International Journal of Water Resources Engineering
Vol. 1: Issue 1
www.journalspub.com

Removal of Nitrogenous Compounds Using Trickling Filter with Hexagonal Close Packed Media

Joan Dolly Chung Zie Wei, Ir. Law Puong Ling, Ir. Frederik Josep Putuhena*
Department of Civil Engineering, University Malaysia Sarawak, Malaysia

Abstract

Nitrogenous compound in the domestic wastewater has the capability of impounding adverse effects on the surface water and for the purpose of this study trickling filter (TF) is utilized for the removal of pollutants, inclusive of ammonia contained in domestic wastewater. This system, which is an attached growth process, adopts the usage of media in the form of hexagonal close-packed (HCP) as a platform for the growth of biofilm with the aid of microorganisms which in turn removes the pollutants when in contact with the feed. The HCP is reported to have a surface area of 130 m^2 which exceeds the value of a conventional media. Prior to experimental run, the system underwent start-up process, of which a concoction of wastewater, sludge and inoculated yeast agar was fed to the TF system in order to stimulate biofilm growth. Post experimental start-up, bacteria isolation was performed to ensure the existence of Nitrosomnas on the media surface, as this class of bacteria will ensure the removal of Ammonia. Experimental run was carried out for the span of 25 days, by replacing the aforementioned concoction with raw wastewater. Prime parameters investigated are Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Ammonia.

Keywords: *Trickling Filter, biofilm, ammonia, hexagonal close-packed, BOD, COD*

***Author for Correspondence**: *Email ID: mukututu@gmail.com*

INTRODUCTION

Nitrogenous compounds present in the wastewater have caused a great deal of toxicity in the receiving waters, also causing toxicity to aquatic lives, contribution to eutrophication and health hazards such as stomach cancer if ingested[1]. Hence, the control of nitrogenous compounds is very much essential in wastewater. In general, these pollutants can be eliminated through biological oxidation with the aid of bacteria, specifically nitrifying microorganisms. These nitrifying organisms are namely *Nitrosomonas* and *Nitrobacter*[1,2]. Both *Nitrosomonas* and *Nitrobacter* are responsible for nitrification, which is a process involving biological oxidation of ammonia with oxygen into nitrite followed by the oxidation of these nitrites into nitrates[3,4]. The overall general equation of nitrification can be expressed as follows

$$NH_4^+ + 1.83O_2 + 1.98HCO_3^- \rightarrow 0.021C_5H_7NO_2 + 0.98NO_3^- + 1.041H_2O + 1.88H_2CO_3$$

In this research, nitrification takes place in a trickling filter, which is one of the essential reactors used for nitrification of waste waters. This type of reactor is easy in operation and low in maintenance.

MATERIALS AND METHODS

Description of Trickling Filter

The trickling filter used in this research is a lab-scale size, with the height: 126.5 cm and a diameter of 13.5 cm fabricated with aluminum and filled with media for the purpose of biofilm development. It is illustrated as represented in Figure 1. The media consist of clusters of perforated spheres in the arrangement of hexagonal close-packed (HCP), made from celluloid materials. Nozzle is fitted at the top of the trickling filter for the distribution of wastewater on the media in a down-flow manner.

The commencement of the experimental run starts with the filling of aeration tank with wastewater along with proper aeration and mixing. A small amount of the mixture was extracted for the isolation of bacteria. The wastewater was subsequently accumulated in the secondary tank to be pumped into the trickling filter via fitted nozzle that was connected to the submerged pump. The operational system of this trickling filter is depicted in Figure 2.

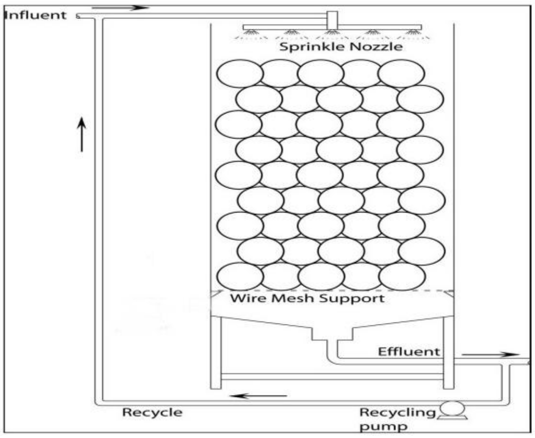

Fig.1: *Trickling Filter with HCP Media.*

The operational system of this trickling filter is depicted in Figure 2. The total experimental run was carried out for 25 cycles, of which, one cycle is approximately 1 day. The system is assembled as depicted in the schematic diagram below. The flow rate of feed was stated at 8.0269 l/hr while recirculation flow rate was 21.1644 l/hr.

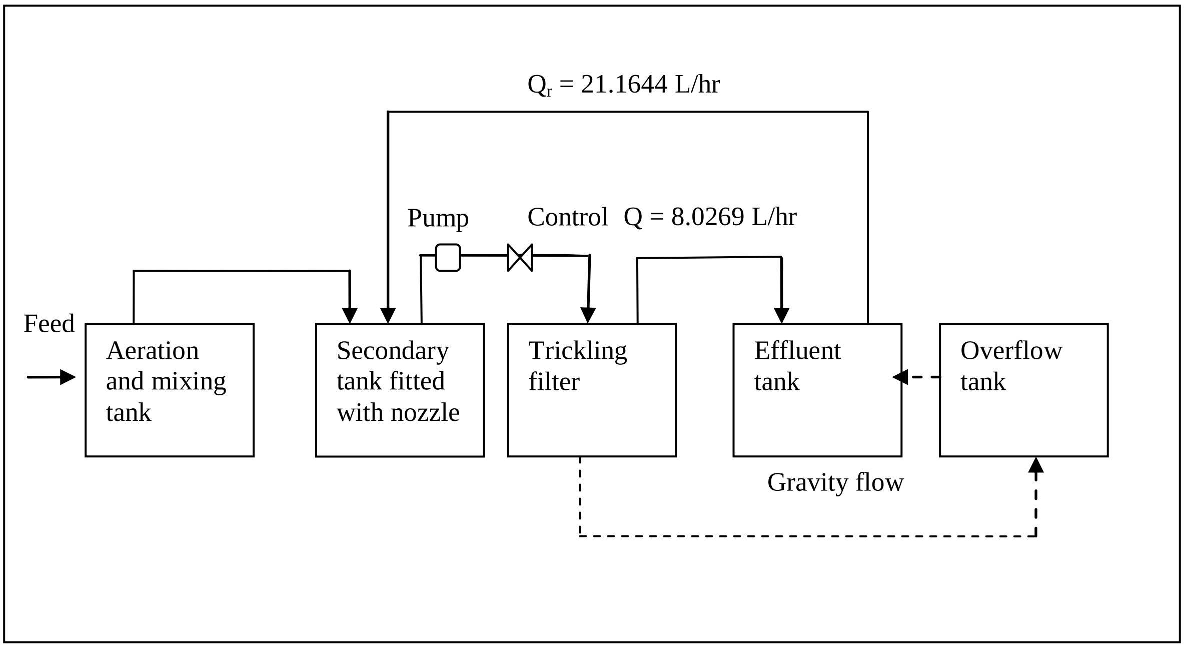

Fig. 2: *Schematic Diagram of the Operation of Trickling Filter.*

Experimental Start-Up

Prior to the treatment of the wastewater, the trickling filter is continuously run with a concocted broth to allow the development of bio-film on the outer and inner surface of the perforated media. The concoction consists of 500 ml of sludge, 500 ml wastewater, 1000 ml yeast agar broth that was enriched with wastewater. The mixture was then diluted to a total amount of 4500 ml into the aeration tank for aeration and mixing purposes. It was then aerated for several hours before being transferred to the secondary tank, which was then pumped into the trickling filter for the development of bio-film on the media. Preparation of agar was as follows- 23 g of yeast extract agar was suspended in 1 l of distilled water.

The mixture was brought to a boil to dissolve the powder form of yeast extract agar completely, thereafter sterilizing the solution by autoclaving at 121°C for 15 minutes and allowed to cool. Meanwhile, Petri dishes were prepared and sterilized. The agar solution is then poured into Petri dishes and a small amount of wastewater was added to the Petri dishes as well. The Petri dishes containing the agar and wastewater mixture were then incubated for roughly 24 hrs prior to usage.

Fresh change of wastewater was fed to the secondary tank daily while bacteria enrichment via preparation of yeast agar was conducted once a week. This was to stimulate the growth of biofilm on the media. The routine was carried out for 3 weeks, which resulted in the formation of a thin film of biomass on the media, mostly in the inner surface of the perforated media. Isolation of bacteria was carried out and nitrifying microorganisms were found to be present in the trickling filter. The growth of the bacteria was further enhanced by enrichment of the feed using agar method.

Analytical Methods

Isolation of Ammonia-Oxidizing Bacteria

Prior to the experimental run, isolation of ammonia-oxidizing bacteria solution was prepared and the composition is described in Table 1.

The ammonia-oxidizing bacteria were isolated to ascertain the presence of *Nitrosomonas* in the wastewater under treatment. 60 ml of the solution was added to Erlenmeyer flasks (300 ml capacity) and sterilized by autoclaving at 120°C for 15 minutes. These flasks are then inoculated with 5 ml of wastewater and subsequently incubated at 28°C for several weeks to a month.

The appearance of *Nitrosomonas* is indicated through the change of the color of the solution from orange to yellow.

Table 1: *Isolation of Ammonia-Oxidizing Bacteria by Drews*[5].

Chemical component	Weight (g)
$(NH_4)_2SO_4$	1.0
K_2HPO_4	0.5
NaCl	2.0
$MgSO_4.7H_2O$	0.2
$FeSO_4.7H_2O$	0.05
$CaCO_3$	6.0
Phenol Red (0.5%)	0.01
Distilled water to 1l	-

Influent and Effluent Parameters

The influent and effluent parameters namely–Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal-Nitrogen (NH_4^+–N), Nitrate (NO_3^-–N) were ascertained using Standard Methods[6] and pH, Dissolved Oxygen (DO), Turbidity and Suspended Solids (SS) were respectively determined using Eutech Instruments Ion 520 pH meter for pH and temperature, Water Checker U-10 for DO and Turbidity. SS was determined in accordance to Standard Methods[6].

RESULTS AND DISCUSSION

During experimental start-up, the presence of nitrifying bacteria in the trickling filter was identified using the isolation technique.

The change of color from orange to yellow as depicted in Figure 3 below indicates the presence of nitrifying bacteria[5].

***Fig. 3:** Color Change Indication from the Isolation Technique.*

Following the isolation of bacteria, the attributes of the feed wastewater (influent wastewater) were identified. The following Table 2 describes the characteristics of the feed wastewater:

Throughout the experiment- DO, pH, turbidity and suspended solids were monitored. Graphs below illustrate the patterns of the stated parameters in the experiment cycle.

***Table 2:** Characteristics of Influent Wastewater.*

BOD in 5 days at 20°C	37.3 mg/L
COD	564 mg/L
NH_4^+-N	53.3 mg/L
NO_3^- -N	23.9 mg/L
Suspended Solids	205 mg/L
Turbidity	187 Nephelometric Turbidity Units (NTU)
pH	6.79
Temperature	20.3°C

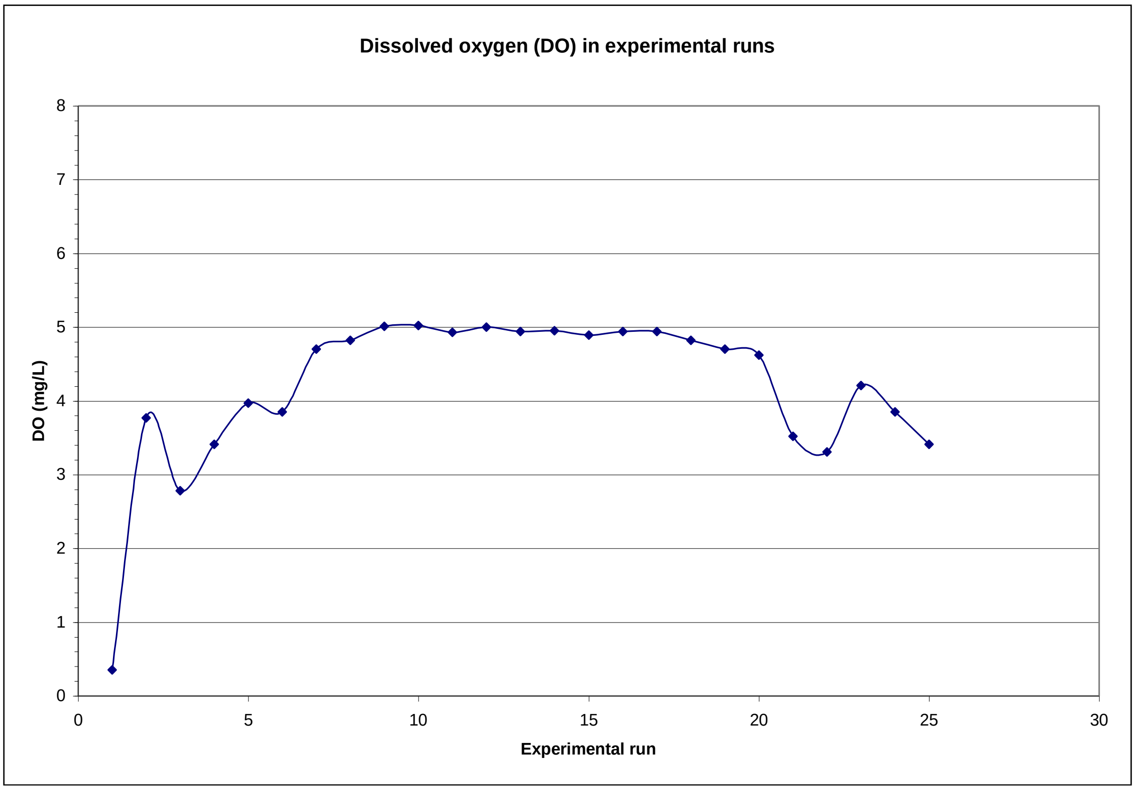

***Fig. 4:** Dissolved Oxygen in the Span of Experimental Runs.*

DO in the experimental run experiences a gradually increment at sequence 1 to 6 as seen in Figure 4 above, and remained constant throughout. However, at sequence 21, there is sharp drop in the DO and the commencement of the experiment ended at sequence 25, after seeing subsequent drop at sequence 21. For processing of nitrification, oxygen should be well distributed and its level should not be less than 2 mg/L[7].

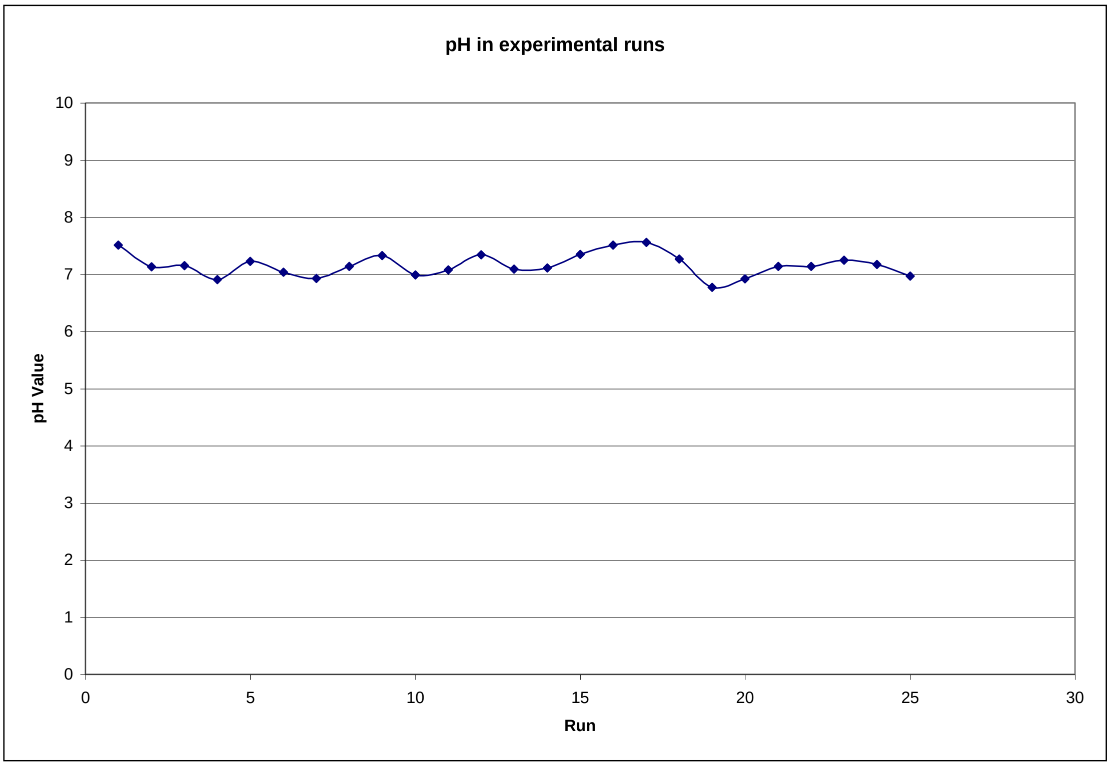

Fig. 5: *pH in the Span of Experimental Runs.*

As seen in Figure 5 above, the pH remained almost in alkaline manner, with the lowest pH recorded at 6.91 and the highest at 7.56. The alkaline state is crucial to be maintained in order to create a more conducive environment for the growth of nitrifying Bacteria hence, a small amount of alkalinity namely- sodium bicarbonate ($NaHCO_3$) was added to the trickling filter from time to time in order to prevent the lapse in the pH to acidic state.

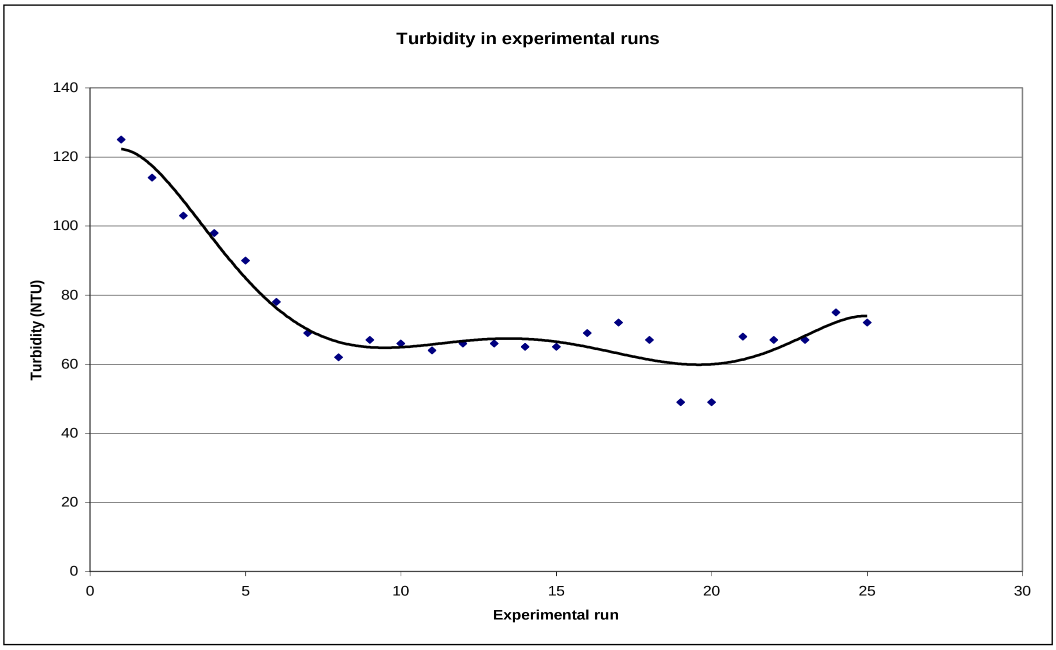

Fig.6: *Turbidity in the Span of Experimental Runs.*

As the experimental runs progressed, the turbidity was observed to have sharp decline from sequence 1 to 8 and from then onwards a rather constant turbidity is seen throughout the experiment. The trend of the turbidity throughout the experiment as seen in Figure 6 generally has a downward trend, but there was slight increment from sequence 10 to 15 and sequence 20 to 25. This increment of turbidity is an indication of biofilm sloughing, which will be detailed in the following parameter

.

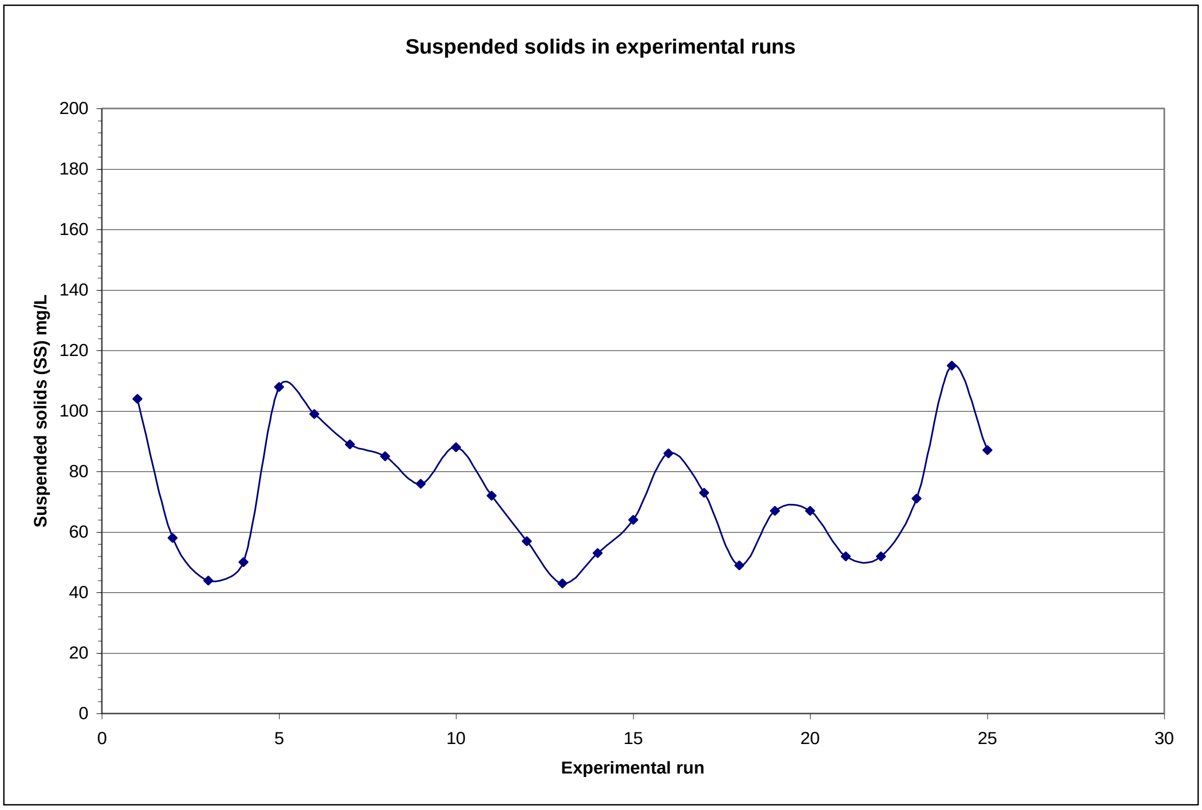

Fig. 7: *Suspended Solids in the Span of Experimental Runs.*

The SS graph in Figure 7 shows constant ups and downs throughout the experimental runs due to the biofilm sloughing off from time to time, contributing to the increment in SS. Biofilm sloughing is a phenomenon where the biofilm thickens over the time due to growth of microorganisms on the surface of the media in the trickling filter and this leads to the inability to adhere to the media.

This causes a small portion of the biofilm to detach from the media surface and when this happens, the sloughing contributes the addition of SS and the increment of turbidity in the effluent that resulted in the upward trend in both Figure 6 and 7.Stated in the Table 3 below are the final values of parameters at the end of the 25 experimental runs.

Table 3: *The Effluent Wastewater Characteristics.*

Composition	Unit
BOD in 5 days at 20°C	16.8 mg/L
COD	132 mg/L
NH_4^+-N	23.5 mg/L
NO_3^- -N	2.15 mg/L
Suspended Solids	87 mg/L
Turbidity	72 NTU
pH	6.97
Temperature	19.8°C

The reduction of pollutants can be expressed as such:
Influent removal percentage,

$$R = \frac{S_O - S}{S_O} \times 100\%$$

Where S_O is influent concentration while S is effluent concentration and removal, R is expressed in percentage. From the tabulated data, BOD is found to reduce from the influent concentration by 54.96% and COD is reported to have a removal rate of 76.6%. Nitrogen wise, NH_4^+–N removal is 55.91% while 91% reduction is noted for NO_3^-–N. For SS, a total reduction of 57.60% is reported whereas for turbidity 61.50%.

CONCLUSION

The study of the trickling filter showed that for this unique hexagonal close-packed media, the biofilm developed with ease in the inner surface of the perforated media, while additional growth on the outer surface helped tremendously in the removal of the pollutants. The biofilm, which consisted of a vast population of microorganisms, of which nitrifying bacteria was present too. Optimal pH for the growth of nitrifying bacteria would be alkaline state, at pH 8 ± 0.5[4].

Hence, the addition of small amount of alkalinity to the trickling filter is essential to prevent the pH from plundering to acidic state. Overall, the trickling filter for this research produced a total removal of 55.91 % for NH_4^+–N while 91% reduction for NO_3^-–N.

REFERENCES

1. Raj S.A., Murthy D.V.S. Nitrification of synthetic wastewater in a cross flow medium trickling filter. *Bioprocess Engineering*. 1998; 19: 149–54p.
2. Grunditz C., Dalhammar G. Development of nitrification inhibition assays using pure cultures of Nitrosomonas and Nitrobacter. *Pub Med*. 2001; 35: 433–40p.
3. Zhao H.W., Mavinic D.S., Oldham W.K., *et al*. Controlling factors for simultaneous nitrification and denitrification in a two-stage intermittent aeration process treating domestic sewage. *Water Research*. 1999; 33: 961–70p.
4. Dincer A.R., Kargi F. Kinetics of sequential nitrification and denitrification processes. *Enzyme and Microbial Technology*. 2000; 27(1–2): 37–42p.
5. Austin B. *Methods in aquatic bacteriology*. University of Minnesota. New York, U.S.: John Wiley and Sons Ltd.; 1991.
6. Rice E.W., Baird R.B., Eaton A.D., *et al. Standard Methods for the examination of water and wastewater*. 21st Edn. APHA, AWWA, Washington; 2005.
7. Bitton G. *Wastewater Microbiology*. New York, U.S.: John Willey & Sons Inc.; 1994; 139–229: 3–51p.

