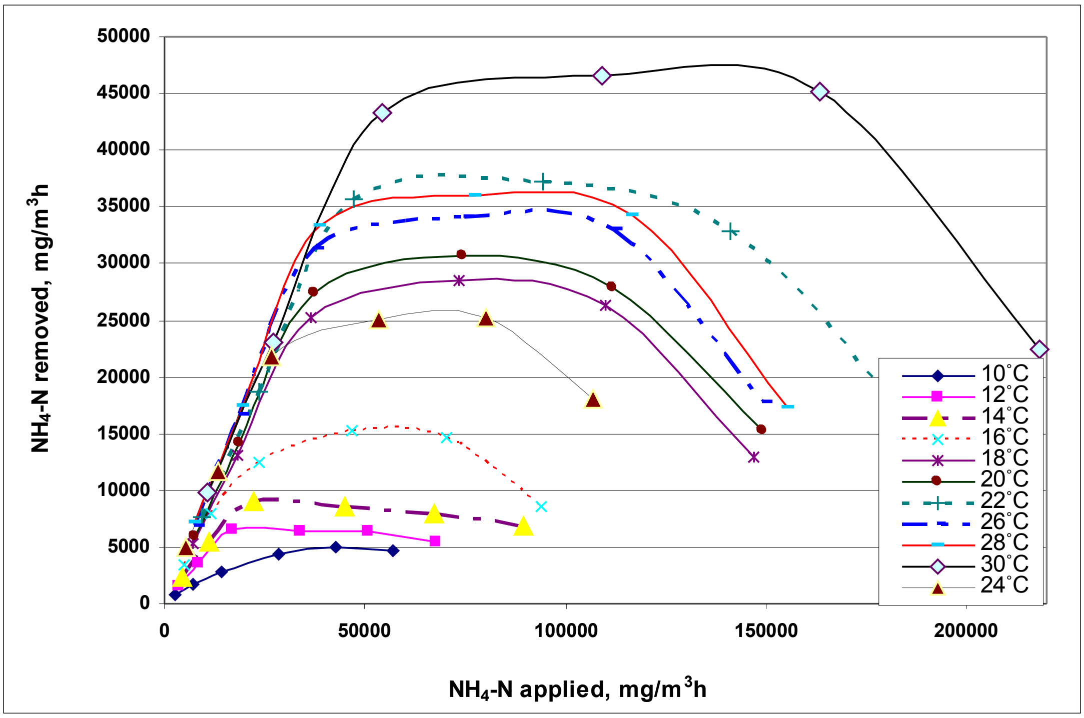

Figure 3. Nitrification rate Vs NH4-N loading at various temperatures

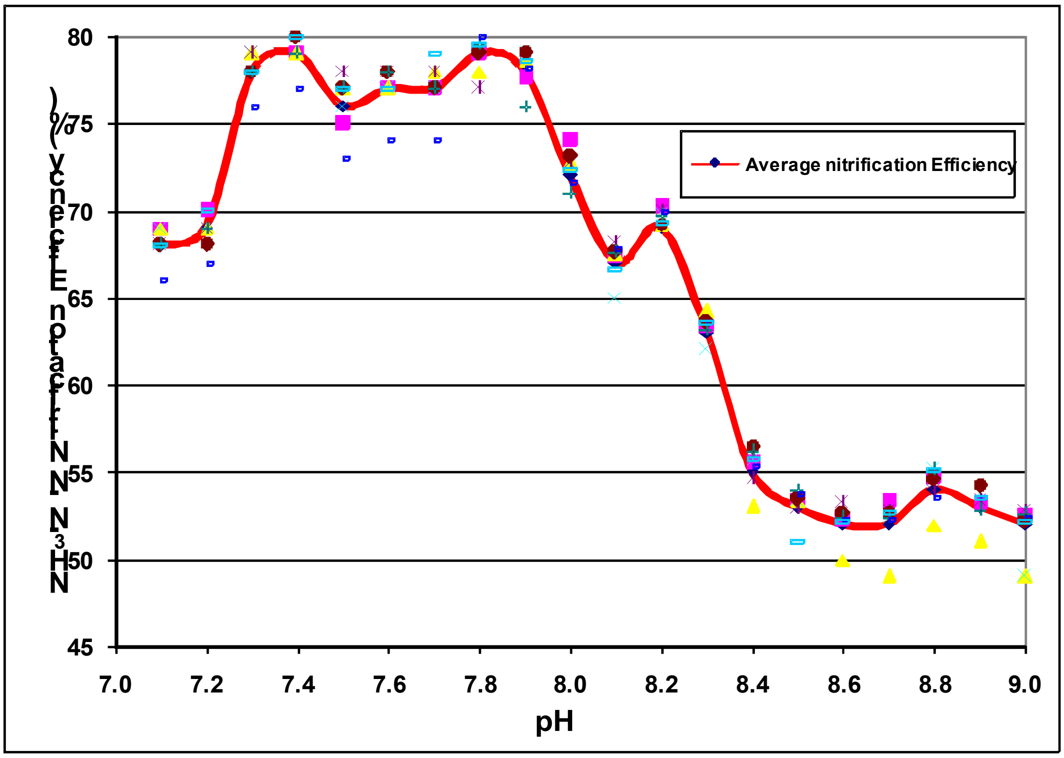

Figure 4. Nitrification at various pH