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Nitrification Efficiency Analysis in Single and Series Reactors Using Biofringe Media

by

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A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"Nitrification Efficiency Analysis in Single and Series Reactors Using Biofringe Media"** submitted by Ms. Garima Gauli in partial fulfilment of the requirement for the degree of Master of Science in Environmental Engineering.

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ABSTRACT

Underground water is used as one of the major source in Kathmandu valley. Groundwater quality is found to be degraded from various anthropogenic and natural sources. Nitrogen contamination of ground water has become one of the major issues. The average constituent of ammonium-nitrogen is found to be greater than the value recommended by WHO guidelines and NWDQS in the Kathmandu Valley. Nitrification process is the effective and efficient process to remove ammonium nitrogen content compound. This research was conducted to study the efficiency of ammonia oxidation in the single and series reactors using bio fringe media. Nitrification was performed at the varying hydraulic retention time. From this study, shows that the overall removal efficiency of ammonium nitrogen is more in series reactor than single reactor in the same site condition. The removal was achieved to be higher in case of high ammonia concentration of influent water. The maximum average ammonia nitrogen oxidation efficiency was achieved up to 98.93% in series reactor whereas 92.30% in the single reactor for HRT 9.12 hrs and the minimum efficiency was achieved at HRT of 1.82 hrs which was 20.66% and 25.87% for single and series reactor respectively. At higher HRT, the bacterial efficiency was found satisfactory using biofringe media in series reactor as compared to single reactor.

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Garima Gauli

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

CFU	Colony Forming Unit
HRT	Hydraulic Retention Time
KUKL	Kathmandu Upatyaka Khanepani Limited
NDWQS	Nepal's Drinking Water Quality Standards
NTU	Nephelometric Turbidity Units
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization
mg/l	Milligram per litre
mg	Milligram
ml	Millilitre
µS/cm	Millisiemens per centimetre

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Water is the most important substance on earth upon which the survival of all the plants and animals is dependent. The unavailability of water will be responsible for the elimination of all the life on earth. Regardless of this fact, nearly half of the population of the world is beyond the reach of drinking water that is of allowable standard. Accessibility of reliable and safe drinking water is a fundamental element for the development and sustainable growth of population. About 1.8 billion people have used a source of drinking water with fecal contamination (UNICEF and WHO, 2015). According to WHO, consuming contaminated water is one of the principal causes of diarrheal diseases which is the second main cause of child mortality responsible for the annual death of about 760,000 children aged under 5 (Budhathoki et al., 2016). Thus, the wellbeing of people is influenced by the provision of the clean drinking water and the availability of safe and reliable drinking water can help to decrease or remove the deaths resulting from contaminated water such as water based diseases, water borne diseases and enhance the quality of life of the people belonging to low income households around the world. Groundwater is generally a good source of drinking water as by the process of slow percolation through the soil, it undergoes natural purification. Nowadays, the use of groundwater as a source of drinking water has been expanding and groundwater is an important source of water supply for approximately one third of world population (Nickson et al., 2005). In Kathmandu valley, about 45% of population use groundwater for the drinking and other domestic purposes (Pant, 2010).During rainy season, approximately one half of the total water supply is achieved from government's authentic operator and KUKL and during dry season 60-70% of total supply is obtained from groundwater source (Shrestha et al., 2012).

Rapid urbanization, increasing population and haphazard urbanization has led to the stress on the water resource and the ground water pollution. Over exploitation, the anthropogenic activities as well as the natural sources has caused the degradation of ground water quality in many places. Contamination from sewer line, open pit latrines, septic failures, direct disposal of industrial and domestic wastes to surface

water and leaching from landfill sites are some of the issues that have degraded the groundwater quality in Kathmandu valley (Ganesh et al., 2018). In the study undertaken to assess the groundwater quality of Kathmandu valley, from the samples collected randomly from shallow well, deep well and tube well located at different places of Lalitpur, Bhaktapur and Kathmandu districts, it was found that presence of iron was 1.9 mg/l and coliform bacteria was 267 CFU/100 ml which were higher than the acceptable limit of WHO guidelines for drinking water quality making groundwater vulnerable to drink. Similarly, electrical conductivity and turbidity were found to be 875µS/cm and 55 NTU respectively which also exceeded the limit recommended by WHO (Pant, 2010). It was also found in the study carried out to assess the groundwater quality map from unconfined aquifer of Bhaktapur municipality area that the quality of groundwater exceeded the limit recommended by NDWQS on the basis of the value measured for nitrate, ammonia and chloride in majority of sample wells (Ganesh et al., 2018).Thus the drinking water quality has been one of the major concern in the Kathmandu valley. Furthermore, as compared to surface water, treatment of the contaminated groundwater is done with much difficulty and it is the time consuming process.

1.2 Rationale of the Study

Nitrogen contamination of shallow groundwater has been one of the major issues in Kathmandu valley. Field investigation and lab tests have shown most of the underground water at Kathmandu valley have high concentration of ammonia. About 96.51 % of the sample wells selected during groundwater assessment was found to contain ammonia more than 1.5 mg/l which is more than the limit recommended by NDWQS (Ganesh et al., 2018). An average concentration and maximum concentration of NH_4^+-N was found as 23.3 mg/l and 119.8 mg/l respectively for deep groundwater whereas for shallow groundwater an average concentration and maximum concentration of NH_4^+ - N was found as 5.3 mg/l and 12.3 mg/l respectively. The permissible limit recommended by WHO is 50 mg/l for total nitrogen whereas the permissible limit recommended by NWDQS (2062 BS) for NH_4^+ - N is 1.24 mg/l (Shrestha et al., 2012). This shows that nitrogen is present in groundwater in high concentration and effective measures are required to be adopted for the remediation. Some of the major concerns related to presence of ammonia in water are as follows:

i) At the low concentration of ammonia, it is found to pose no any health risk in people. However, the presence of ammonia in water can cause the oxidation of ammonia resulting high concentration of nitrate that can cause health implications. At ammonia levels exceeding 1.5 mg/l, the serious threat is imposed upon infants. The transformation of nitrate into nitrite in the digestive system results to health risk. The nitrite results in the formation of methemoglobin by oxidizing iron in the hemoglobin of red blood cells which reduces the capacity of hemoglobin to carry oxygen. This state is termed as methemoblobinemia also termed as blue baby syndrome where the blue appearance of veins and skin is found (Amatya et al., 2011)

ii) The presence of ammonia at high levels requires high doses of chlorine resulting decreased efficiency of disinfection. When the water containing 0.2 mg per litre of ammonia is subjected to chlorination, 68% of the chlorine may undergo reaction with the present ammonia and becomes unavailable for disinfection. (WHO, 2003)

iii) Ammonia is found to render bad odor and taste in drinking water.

iv) Interference with the operation of manganese removal filter is also caused due to presence of high level of ammonia in water. (WHO, 2003)

Ammonia contamination has become one of the global issues and requires attention towards research of the methods and techniques that can settle down the issues. Detail study of the prevailing methods, processes and performance conditions of various approaches are necessary for dealing with the successful ammonia remediation. So as an effective method, biological nitrification is used which is a microbe based process implemented to eliminate nitrogenous compounds from water. In the context of Nepal, this method is safe, reliable, cost effective and produces no any unwanted by products as compared to the expensive physico – chemical technologies for removal of ammonia. Biofringe is a novel acryl resin fiber material which has been used as a carrier material making the nitrification process as an attached growth process which can be an effective alternative to conventional suspended growth process.

1.3 Objectives of the Study

The main objective of the study is to investigate and compare the ammonia removal efficiencies variation in the single and series nitrification reactors using biofringe media.

Beside this the specific objectives of the study is to investigate about:

- To study the performance of the single and series reactors in the removal of ammonia.
- To study the efficiency of ammonia nitrogen conversion in the reactors.
- To study the performance of ammonia, nitrate and nitrite removal processes on increasing hydraulic retention time.

1.4 Limitations of the Study

Various factors were encountered during the work process that caused inhibition in the work process. Some of the factors are listed below.

- Air flow control is not done due to unavailability of the flow control device. Flow is tried to be controlled by using air control valve such that the DO in water is higher than the minimum DO required for nitrification.
- Ammonia is only considered in the study period. Other constituents in the groundwater influent are not considered.
- The influent flow fluctuation during sampling hour is not taken into account.
- The daily variation in the system is (±2˚C) is considered in the reactors.

1.5 Organization of Report

This report is organized into five chapters.

Chapter 1: Introduction

This chapter deals with background, rationale, objectives and limitation of study.

Chapter 2: Literature Review

This chapter describes the theories related to the study. It consists of literature review and research design, related data and information available in past papers, research, journals.

Chapter 3: Methodology

This chapter deals with the methodology and approach adopted to accomplish the objectives of the study.

Chapter 4: Results & Discussions

This chapter presents the results and discussions of the parameters under study obtained from the results after the analysis of samples in lab.

Chapter 5: Conclusions and Recommendations

This chapter consists of conclusions and recommendations regarding the whole study, so it will help for future research and study of same nature.

Appendices contains summary of test and data along with the related photographs.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Source and effect of ammonia contaminated water

In most of the organic compounds, ammonia gas NH_3 is the oxidation state. Ammonia can exist as either ammonium ion NH_4^+ or either ammonia gas NH_3 in aqueous solutions depending upon pH. In pH range of most of the natural waters, nitrogen is found mainly as NH_4^+. Ammonia is present in groundwater from either degradation of naturally occurring organic matter or from manmade sources. Application of nitrogen fertilizer, operations related to livestock, industrial processes, infiltration of sewage and lining of cement mortar pipe are some of the reasons for the presence of ammonia in water. Ammonia concentration at 0.1 – 1.0 mg/l is found to be fatal for the wildlife. Impermeability of biological membranes to ammonium ions but permeable for ammonia shows that toxicity of ammonia depends upon pH (Abeliovich, 1992). The concentration of ammonia in the range of 0.2 – 0.5 mg/l is found to be fatal for the fishes (Miladinovic & Weatherley, 2008). The presence of ammonia can result in the formation of nitrite as an intermediate product during the oxidation process of ammonia. Studies have shown, at concentration of nitrite above 45 mg/l, it can result anemia in infants and pregnant women (Odjadjare & Okoh, 2010). Under anaerobic condition in the digestive system, conversion of nitrate to nitrite could cause methemoglobin (Greer & Shannon, 2005).

2.2Ammonia Removal Technologies

Several methods have been employed for removing ammonia from water. Wide range of technologies has been employed with the motive of protecting the environment by reducing the release of ammonia nitrogen. These technologies include air stripping method, ion exchange method, chlorination and biological nitrification method.

Ammonia stripping method occurs at the alkaline medium where desorption of molecular ammonia occurs at air water interface (Idelovitch and Michail, 1981). High pH is required for for effectiveness and in order to increase the pH values lime is required (Kinidi et al., 2018). Repumping of water to stripping tower that require higher maintenance and require high power, formation of scale that must be removed hydraulically, chance of air pollution problem from ammonia and sulphur dioxide

reaction are some of the issues related to this process of ammonia removal (EPA, 2000).

Ion exchange method employs reversible exchange of ions between solid and liquid phase. Similar charge ions can replace mobile ions of ion exchange material from surrounding medium (Ding & Sartaj, 2016). This process has some drawbacks such as the method leads to large pH changes in the process of production, long cycle of production, results some poor quality product and it is not always possible to find suitable resin (Chen & Wang, 2017).

Chlorination process is a widely used commercial method. However it renders bad taste and odor and may be responsible for health hazards such as cancer and miscarriages (Amatya & Kansakar, 2005).

Biological nitrification process is a microbe mediated process which is safe and cost effective. As this process does not render any side effects, it is becoming popular nowadays. When ammonia concentration is greater than 1.5 mg/l, the operation cost of biological nitrification is less than the chlorination method (Amatya & Kansakar, 2005).

2.3 Concept of Biological Nitrification

Nitrification of ammonia occurs from consecutive action of two different groups of chemolithotropic organisms, Nitrosomanas which is an ammonia oxidizing bacteria and Nitrobacter which is nitrite oxidizing bacteria. (Metcalf & Eddy, 2003).These chemolithotrophs use nitrite or ammonia as their energy source, oxygen as a electron acceptor and carbondioxide is used as a carbon source. Thus, Nitrification is a two step oxidation process employing two different groups of bacteria. The equation representing two step oxidation of ammonia to nitrate is shown as follows:

For Nitrosomanas,

$$55NH_4^+ + 76O_2 + 109HCO_3^- \longrightarrow C_5H_7O_2N + 54NO_2^- + 57H_2O + 104H_2CO_3 \quad \text{..Eq 2.1}$$

For Nitrobacter,

$$400NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3^- + 195O_2 \longrightarrow C_5H_7O_2N + H_2O + 400NO_3^- \quad \text{..Eq 2.2}$$

The stoichiometric equations for nitrification are

$NH_4^+ + 1.5O_2 \longrightarrow 2H^+ + H_2O + NO_2^-$

..Eq 2.3

$NO_2^- + 0.5O_2 \longrightarrow NO_3$

..Eq 2.4

It is found theoretically that while destroying 1 pound of ammonia to nitrate 7.2 pounds of alkalinity is destroyed. For the control of alkalinity and pH control, quick lime (CaO) or Calcium hydroxide ($Ca(OH)_2$) is often used. Formation of hydrogen ions occurs in the oxidation process of ammonia to nitrite. Bicarbonate ions in raw water will neutralize the hydrogen ions of water if the pH is less than 8.3.

$H^+ + HCO_3^- \longrightarrow CO_2 + H_2O$

..Eq 2.5

It is found that for the oxidation of 1 mg of ammonia nitrogen to nitrate nitrogen, consumption of nearly 4.3 mg of O_2 and 8.64 mg of alkanity in the form of HCO_3^- occurs (Amatya et. al, 2011).

2.4 Factors affecting nitrification process

Rate of nitrification is controlled by environmental factors and most significant factors include substrate concentration, pH, temperature and oxygen availability (Jones & Hood, 1980).These factors are discussed below.

i) Effect of concentration of substrate

Nitrifying bacteria show sensitivity towards different concentration of ammonia (Suwa et al., 1994). High ammonia concentration is found to inhibit ammonia oxidation. Free ammonia (NH_3) is found to inhibit ammonia oxidisers as compared to total ammonium ions. pH and temperature are the factors that determine the concentration of ammonia which is in equilibrium with ammonium ions. (Anthonisen et al., 1976). Nitrite oxidising bacteria are found to be more sensitive at the concentration of 0.1 – 1.0mg/l of NH_3 – N whereas inhibition of ammonia oxidizer bacteria occurs at the concentration of 10 – 150 mg/l. Thus if the free ammonia level is high in the reactor, it can lead to greater accumulation of nitrite or even ammonium (Welander et al., 1998). Thus free ammonia level should be low to avoid the inhibition of ammonia or nitrite oxidation.

ii) Effect of pH

It is found that nitrifying bacteria are very sensitive towards pH. Optimal pH for Nitrosomanas is in the approximately between 7 and 8 and for nitrobacter the range is approximately 7.5 to 8. Increase in pH greater than 9 can reduce nitrification (EPA, 2002).

Rates of nitrification can also reduce significantly at pH below 6.8 whereas at pH range near 5.8 – 6, nitrification rate is found to be 10 – 20 percent of the nitrification rate at pH 7 (Metcalf & Eddy, 2003).

iii) Effect of Dissolved Oxygen (DO)

Sufficient amount of oxygen is required as nitrification is an aerobic process and low DO could result in the effect on the activity of bacteria. At DO concentration below 0.5 mg/l, there is found to be inhibitory effect on nitrification rate which is higher for Nitrobacter than for Nitrosomanas. That results in the incomplete nitrification and greater concentration of NO2-N would result in the effluent (Metcalf & Eddy, 2003). It has been found that for nitrification DO concentration between 0.3 mg/l to 1 mg/l is required and below 0.2 mg/l, nitrification is found to cease. It was observed that DO uptake rate as the function of DO concentration. They found that the growth rate of Nitrosomanas was not dependent at DO concentration above 1 mg/l whereas this value was above 2 mg/l for Nitrobacter. Factors such as double substrate limited kinetics, variation in measured results due to dynamic and steady state measuring techniques and oxygen diffusion in flocs are found to be responsible for wide range of nitrification rate with varying DO concentration (Stenstrom & Poduska, 1980).

iv) Effect of temperature

Temperature is found to have effect in nitrification rate. Maximum nitrification rate is observed at the temperature of 30°C. Below 15°C, sharp decline in nitrification rate is found. Rate at 27°C was observed as 90% that of 30°C whereas at 17°C, it was 50% as that of 30°C. At temperature between 7°C to 26°C, growth rate for nitrifiers is observed whereas at 5°C, 53% decrease and at 7°C, 21% decrease in growth rate is found as compared to 26°C. The inhibitory effect at low temperature of about 10°C or

less was observed more for Nitrobacter as compared to Nitrosomanas which was concluded from nitrite build up at 12°C to 14°C in the reactors (Shammas, 1986).

2.5 Effect of media in nitrification

Media used in nitrification system affects the performance. Media plays key role when the specific surface area (SSA) and biofilter space is considered. In the same volume of the reactor, different surface area is produced from different SSA. Higher volume of reactor is required for the media having lower SSA to have same surface area as compared to media having high SSA (Harwanto et al., 2011). The media should have the property of high specific surface area, less clogging and low specific gravity such that the optimum nitrification rate can occur (Sajuni et al., 2010). Biofringe (BF) carrier is a novel acryl resin fiber material has been used in the recently developed swim bed treatment technology. BF consists of yarns which is 100mm in length and 3mm in diameter and attached to a support filament as shown in figure below. This process is the attached growth process which consists of advantages such as no need to recycle sludge, greater treatment efficiency, reduced sensitivity towards toxic loads, greater concentration of biomass, high sludge retention time (Ha et al., 2005).

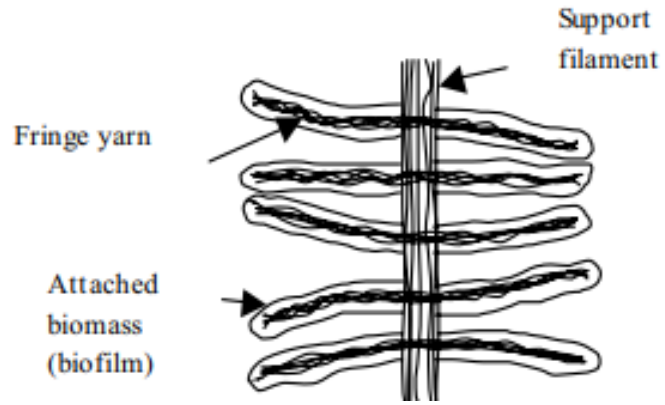

Figure 2.1: Configuration for biomass carrier (Ha et al., 2005).

CHAPTER THREE

3. METHODOLOGY

3.1 Experimental Setup

The experiment was carried out on nitrification of groundwater in a continuous down-flow reactors with one set placed in series and one reactor placed single using biofringe media. The reactors were made by using Polyvinyl chloride (PVC) pipe columns with diameter 75 mm and height of 1.1m and 0.5m respectively for single and series reactors. 0.9 m and 0.3 m of biofringe media was placed in single and series reactors respectively. The oxygen was supplied from the bottom of the reactor by injecting air from the air pump into the nitrification reactors using cylindrical air stones. Sampling port was provided in each reactors. The schematic diagram of the experimental setup is provided in figure 3.1.

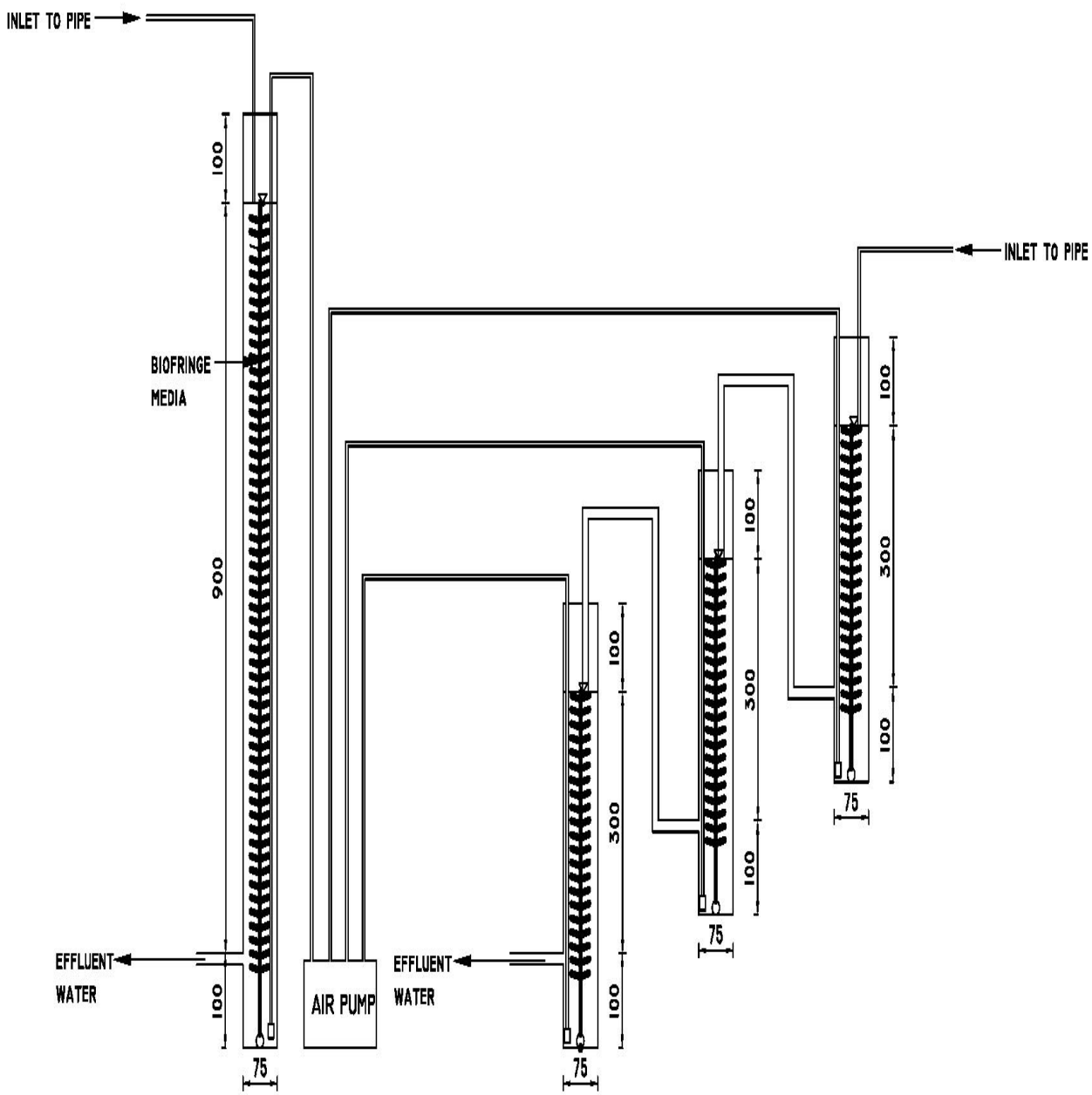

Figure 3.2: Schematic diagram of single and series reactor

3.2 Media for biofilteration

Biofringe (BF) media of total length of 0.9m and 0.3 m was suspended vertically at the centre for single and series reactor respectively. The carrier material contained fringe yarns and support filament made of hydrophilic acrylic fibers. The special structured biofringe carrier consisted of high density at the core point and loosely knit outside that enabled the easy and quick attachment of biomass. The biofringe carrier was choosen as the media as they have shown the high degree of contact between

substrate and biomass. The incoming water and the aeration cause the fringe yarns to fled up and down making the process as the swim bed technology.

3.3 Startup and operation of Reactor

The seed nitrifying culture was obtained from the dripping nitrification system located near Girls Hostel of IOE Pulchowk Campus. The nitrifying seed culture was mixed with the ammonia water in nitrification reactors which was retained and aerated for about 21 days. The experiment was started after this time period. Study was started at HRT of 1.82 hrs. Study was conducted maintaining the constant temperature at 66 days at HRT 9.12hrs. The oxygen source was constantly supplied from the bottom of the reactor in order to maintain enough DO required for nitrification process. Changes adopted during the study are given in the table below.

Table 3.1: Summary of changes adopted during study

Duration	**Parameters**
66^{th} day	Started reactor at 9.12 hrs HRT (flow rate of 7.29 ml/min)
129^{th} day	Started reactor at 0.46 hrs HRT (flow rate of 145.2 ml/min)
175^{th} day	Started reactor at 0.91 hrs HRT (flow rate of 72.59 ml/min)
215^{th} day	Started reactor at 1.82 hrs HRT (flow rate of 36.29 ml/min)

3.4 Collection of Sample

Standard procedure was used for sampling. Frequency of sampling was generally of 2 days except for some days where uncertainties in site were met. Samples from port of series reactors, single reactor and from raw water inlet were collected in sample bottles. DO and temperature were measured directly at the site.

3.5 Analytical Methods

Sample analysis was done using standard procedure. For the analysis, laboratory of IOE, Pulchowk Campus was used. Following methods and instruments were using for the examination of sample.

Table 3.2: Analysis Parameters, methods & instruments

S.No.	Parameters	Methods/Equipments used
1	DO and temperature	DO meter ID-150, SUMA ELECTRONICS CORP
2	pH	Standard pH Meter HI98129, Hanna Instruments.
3	NH_4-N, NO_2-N, NO_3-N	Spectrophotometric Screening (Instrument – UVmini-1240, UV-VIS Spectrophotometer)
4	HCO_3-	Volumetric Analysis by Titration Method

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1 Ammonia Nitrogen (NH_4-N)

In groundwater, the concentration of ammonia varied from 78.99 mg/l to 153.85 mg/l in the initial storage tank and after passing through the nitrification reactors, it got reduced as the biological oxidation process occurs in the reactors. The analysis of ammonia concentration reduction through the reactors has been done by observing raw water ammonia concentration from 80-100 mg/l, 100-120 mg/l, 120-140 mg/l and 140-160 mg/l and the respective ammonia concentration at each reactors for HRT 9.21 hrs, 0.46 hrs, 0.91 hrs and 1.82 hrs respectively which is shown in figure 4.1 to figure 4.9 shown below.

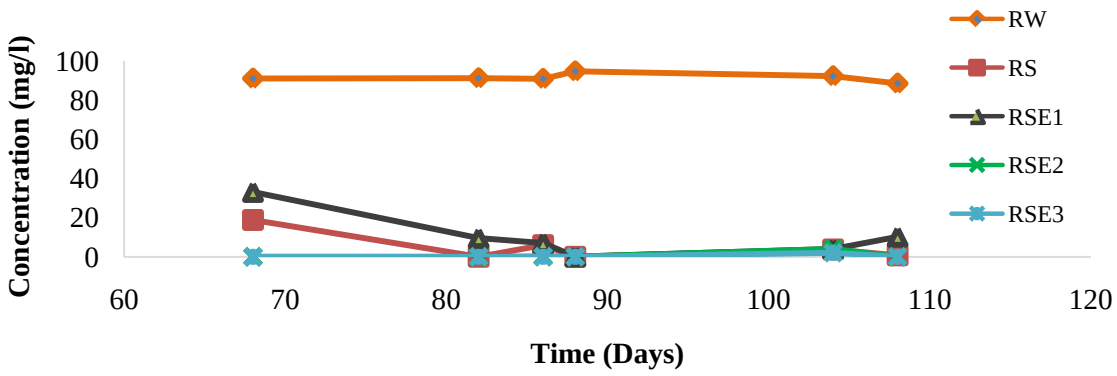

Figure 4.1: NH_4-N concentration at HRT 9.12 hrs for Influent concentration of 80-100 mg/l

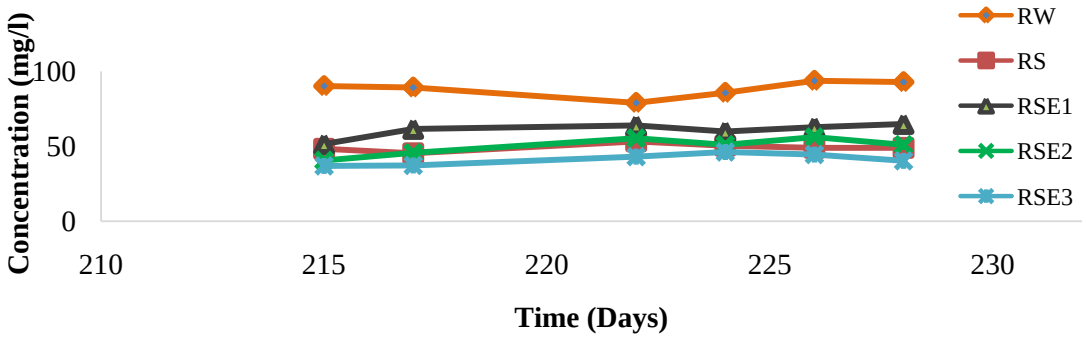

Figure 4.2: NH_4-N concentration at HRT 1.82 hrs for Influent concentration of 80-100 mg/l

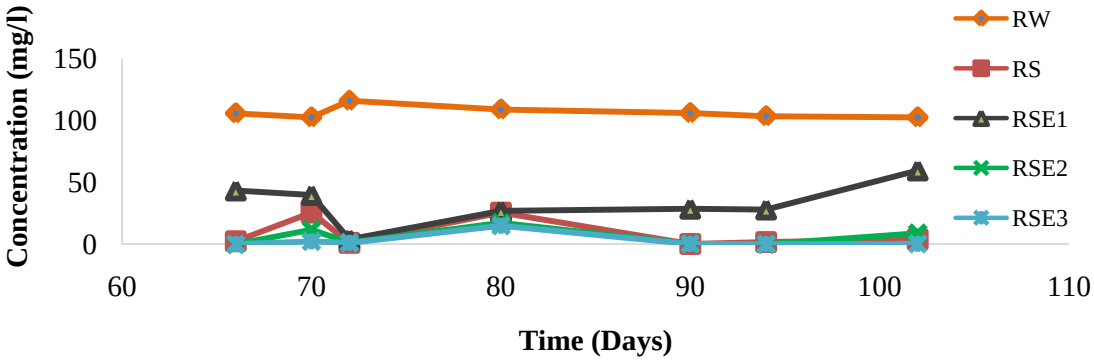

Figure 4.3: NH_4-N concentration at HRT 9.12 hrs for Influent concentration of 100-120mg/l

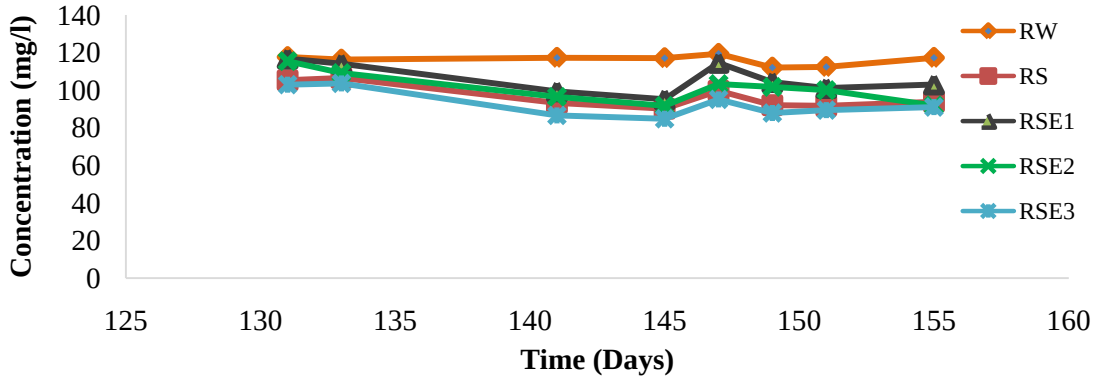

Figure 4.4: NH_4-N concentration at HRT 0.46 hrs for Influent concentration of 100-120mg/l

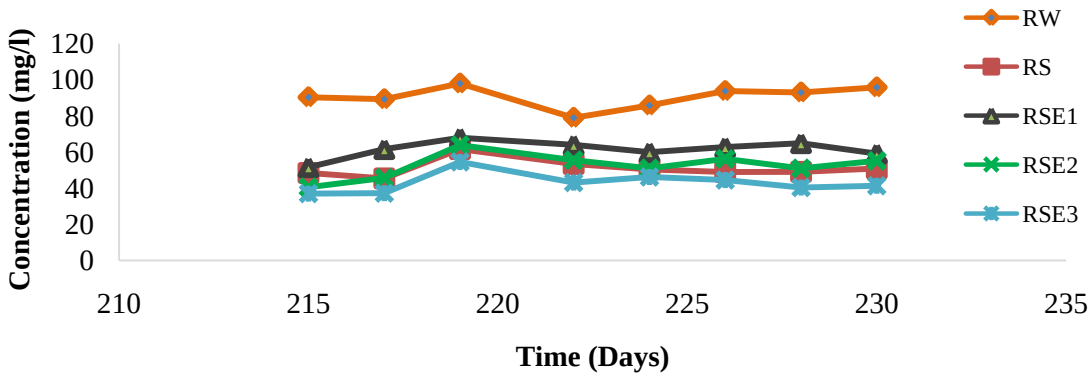

Figure 4.5: NH_4-N concentration at HRT 1.82 hrs for Influent concentration of 100-120mg/l

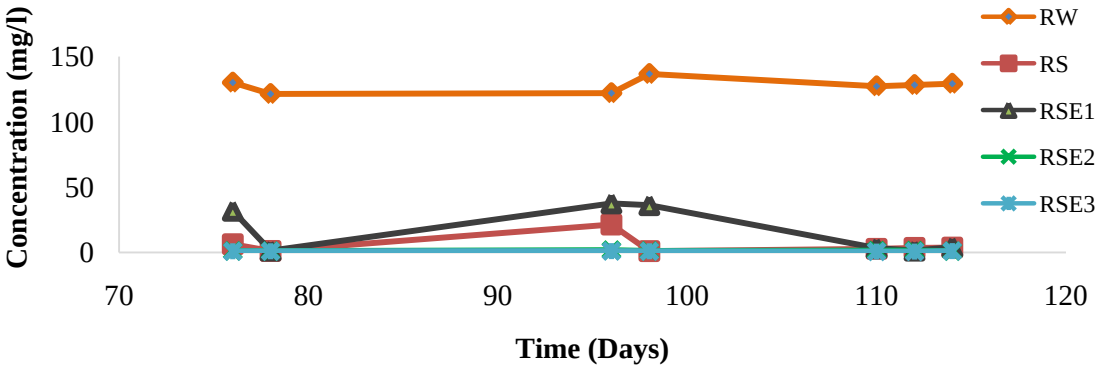

Figure 4.6: NH_4-N concentration at HRT 9.12 hrs for Influent concentration of 120-140mg/l

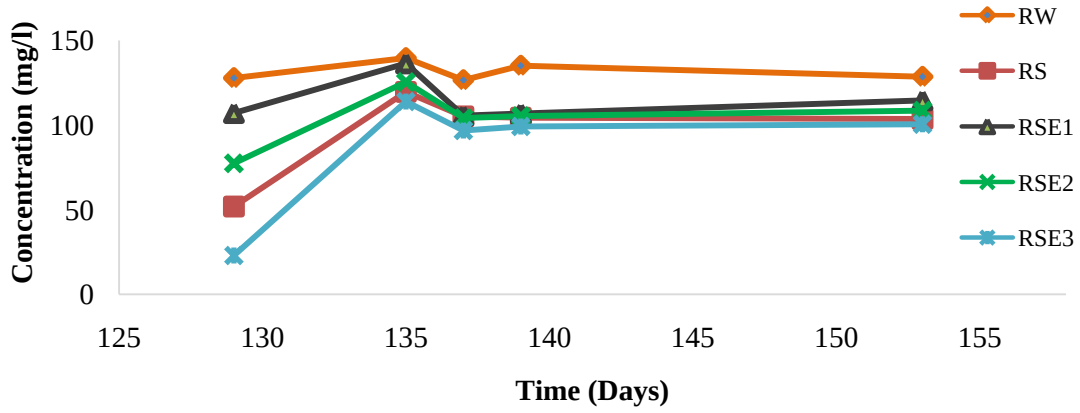

Figure 4.7: NH_4-N concentration at HRT 0.46 hrs for Influent concentration of 120-140mg/l

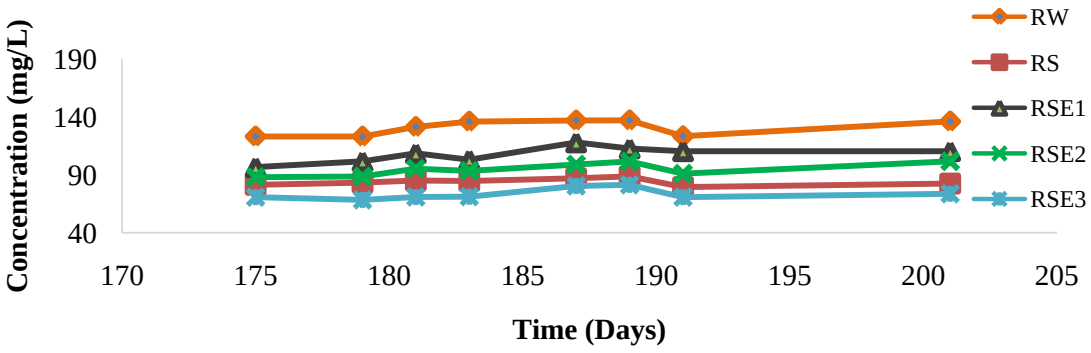

Figure 4.8: NH_4-N concentration at HRT 0.91 hrs for Influent concentration of 120-140mg/l

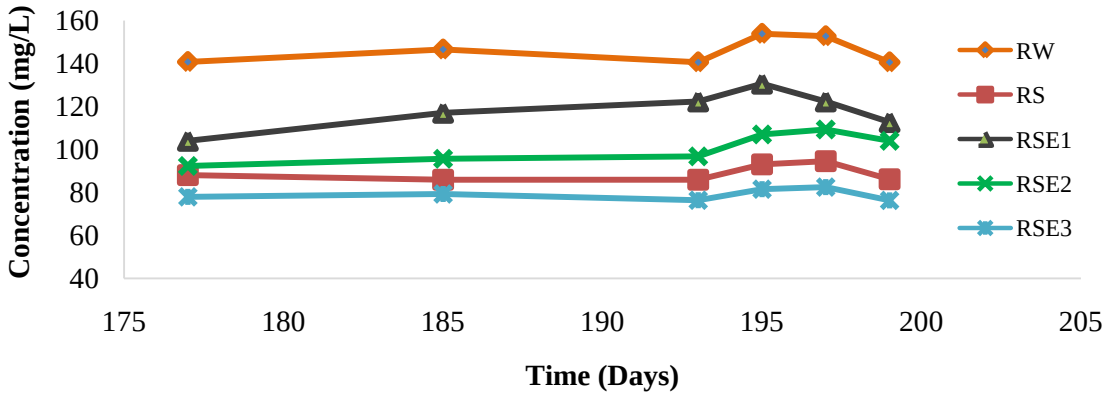

Figure 4.9: NH_4-N concentration at HRT 0.91 hrs for Influent concentration of 140-160mg/l

Ammonia is the main parameter to be reduced through nitrification process. The maximum removal of ammonia is found to occur at the HRT of 9.12 hrs as the contact with oxygen and the bacteria is high during this time period as compared to the HRT 0.46, 0.91 and 1.82 hrs respectively. The ammonia removal performance is found to be high in case of series reactors as compared to the single reactor. The influent concentration for the flow rates was found to be varying from the same ground water.. The reduction rate is found to be higher at high ammonia load in the reactors as compared to low ammonia concentration at higher HRT of 9.12 hrs. From observation it was found that the ammonia removal rate is higher at high ammonia concentration for all the flow rates taken for study. This might be because higher substrate is consumed by the bacteria leading to higher rate of oxidation of ammonia. The concentration was reduced in maximum amount at HRT 9.12 hrs where the final concentration was achieved to be 0.36 mg/l in effluent of series reactor and 4.89 mg/l from the effluent of single reactor where the influent concentration. Difference in removal efficiency was found between single and series reactors for the same influent concentration and other parameters remaining same.

4.2 Nitrate Nitrogen (NO_3-N)

Nitrate is the final product of nitrification and is formed from the oxidation of nitrite. The nitrate concentration of influent water was found to be in the range between 0.06 mg/l to 4.99 mg/l. The nitrate build up during the study period at 9.12, 0.46, 0.91 and 1.82 hrs HRT period is shown in Figure 4.10 to 4.18 shown below.

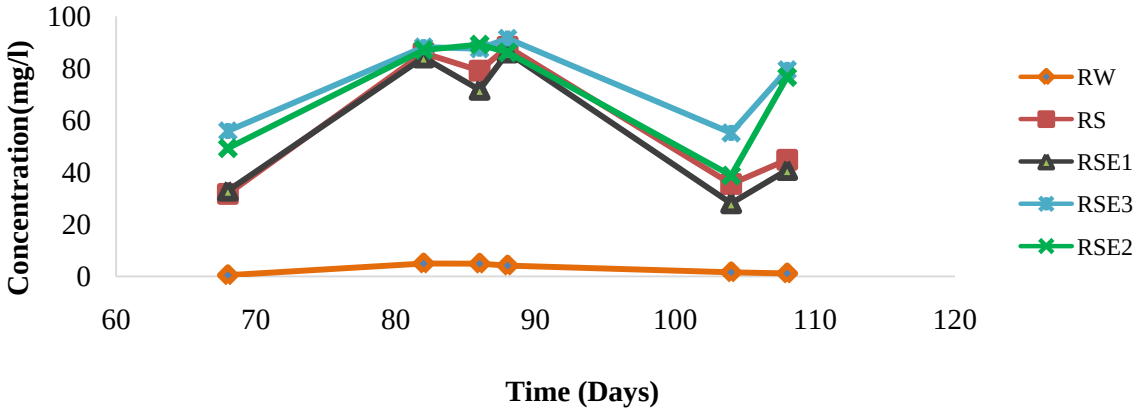

Figure 4.10: NO_3-N concentration at HRT 9.12 hrs for Influent concentration of 80-100mg/l

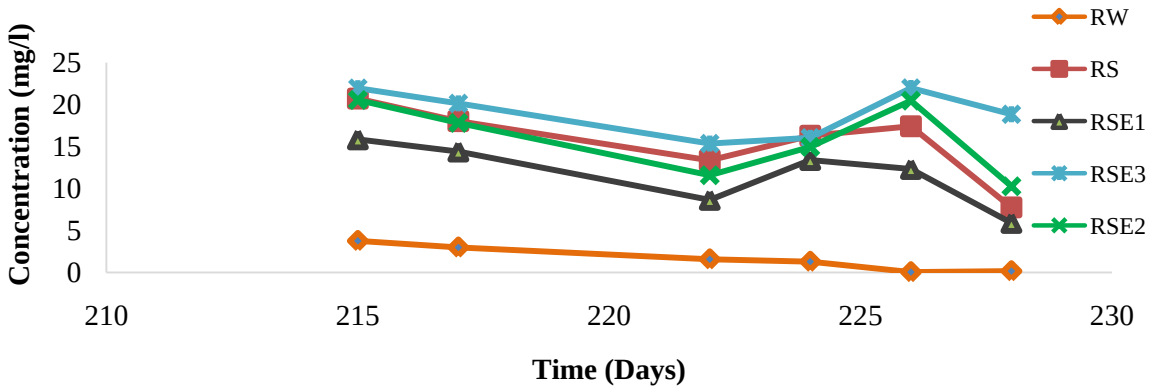

Figure 4.11: NO_3-N concentration at HRT 1.82 hrs for Influent concentration of 80-100mg/l

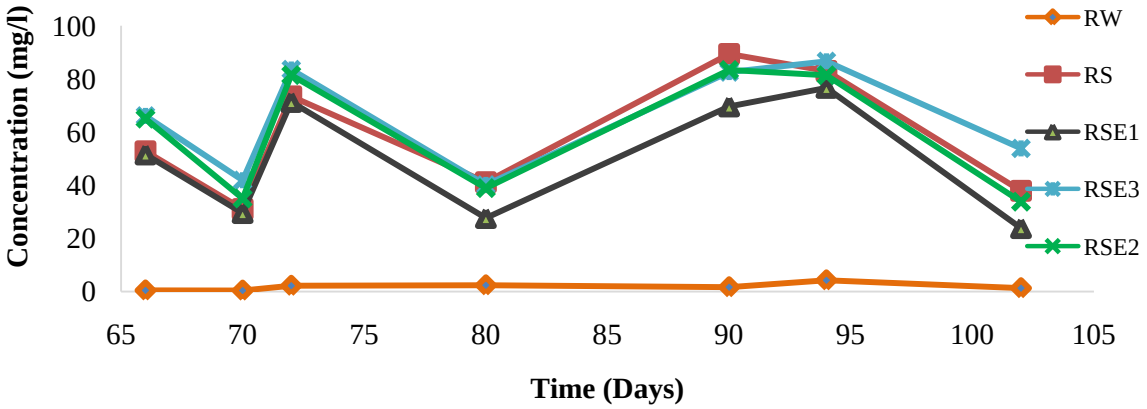

Figure 4.12: NO_3-N concentration at HRT 9.12 hrs for Influent concentration of 100-120mg/l

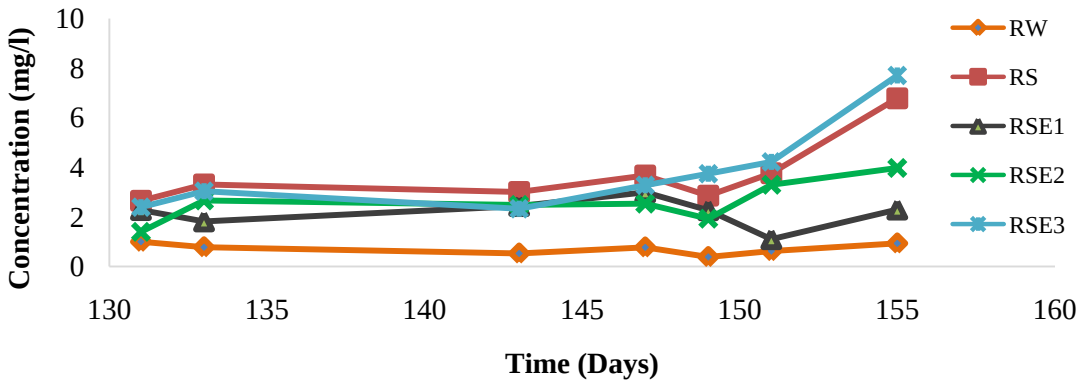

Figure 4.13: NO_3-N concentration at HRT 0.46 hrs for Influent concentration of 100-120mg/l

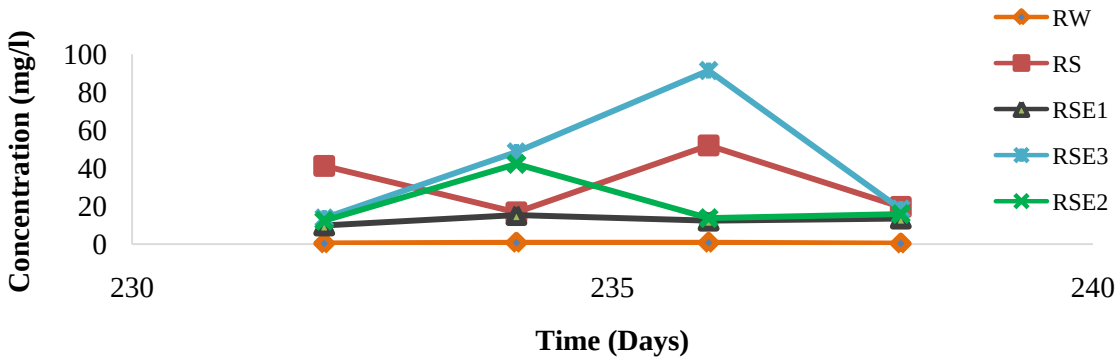

Figure 4.14: NO_3-N concentration at HRT 1.82 hrs for Influent concentration of 100-120mg/l

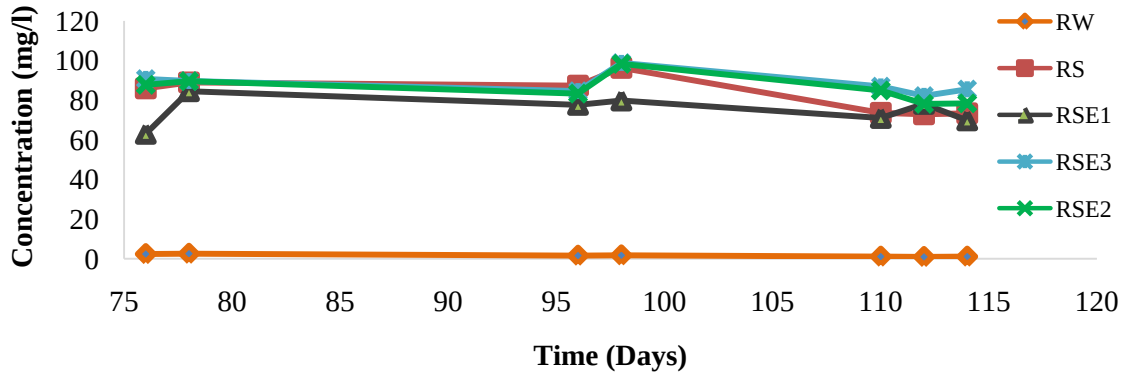

Figure 4.15: NO_3-N concentration at HRT 9.12 hrs for Influent concentration of 120-140mg/l

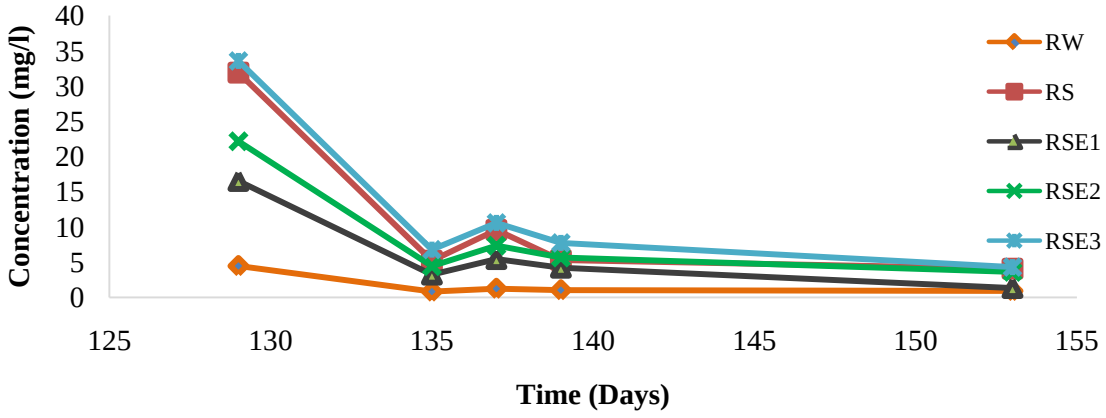

Figure 4.16: NO_3-N concentration at HRT 0.46 hrs for Influent concentration of 120-140mg/l

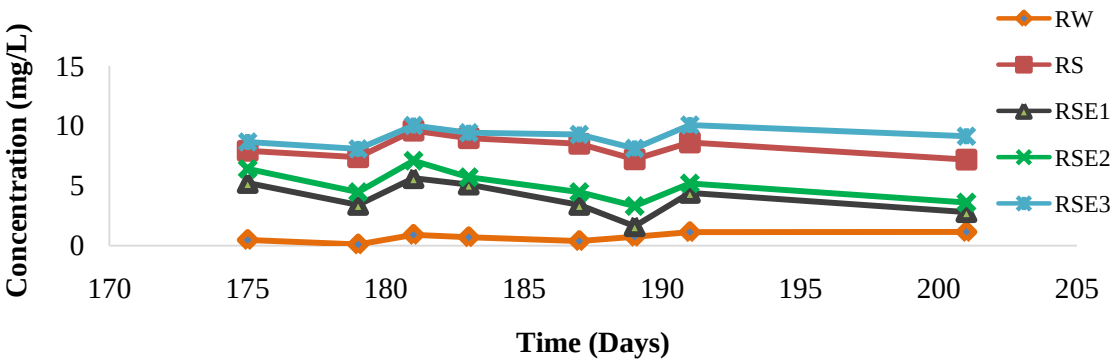

Figure 4.17: NO_3-N concentration at HRT 0.91 hrs for Influent concentration of 120-140mg/l

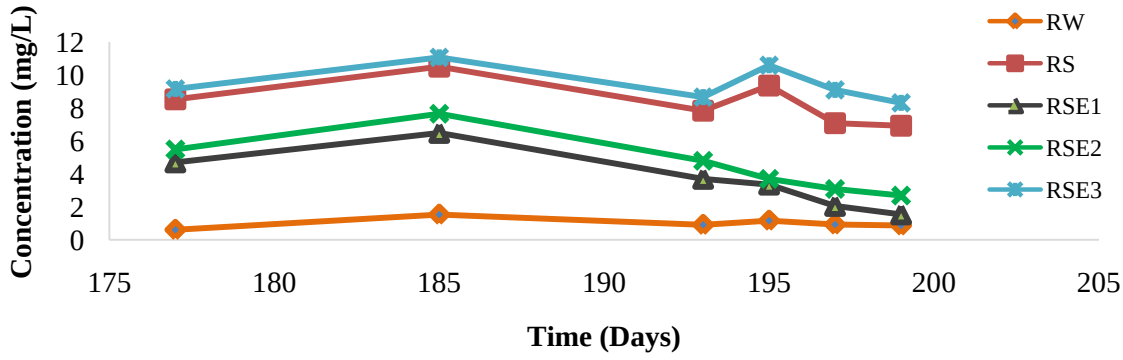

Figure 4.18: NO_3-N concentration at HRT 0.91 hrs for Influent concentration of 140-160mg/l

The nitrate formation trend is found to be dependent on nitrite oxidation process. The formation of nitrate was observed to be in fluctuating trend which might be due to non uniform oxidation rate of nitrite as it is an intermediate product after oxidation of ammonia. Nitrate formation rate is observed to be higher at high influent ammonia concentration at higher HRT of 9.12 hrs. At this detention time bacterial contact time might be higher providing higher activity of bacteria for the ammonia conversion to final product of nitrate.

4.3 pH

pH in the inlet was found in the range between decreased from inlet sample. The pH in the inlet ranged from 7.15 to 9.53. The range of pH in each reactor is in the range between 6.5-9 which is found be the range where the nitrification activity is satisfactory for bacterial activity. pH value during the study period at 9.12, 0.46, 0.91 and 1.82 hrs HRT period is shown in Figure 19 to Figure 22 below.

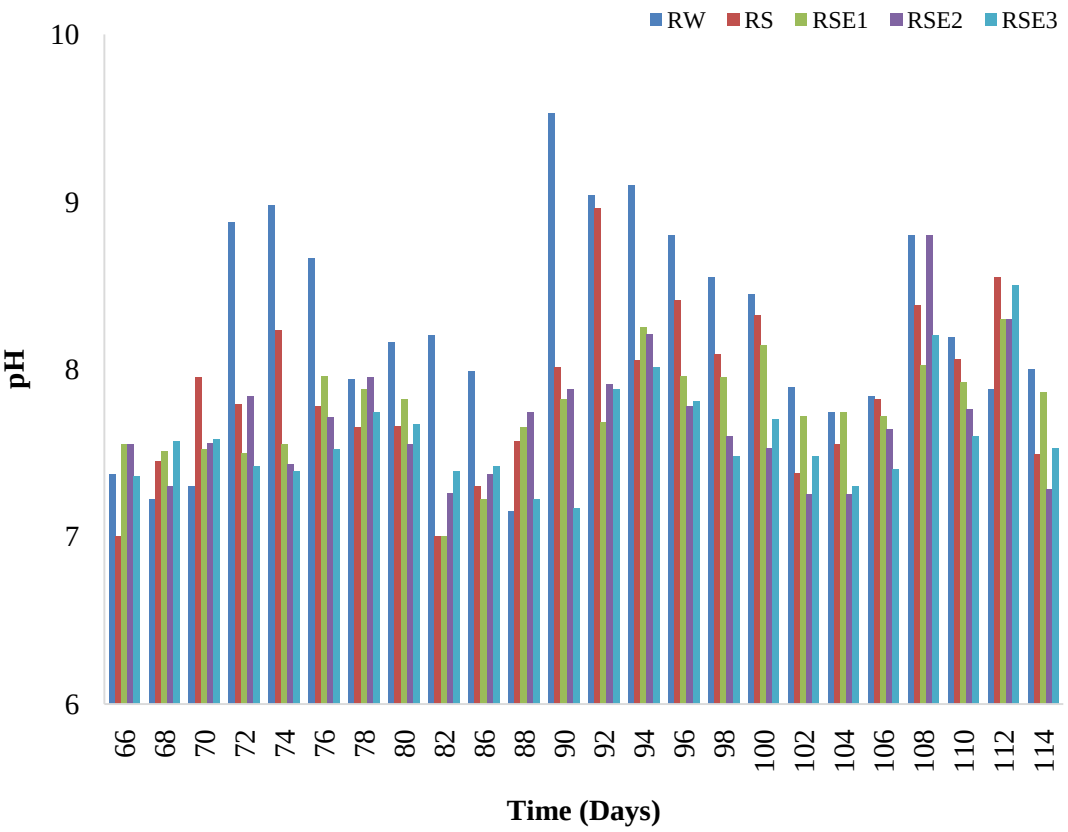

Figure 4.19: pH in the reactors at HRT 9.12 hrs

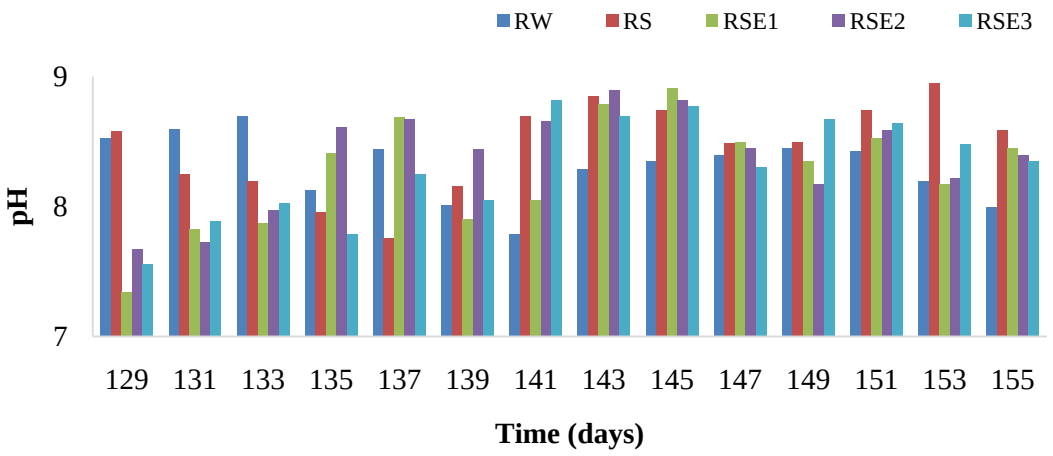

Figure 4.20: pH in the reactors at HRT 0.46 hrs

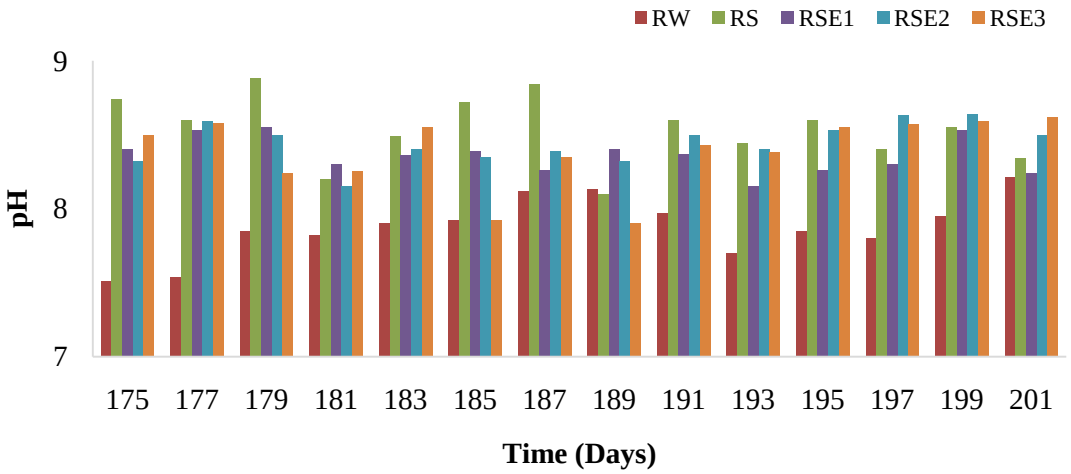

Figure 4.21: pH in the reactors at HRT 0.91 hrs

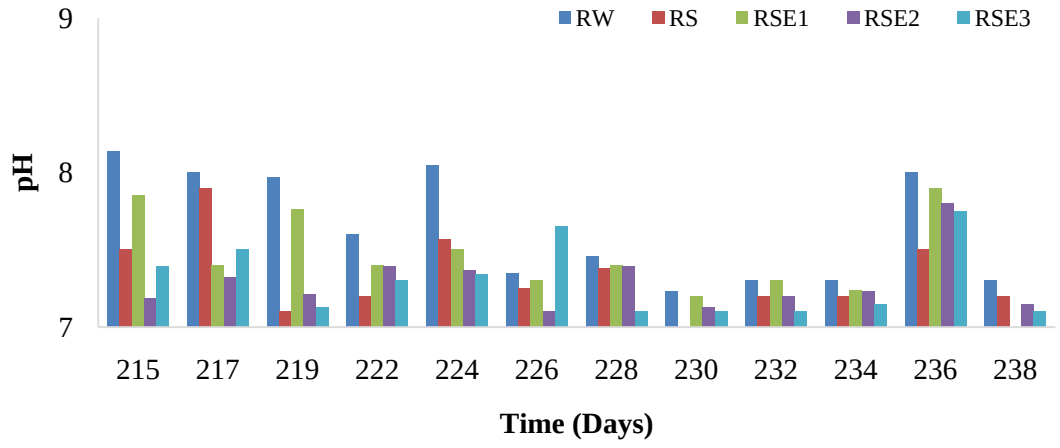

Figure 4.22: pH in the reactors at HRT 1.82 hrs

4.4 Alkalinity

The alkalinity in raw water inlet ranged from 802.15 mg/l to 957 mg/l. The effluent alkalinity was lower than the influent, suggesting consumption of alkalinity. During the nitrification alkalinity is consumed. The alkalinity of raw water was higher sufficient enough to carry out the nitrification process. No additional carbon source was required for the bacterial process. The consumption of alkalinity was observed higher in final reactor of series as compared to other reactors which suggested higher oxidation of ammonia in the series reactor as compared to single reactor. The alkalinity variation at HRT 9.12, 0.46, 0.91 and 1.82 hrs is shown in Figure 4.23 to Figure 4.26 below.

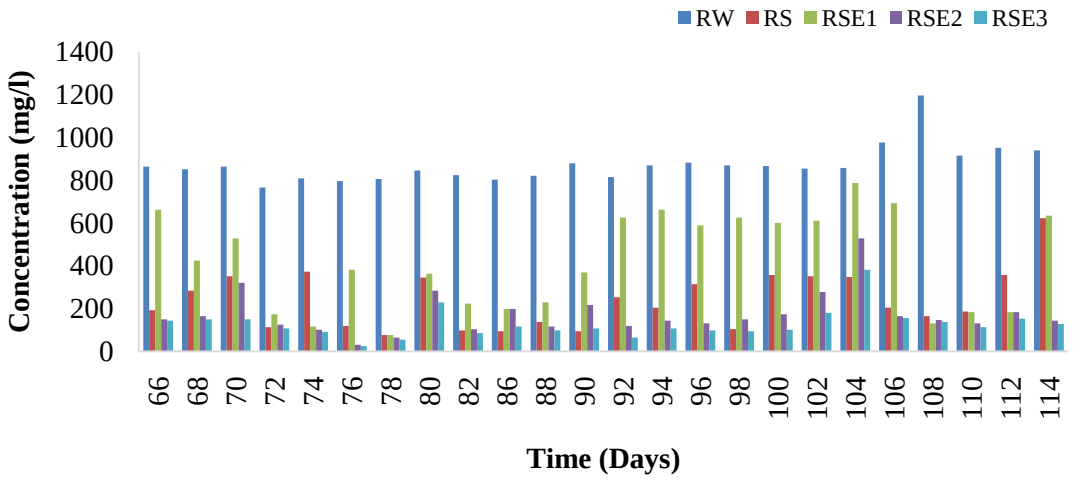

Figure 4.23: Alkalinity concentration at HRT 9.12 hrs

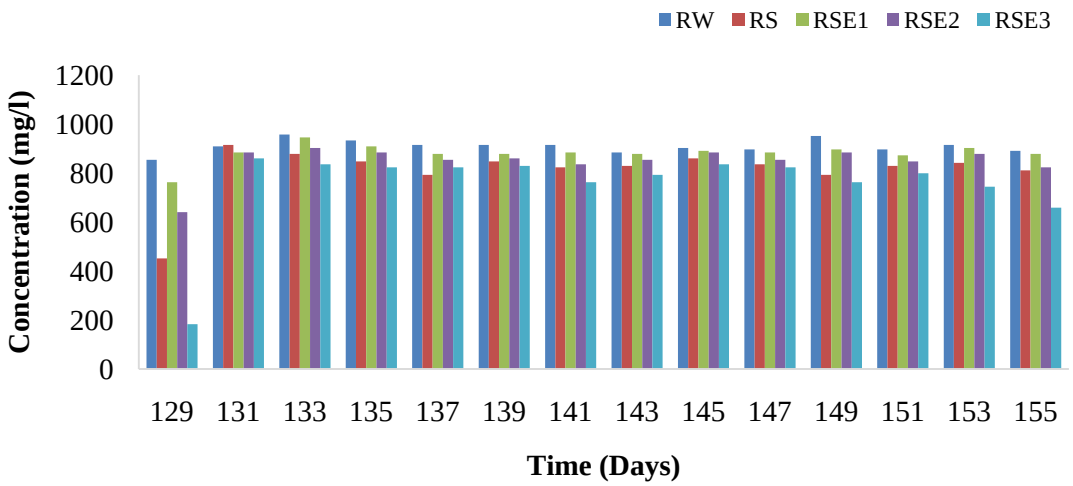

Figure 4.24: Alkalinity concentration at HRT 0.46 hrs

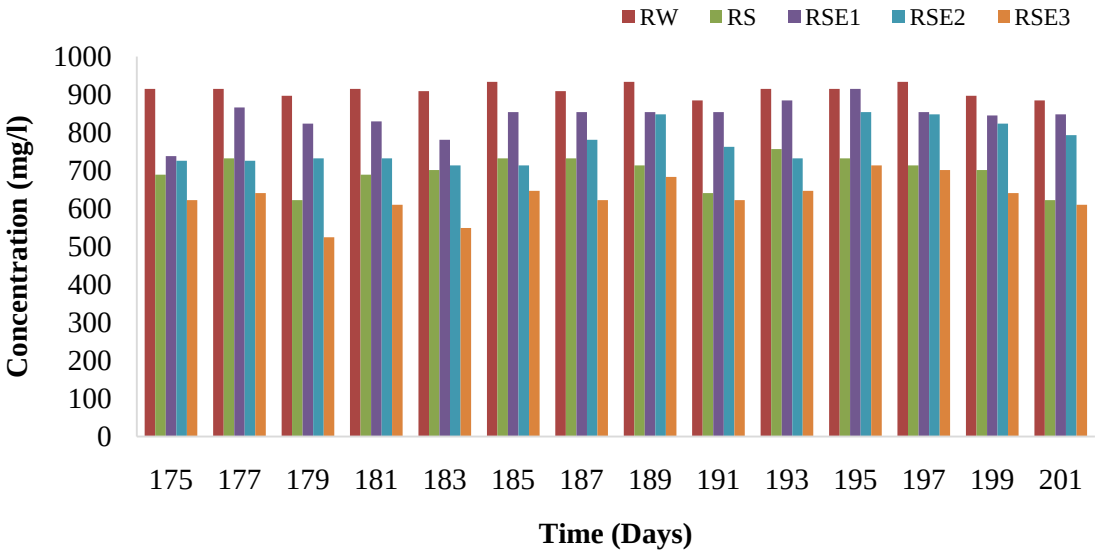

Figure 4.25: Alkalinity concentration at HRT 0.91 hrs

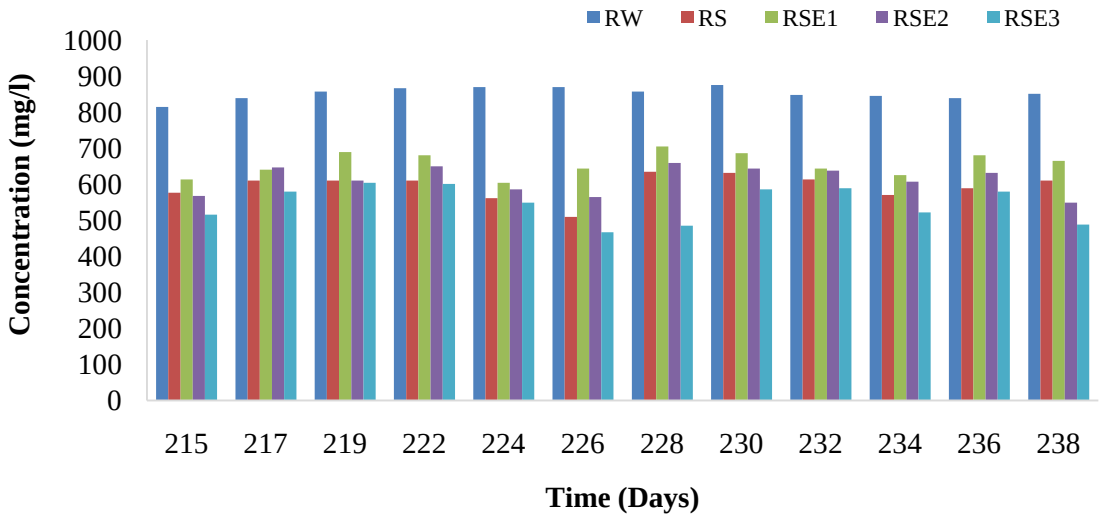

Figure 4.26: Alkalinity concentration at HRT 1.82 hrs

The alkalinity was reduced up to 24.40 mg/l, 183 mg/l, 524.60 mg/l and 466.65 mg/l at HRT 9.12, 0.46, 0.91 and 1.82 hrs respectively in series reactor and in single reactor it was reduced up to 76.25 mg/l, 793 mg/l, 622.20 mg/l and 509.35 mg/l at HRT 9.12, 0.46, 0.91 and 1.82 hrs respectively.

4.5 Dissolved Oxygen (DO)

DO measurement is taken directly on the site and the data is taken by transferring the effluent water from the reactor into the measuring cylinder and observing data by

placing DO meter into the cylinder. Since nitrification requires oxygen for the oxidation process, DO is vital for reaction to occur. The dissolved oxygen of raw water is in the range between 0.12 – 6.8 mg/l. The air supply from the air pump device through air stones has allowed dissolving oxygen in the concentration between 4 mg/l to 5.7 mg/l in the series reactor and for the single reactor the range is between 3.2 mg/l to 4.6 mg/l in series reactors respectively.

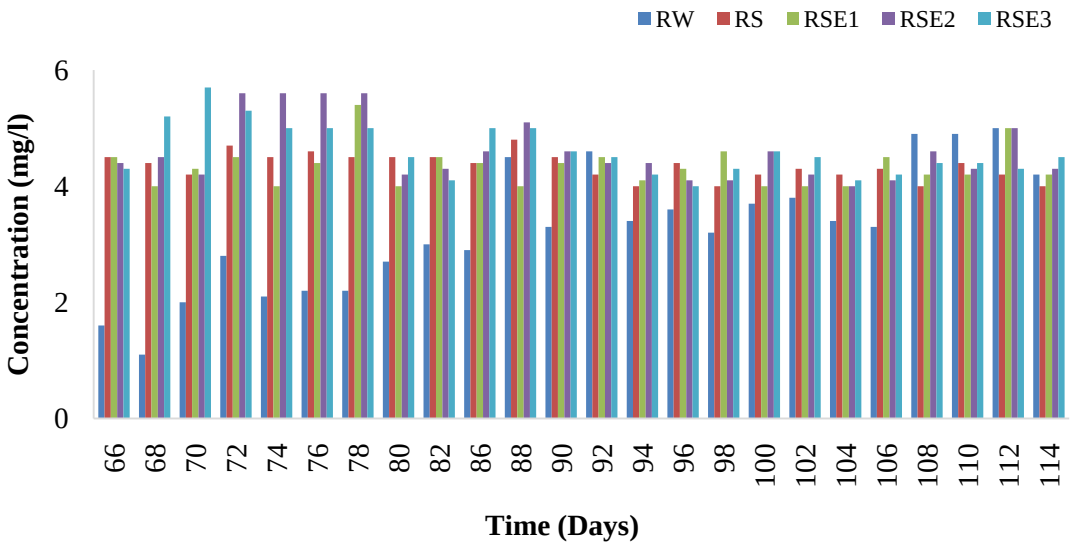

Figure 4.27: Dissolved Oxygen concentration at HRT 9.12 hrs

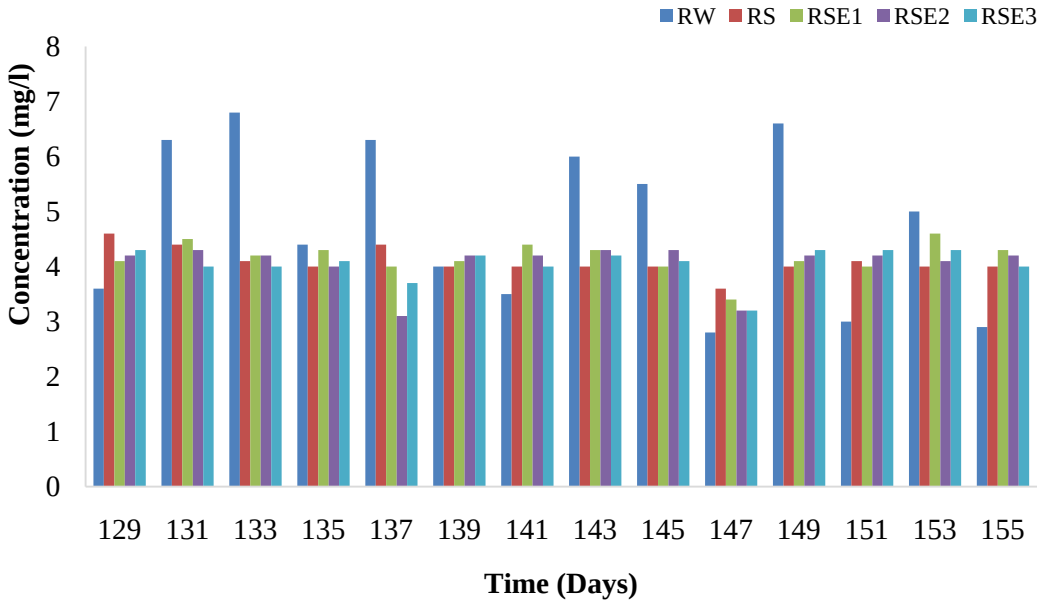

Figure 4.28: Dissolved Oxygen concentration at HRT 0.46 hrs

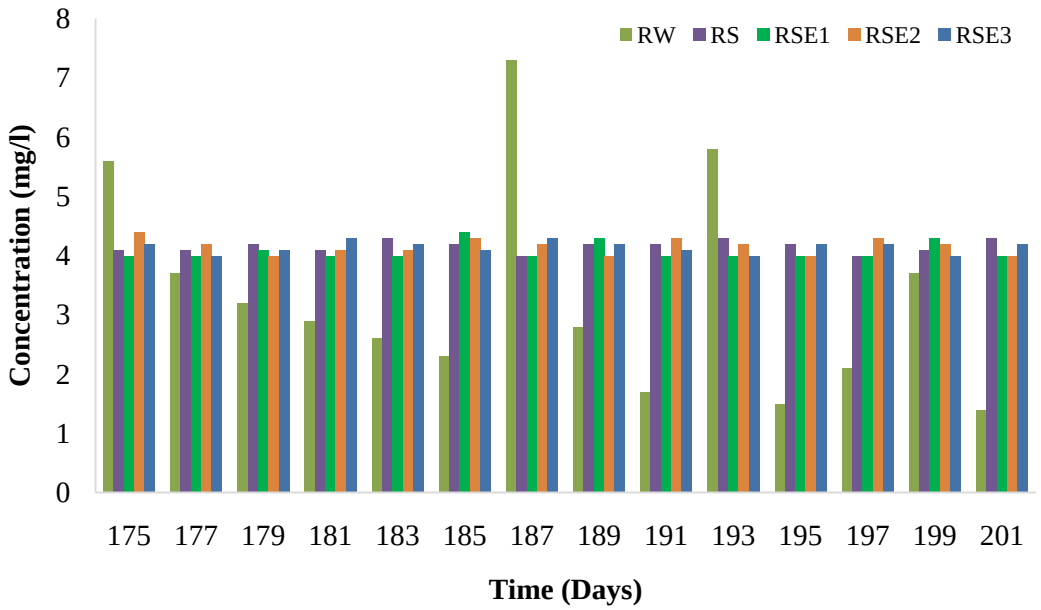

Figure 4.29: Dissolved Oxygen concentration at HRT 0.91 hrs

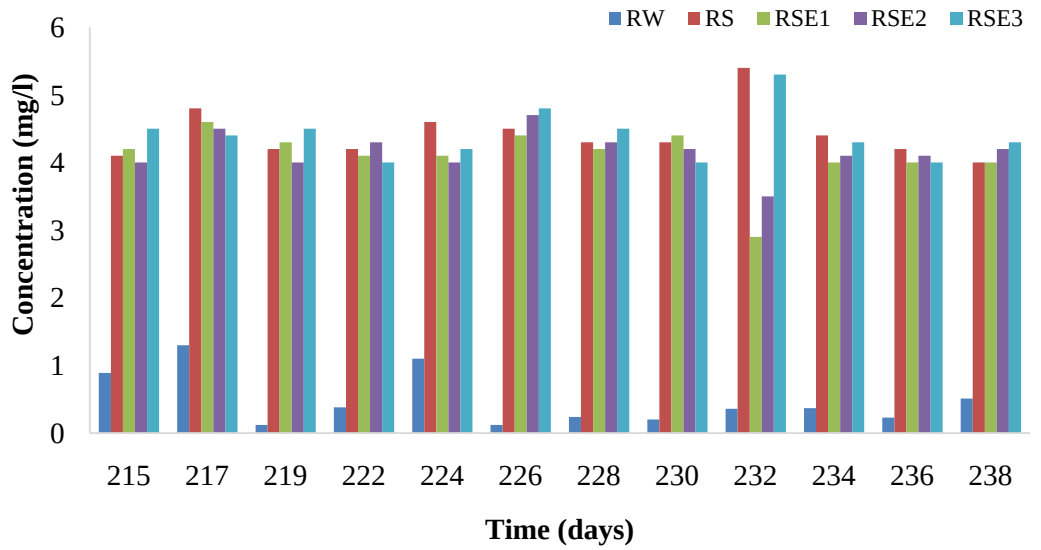

Figure 4.30: Dissolved Oxygen concentration at HRT 1.82 hrs

4.6 Temperature

Temperature plays a crucial role in the function of the bacteria and their growth. Temperature was taken of the effluent of each of the reactors. Temperature in the reactor was maintained to keep the bacterial population

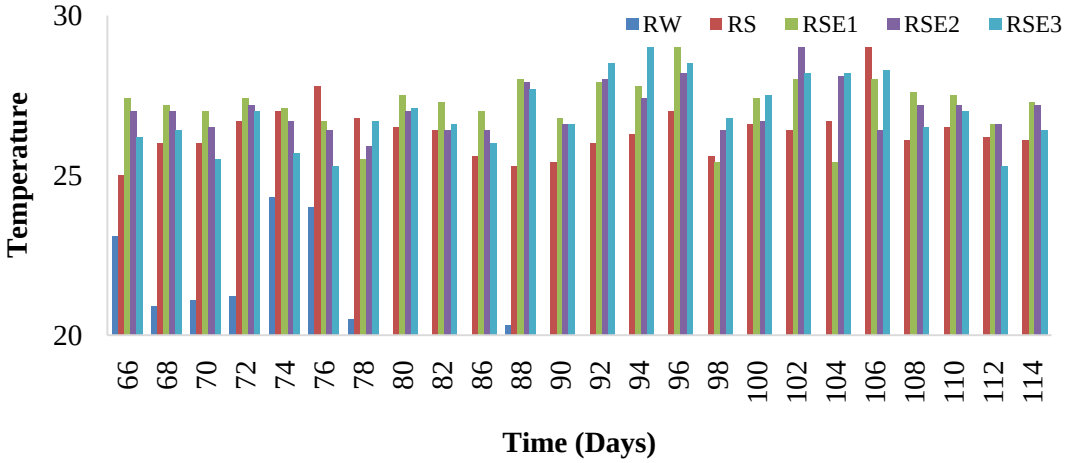

Figure 4.31: Temperature at reactors at HRT 9.12 hrs

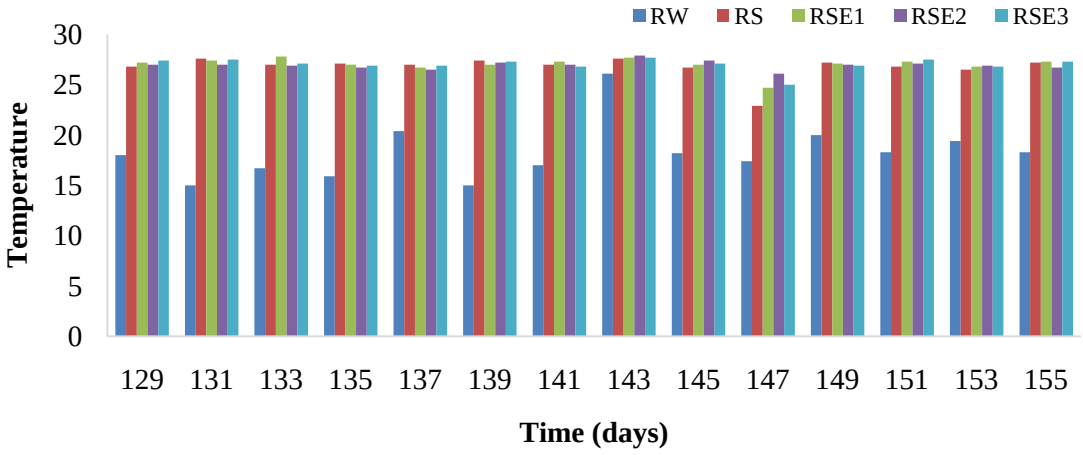

Figure 4.32: Temperature at reactors at HRT 0.46 hrs

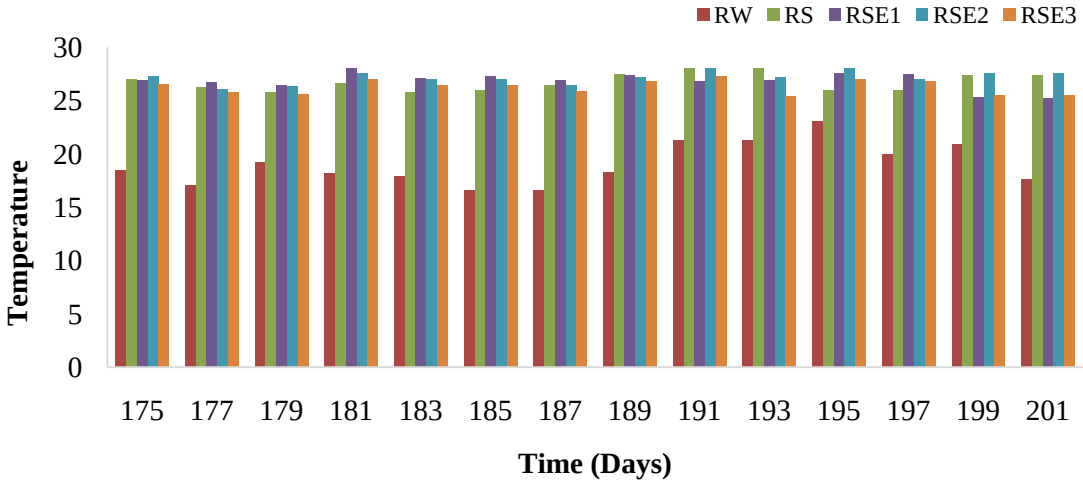

Figure 4.33: Temperature at reactors at HRT 0.91 hrs

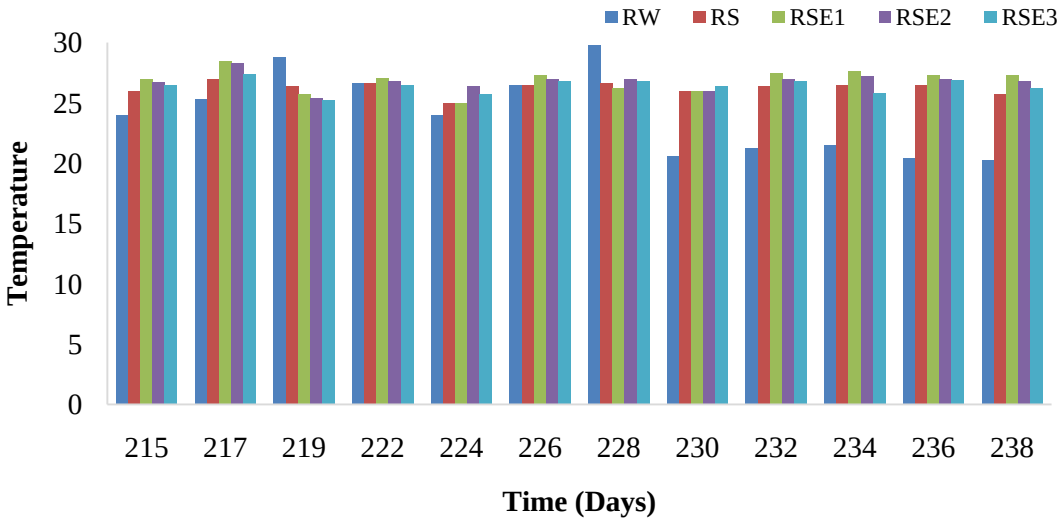

Figure 4.34: Temperature at reactors at HRT 1.82 hrs

Temperature was maintained at 27±2˚C using heaters in the reactors.

4.7 Efficiency

The removal efficiency of ammonia is found to be higher in the reactor in the HRT of 9.12 hrs. Low removal efficiency was observed at HRT of 0.46 hrs. This is low retention time allowing less time of contact of water with oxygen and the bacteria. The formation of nitrate was found to be in fluctuating trend which might be due to incomplete oxidation of nitrite.

The removal percent of ammonia was observed higher in case of higher ammonia load in the reactor as compared to low ammonia concentration and in high retention time in the reactor. The average removal efficiency of 98.93%, 25.87%, 44.71% and 59.43% was found in series reactor at HRT of 9.12, 0.46, 0.91 and 1.82 hrs respectively whereas in case of single reactor, the removal efficiency was found to be 92.30%, 20.66%, 37.12% and 51.62% at HRT of 9.12, 0.46, 0.91 and 1.82 hrs respectively. The removal efficiency of series reactors was thus found to be higher as compared to single reactor according to the study conducted. This might be due to proper mixing and contact of the influent water with the oxygen and bacteria as compared to the single reactor. The efficiency of the removal of single and series reactor is shown in figure 4.35 to figure 4.38 below.

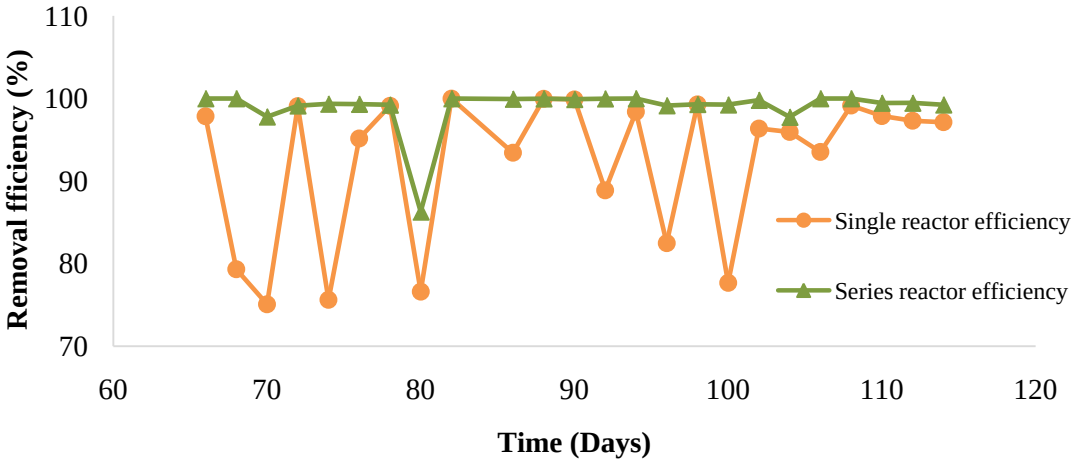

Figure 4.35: Efficiency of single vs series reactor for HRT of 9.12 hrs

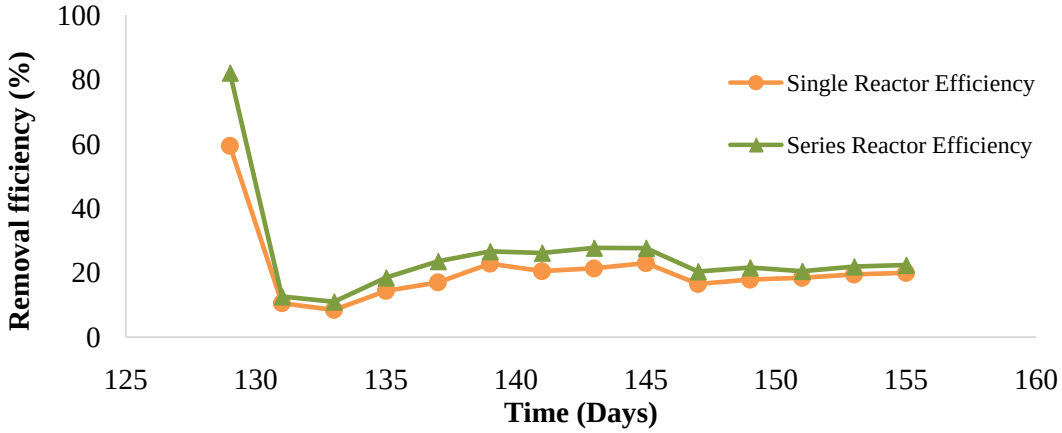

Figure 4.36: Efficiency of single vs series reactor for HRT of 0.46 hrs

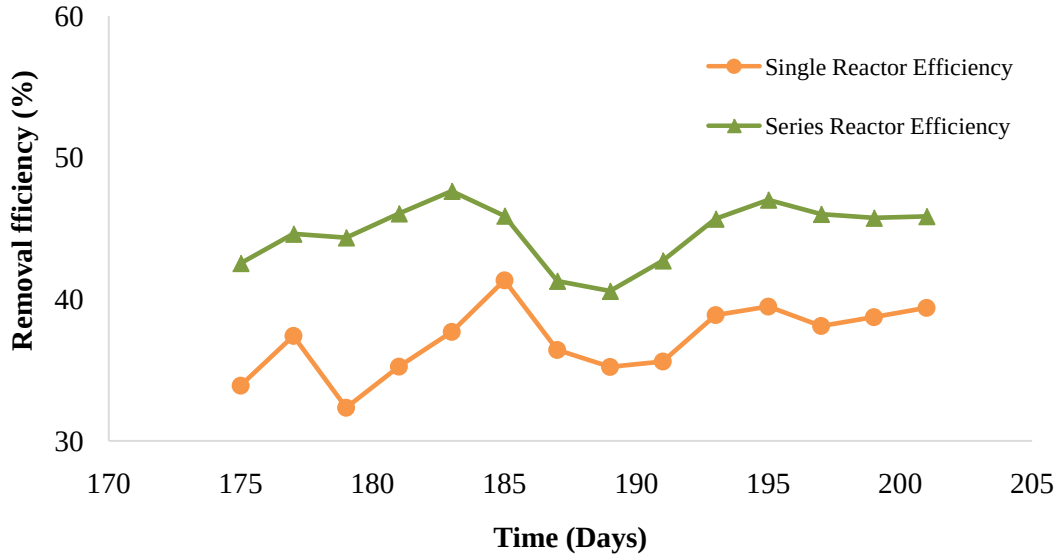

Figure 4.37: Efficiency of single vs series reactor for HRT of 0.91hrs

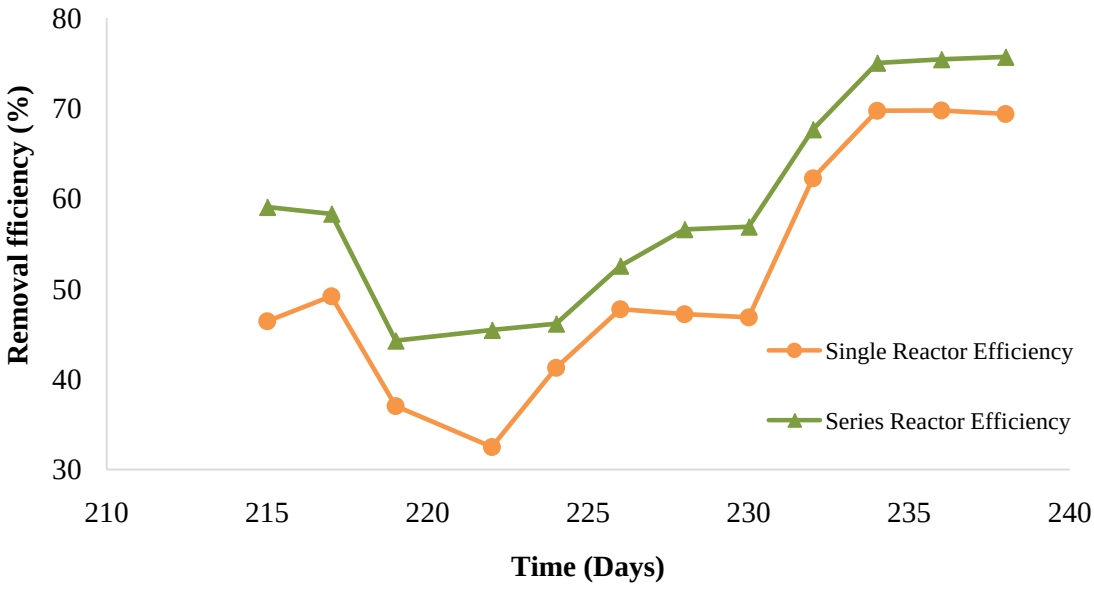

Figure 4.38: Efficiency of single vs series reactor for HRT of 1.82 hrs

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Different research has been carried out using different methods in order to remove nitrogen from the groundwater as it has been one of the global issues. Various chemical process and physical process have been developed for the nitrogen removal but theses process are costly and render by products that requires further treatment. However, the biological treatment is less expensive and renders no harmful end products. This has developed an interest among the researchers to study various biological methods that can be employed in an effective way to address the issues of groundwater contamination with nitrogen.

Various researches are being conducted on the optimal ammonia removal performance of various media in the biological treatment process. Selection of the suitable filter media is critical in the biological operation in order to achieve the desired effluent properties. This research is also conducted to get the better understanding of the performance of the biofringe media and its suitability in the treatment process. The study was proposed and conducted using biofringe media at different hydraulic retention time using two models of reactors i.e. placing reactor in single and placing equivalent height of reactor in series. The effect of the hydraulic retention time on the performance of the biological process using biofringe media in two different models of reactor was the main purpose of the study.

Various variations and fluctuations was difficult to be kept under control since the study was conducted directly on the site. Temperature and DO was directly taken from the site and the data of temperature and DO was taken from the effluent. Temperature was not significantly different among the reactors . The difference of 27±2˚C was maintained among the reactors during the study period . The temperature of 25˚C to 29˚C was able to be kept using heaters throughout the study period. This range of temperature was considered to be satisfactory for the performance of nitrifying bacteria. pH was found to vary between 7 to 9.18. Higher pH was found in the reactors than the influent water which might be due to the accumulation of nitrite in the reactors. DO was maintained above 4 mg/l throughout the study period in all the reactors.

Ammonia reduction was found to be satisfactory in both model of reactors however it was found higher in case of the series reactor as compared to single reactor. Nitrite oxidation was observed to quite unsatisfactory thus leading to low formation of nitrate which was observed in high flow rate of influent water. The unprecedented accumulation of nitrite can be attributed to the inadequate contact of water in the reactor with the bacteria due to the movement of water in the reactor because of the upward flow of oxygen creating the vertical current in the reactor leading to short detention time than the theoretical detention time.

In spite of the problems faced during the study and incomplete oxidation into nitrate, performance difference was observed between the two different model of reactors. Efficiency of the series reactor was found higher as compared to the single reactor. The difference may seem small in this scale but it is quite sure to make significant impact in a large scale.

This study was focused to determine the performance of the media at different HRT in two different models of reactor. Series placing of the same diameter of the reactor gave better performance at high HRT as compared to the single reactor. Hence series reactor can be concluded to perform better at high ammonia load of influent using biofringe media at high HRT of 9.12 hours using biofringe media as compared to single reactor.

5.2 Recommendations

Incomplete nitrification reaction was observed during the study period, thus better comparison can be done with complete nitrification process and derivation of proper mathematical equation can be done. Some of the works that can be done for the further detailed studies are listed below:

a. The optimum reactor size can be studied for the complete nitrification process in the same site condition.
b. The study of performance of the reactors using single and double yarn of biofringe media in the reactors can be done.
c. The performance of the reactors using biofringe media at varying temperature at the given hydraulic retention time can be studied to observe the performance of the bacteria in the reactor.

d. The study of biological process can be done at different time within the day at the given hydraulic retention time.
e. The minimum requirement of oxygen gas and its optimization can be studied.

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APPENDICES

ANNEX-1: Test Data and Calculations

ANNEX-2: Test Procedures

ANNEX-3: Photographs

ANNEX-1: Test Data and Calculations

1. HRT 9.12 hrs

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample date**	**Sample type**	**pH**	**Tempt.**	**DO**	**HCO3- (ppm)**	**NH4-N**	**NO2-N**	**NO3-N**
1	66	RAW WATER	**7.37**	**23.1**	**1.6**	**863.15**	**105.77**	**0.01**	**0.44**
		R	**7**	**25**	**4.5**	**192.15**	**2.28**	**46.62**	**52.79**
		R1	**7.36**	**26.2**	**4.3**	**143.35**	**-0.08**	**37.80**	**66.08**
		R2	**7.55**	**27**	**4.4**	**149.45**	**-0.06**	**39.74**	**65.09**
		R3	**7.55**	**27.4**	**4.5**	**661.85**	**43.32**	**9.10**	**51.60**
2	68	RAW WATER	**7.22**	**20.9**	**1.1**	**850.95**	**91.08**	**0.01**	**0.45**
		R	**7.45**	**26**	**4.4**	**283.65**	**18.84**	**32.43**	**31.76**
		R1	**7.57**	**26.4**	**5.2**	**149.45**	**0.00**	**31.09**	**55.91**
		R2	**7.3**	**27**	**4.5**	**164.7**	**0.02**	**32.43**	**49.27**
		R3	**7.51**	**27.2**	**4**	**423.95**	**33.08**	**19.88**	**32.95**
3	70	RAW WATER	**7.3**	**21.1**	**2**	**863.15**	**102.48**	**0.01**	**0.39**
		R	**7.95**	**26**	**4.2**	**350.75**	**25.53**	**37.71**	**31.06**
		R1	**7.58**	**25.5**	**5.7**	**149.45**	**2.26**	**42.99**	**41.88**
		R2	**7.56**	**26.5**	**4.2**	**320.25**	**11.65**	**47.32**	**35.03**
		R3	**7.52**	**27**	**4.3**	**527.65**	**39.74**	**35.81**	**29.52**
4	72	RAW WATER	**8.88**	**21.2**	**2.8**	**765.55**	**115.90**	**2.67**	**2.19**
		R	**7.79**	**26.7**	**4.7**	**112.85**	**1.07**	**38.25**	**73.44**
		R1	**7.42**	**27**	**5.3**	**106.75**	**1.01**	**30.74**	**83.53**

		Sample basic information					Avg. Concentration mg/l		
SN.	Sample	Sample type	pH	Tempt.	DO	HCO3-	NH4-	NO2-N	NO3-
		R2	**7.84**	**27.2**	**5.6**	**125.05**	**1.35**	**37.16**	**81.45**
		R3	**7.5**	**27.4**	**4.5**	**173.85**	**3.86**	**44.44**	**71.30**
5	74	RAW WATER	**8.98**	**24.3**	**2.1**	**808.25**	**144.21**	**1.92**	**2.49**
		R	**8.23**	**27**	**4.5**	**372.1**	**35.16**	**35.86**	**75.15**
		R1	**7.39**	**25.7**	**5**	**91.5**	**0.93**	**48.23**	**90.16**
		R2	**7.43**	**26.7**	**5.6**	**100.65**	**1.13**	**51.81**	**82.80**
		R3	**7.55**	**27.1**	**4**	**115.9**	**3.30**	**52.48**	**79.97**
6	76	RAW WATER	**8.66**	**24**	**2.2**	**796.05**	**130.06**	**3.60**	**2.38**
		R	**7.78**	**27.8**	**4.6**	**118.95**	**6.29**	**33.43**	**85.98**
		R1	**7.52**	**25.3**	**5**	**24.4**	**0.87**	**35.78**	**90.72**
		R2	**7.71**	**26.4**	**5.6**	**30.5**	**1.18**	**39.65**	**87.74**
		R3	**7.96**	**26.7**	**4.4**	**381.25**	**31.88**	**39.80**	**63.08**
7	78	RAW WATER	**7.94**	**20.5**	**2.2**	**805.2**	**121.40**	**3.64**	**2.56**
		R	**7.65**	**26.8**	**4.5**	**76.25**	**1.07**	**34.72**	**88.94**
		R1	**7.74**	**26.7**	**5**	**54.9**	**0.93**	**35.78**	**89.69**
		R2	**7.95**	**25.9**	**5.6**	**64.05**	**1.00**	**28.44**	**89.65**
		R3	**7.88**	**25.5**	**5.4**	**76.25**	**1.34**	**36.96**	**84.50**
8	80	RAW WATER	**8.16**	**19.8**	**2.7**	**844.85**	**108.83**	**0.06**	**2.42**
		R	**7.66**	**26.5**	**4.5**	**344.65**	**25.44**	**39.15**	**41.19**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample type**	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-N**	**NO3-**
		R1	**7.67**	**27.1**	**4.5**	**228.75**	**14.93**	**42.69**	**40.14**
		R2	**7.55**	**27**	**4.2**	**283.65**	**17.17**	**54.83**	**38.95**
		R3	**7.82**	**27.5**	**4**	**362.95**	**26.88**	**39.76**	**27.69**
9	82	RAW WATER	**8.2**	**19.1**	**3**	**823.5**	**91.23**	**0.12**	**4.99**
		R	**7**	**26.4**	**4.5**	**97.6**	**0.01**	**1.19**	**85.89**
		R1	**7.39**	**26.6**	**4.1**	**85.4**	**-0.01**	**0.03**	**88.15**
		R2	**7.26**	**26.4**	**4.3**	**103.7**	**0.02**	**0.05**	**87.01**
		R3	**7**	**27.3**	**4.5**	**222.65**	**9.58**	**0.29**	**84.11**
10	86	RAW WATER	**7.99**	**17.4**	**2.9**	**802.15**	**90.88**	**0.21**	**4.92**
		R	**7.3**	**25.6**	**4.4**	**94.55**	**5.97**	**9.31**	**79.09**
		R1	**7.42**	**26**	**5**	**115.9**	**0.06**	**3.20**	**87.55**
		R2	**7.37**	**26.4**	**4.6**	**198.25**	**0.17**	**4.08**	**89.11**
		R3	**7.22**	**27**	**4.4**	**198.25**	**7.05**	**8.56**	**71.71**
11	88	RAW WATER	**7.15**	**20.3**	**4.5**	**820.45**	**94.74**	**0.06**	**4.15**
		R	**7.57**	**25.3**	**4.8**	**137.25**	**0.03**	**3.55**	**88.24**
		R1	**7.22**	**27.7**	**5**	**97.6**	**0.02**	**3.09**	**91.45**
		R2	**7.74**	**27.9**	**5.1**	**115.9**	**0.07**	**0.32**	**86.13**
		R3	**7.65**	**28**	**4**	**228.75**	**0.14**	**0.14**	**86.06**
12	90	RAW	**9.53**	**15.6**	**3.3**	**878.4**	**105.91**	**0.02**	**1.69**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample type** WATER	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-N**	**NO3-**
		R	**8.01**	**25.4**	**4.5**	**94.55**	**0.11**	**4.16**	**89.40**
		R1	**7.17**	**26.6**	**4.6**	**106.75**	**0.09**	**10.49**	**82.55**
		R2	**7.88**	**26.6**	**4.6**	**216.55**	**0.31**	**12.32**	**83.37**
		R3	**7.82**	**26.8**	**4.4**	**369.05**	**28.55**	**8.28**	**69.63**
13	92	RAW WATER	**9.04**	**19**	**4.6**	**814.35**	**98.48**	**0.05**	**4.00**
		R	**8.96**	**26**	**4.2**	**253.15**	**10.95**	**16.34**	**74.79**
		R1	**7.88**	**28.5**	**4.5**	**64.05**	**0.02**	**19.93**	**88.03**
		R2	**7.91**	**28**	**4.4**	**118.95**	**0.09**	**12.81**	**80.09**
		R3	**7.68**	**27.9**	**4.5**	**625.25**	**36.44**	**7.91**	**57.47**
14	94	RAW WATER	**9.1**	**19.8**	**3.4**	**869.25**	**103.43**	**0.06**	**4.25**
		R	**8.05**	**26.3**	**4**	**204.35**	**1.66**	**15.82**	**82.98**
		R1	**8.01**	**29**	**4.2**	**106.75**	**0.00**	**8.23**	**86.63**
		R2	**8.21**	**27.4**	**4.4**	**143.35**	**0.02**	**10.85**	**81.39**
		R3	**8.25**	**27.8**	**4.1**	**661.85**	**27.98**	**0.47**	**76.60**
16	96	RAW WATER	**8.8**	**13.9**	**3.6**	**881.45**	**122.06**	**0.60**	**1.58**
		R	**8.41**	**27**	**4.4**	**314.15**	**21.38**	**15.09**	**87.33**
		R1	**7.81**	**28.5**	**4**	**97.6**	**1.04**	**31.78**	**84.60**
		R2	**7.78**	**28.2**	**4.1**	**131.15**	**1.71**	**36.30**	**83.29**
		R3	**7.96**	**29**	**4.3**	**588.65**	**37.52**	**4.46**	**77.62**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample type**	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-N**	**NO3-**
17	98	RAW WATER	**8.55**	**15.1**	**3.2**	**869.25**	**136.69**	**0.61**	**1.76**
		R	**8.09**	**25.6**	**4**	**103.7**	**0.98**	**30.17**	**96.28**
		R1	**7.48**	**26.8**	**4.3**	**94.55**	**0.95**	**27.26**	**98.80**
		R2	**7.6**	**26.4**	**4.1**	**149.45**	**1.16**	**34.57**	**98.33**
		R3	**7.95**	**25.4**	**4.6**	**625.25**	**36.19**	**15.22**	**79.86**
18	100	RAW WATER	**8.45**	**11.9**	**3.7**	**866.2**	**141.23**	**0.68**	**1.23**
		R	**8.32**	**26.6**	**4.2**	**356.85**	**31.54**	**45.38**	**63.84**
		R1	**7.7**	**27.5**	**4.6**	**100.65**	**1.06**	**35.55**	**99.67**
		R2	**7.53**	**26.7**	**4.6**	**173.85**	**1.78**	**39.03**	**97.96**
		R3	**8.14**	**27.4**	**4**	**600.85**	**36.96**	**35.73**	**65.34**
19	102	RAW WATER	**7.89**	**14.4**	**3.8**	**854**	**102.45**	**0.10**	**1.32**
		R	**7.38**	**26.4**	**4.3**	**350.75**	**3.72**	**66.96**	**37.92**
		R1	**7.48**	**28.2**	**4.5**	**179.95**	**0.20**	**37.85**	**53.87**
		R2	**7.25**	**29**	**4.2**	**277.55**	**8.74**	**60.40**	**33.80**
		R3	**7.72**	**28**	**4**	**610**	**59.49**	**14.33**	**23.89**
20	104	RAW WATER	**7.74**	**11**	**3.4**	**857.05**	**92.25**	**0.85**	**1.59**
		R	**7.55**	**26.7**	**4.2**	**347.7**	**3.74**	**46.01**	**35.53**
		R1	**7.3**	**28.2**	**4.1**	**381.25**	**2.06**	**36.73**	**55.19**
		R2	**7.25**	**28.1**	**4**	**527.65**	**3.99**	**44.48**	**38.79**

		Sample basic information					Avg. Concentration mg/l		
SN.	Sample	Sample type	pH	Tempt.	DO	HCO3-	NH4-	NO2-N	NO3-
		R3	7.74	25.4	4	786.9	4.03	51.98	28.11
20	106	RAW WATER	7.84	13.6	3.3	976	91.64	0.19	0.69
		R	7.82	29	4.3	204.35	5.93	24.58	51.22
		R1	7.4	28.3	4.2	155.55	-0.45	17.74	74.99
		R2	7.64	26.4	4.1	164.7	-0.14	15.67	73.82
		R3	7.72	28	4.5	692.35	33.96	14.21	39.94
20	108	RAW WATER	8.8	14.9	4.9	1195.6	88.54	0.45	1.14
		R	8.38	26.1	4	164.7	0.75	37.29	44.85
		R1	8.2	26.5	4.4	137.25	-0.41	0.30	79.43
		R2	8.8	27.2	4.6	146.4	-0.33	8.86	76.65
		R3	8.02	27.6	4.2	131.15	10.26	30.85	40.88
20	110	RAW WATER	8.19	14.9	4.9	915	127.22	0.54	1.11
		R	8.06	26.5	4.4	186.05	2.70	40.41	73.60
		R1	7.6	27	4.4	112.85	0.69	37.64	86.93
		R2	7.76	27.2	4.3	131.15	1.38	38.80	84.91
		R3	7.92	27.5	4.2	183	3.38	44.75	71.05
20	112	RAW WATER	7.88	14.6	5	951.6	128.28	0.51	0.95
		R	8.55	26.2	4.2	356.85	3.45	45.76	72.90
		R1	8.5	25.3	4.3	152.5	0.68	42.00	82.17

		Sample basic information					Avg. Concentration mg/l		
SN.	Sample	Sample type	pH	Tempt.	DO	HCO3-	NH4-	NO2-N	NO3-
		R2	**8.3**	**26.6**	**5**	**183**	**1.40**	**42.06**	**78.11**
		R3	**8.44**	**27.2**	**4.1**	**372.1**	**3.74**	**51.98**	**66.40**
20	114	RAW WATER	**8**	**16.2**	**4.2**	**939.4**	**129.25**	**0.74**	**1.12**
		R	**7.49**	**26.1**	**4**	**622.2**	**3.71**	**52.09**	**73.40**
		R1	**7.53**	**26.4**	**4.5**	**128.1**	**0.98**	**41.50**	**85.52**
		R2	**7.28**	**27.2**	**4.3**	**143.35**	**0.99**	**42.79**	**78.39**
		R3	**7.86**	**27.3**	**4.2**	**634.4**	**4.05**	**51.03**	**69.83**

2. HRT 0.46 hrs

		Sample basic information					Avg. Concentration mg/l		
SN.	Sample date	Sample type	pH	DO	Tempt.	HCO3- (ppm)	NH4-N	NO2-N	NO3-N
1	129	RAW WATER	**8.53**	**3.6**	**18**	**854**	**127.79**	**0.27**	**4.46**
		R	**8.58**	**4.6**	**26.8**	**451.4**	**51.86**	**48.27**	**31.91**
		R1	**7.56**	**4.3**	**27.4**	**183**	**22.92**	**75.99**	**33.56**
		R2	**7.67**	**4.2**	**27**	**640.5**	**77.46**	**28.24**	**22.16**
		R3	**7.34**	**4.1**	**27.2**	**762.5**	**107.14**	**7.25**	**16.54**
2	131	RAW WATER	**8.6**	**6.3**	**15**	**908.9**	**117.66**	**0.33**	**1.00**
		R	**8.25**	**4.4**	**27.6**	**915**	**105.28**	**3.84**	**2.65**
		R1	**7.89**	**4**	**27.5**	**860.1**	**102.87**	**5.70**	**2.39**
		R2	**7.73**	**4.3**	**27**	**884.5**	**115.42**	**3.30**	**1.40**
		R3	**7.83**	**4.5**	**27.4**	**884.5**	**116.75**	**3.96**	**2.27**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**DO**	**Tempt.**	**HCO3-**	**NH4-**	**NO2-**	**NO3-**
3	133	RAW WATER	**8.7**	**6.8**	**16.7**	**957.7**	**116.30**	**0.21**	**0.78**
		R	**8.2**	**4.1**	**27**	**878.4**	**106.51**	**7.46**	**3.31**
		R1	**8.03**	**4**	**27.1**	**835.7**	**103.55**	**8.97**	**3.04**
		R2	**7.97**	**4.2**	**26.9**	**902.8**	**109.16**	**5.35**	**2.66**
		R3	**7.87**	**4.2**	**27.8**	**945.5**	**114.03**	**1.32**	**1.82**
3	135	RAW WATER	**8.13**	**4.9**	**16**	**933.3**	**139.66**	**0.23**	**0.85**
		R	**7.96**	**4**	**26.8**	**847.9**	**119.65**	**8.25**	**5.21**
		R1	**7.79**	**4.2**	**27.1**	**823.5**	**113.92**	**8.90**	**6.78**
		R2	**8.61**	**4**	**27.3**	**884.5**	**125.47**	**2.10**	**4.43**
		R3	**8.41**	**4.4**	**27.6**	**908.9**	**136.49**	**0.03**	**3.24**
4	137	RAW WATER	**8.44**	**4.4**	**15.9**	**915**	**126.60**	**0.25**	**1.24**
		R	**7.76**	**4**	**27.1**	**793**	**105.13**	**7.35**	**9.59**
		R1	**8.25**	**4.1**	**26.9**	**823.5**	**96.85**	**10.36**	**10.57**
		R2	**8.67**	**4**	**26.7**	**854**	**104.18**	**8.49**	**7.35**
		R3	**8.69**	**4.3**	**27**	**878.4**	**105.64**	**8.99**	**5.45**
5	139	RAW WATER	**8.01**	**6.3**	**20.4**	**915**	**135.15**	**0.18**	**1.05**
		R	**8.16**	**4.4**	**27**	**847.9**	**104.35**	**15.21**	**5.30**
		R1	**8.05**	**3.7**	**26.9**	**829.6**	**99.22**	**27.04**	**7.73**
		R2	**8.44**	**3.1**	**26.5**	**860.1**	**105.30**	**24.35**	**5.66**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**DO**	**Tempt.**	**HCO3-**	**NH4-**	**NO2-**	**NO3-**
		R3	**7.9**	**4**	**26.7**	**878.4**	**106.81**	**16.50**	**4.23**
6	141	RAW WATER	**7.79**	**4**	**15**	**915**	**117.18**	**0.21**	**1.33**
		R	**8.7**	**4**	**27.4**	**823.5**	**93.19**	**5.99**	**9.10**
		R1	**8.82**	**4.2**	**27.3**	**762.5**	**86.57**	**6.95**	**14.19**
		R2	**8.66**	**4.2**	**27.2**	**835.7**	**96.40**	**3.83**	**8.24**
		R3	**8.05**	**4.1**	**27**	**884.5**	**99.36**	**2.04**	**5.47**
7	143	RAW WATER	**8.29**	**3.5**	**17**	**884.5**	**107.70**	**0.19**	**0.52**
		R	**8.85**	**4**	**27**	**829.6**	**84.74**	**7.12**	**3.00**
		R1	**8.7**	**4**	**26.8**	**793**	**77.88**	**12.61**	**2.33**
		R2	**8.9**	**4.2**	**27**	**854**	**88.03**	**5.02**	**2.48**
		R3	**8.79**	**4.4**	**27.3**	**878.4**	**88.71**	**2.72**	**2.43**
8	145	RAW WATER	**8.35**	**6**	**26.1**	**902.8**	**117.05**	**0.13**	**0.53**
		R	**8.74**	**4**	**27.6**	**860.1**	**90.17**	**6.81**	**2.50**
		R1	**8.77**	**4.2**	**27.7**	**835.7**	**84.74**	**5.69**	**1.93**
		R2	**8.82**	**4.3**	**27.9**	**884.5**	**91.64**	**3.42**	**2.13**
		R3	**8.91**	**4.3**	**27.7**	**890.6**	**95.14**	**2.15**	**2.39**
9	147	RAW WATER	**8.4**	**5.5**	**18.2**	**896.7**	**119.36**	**0.22**	**0.77**
		R	**8.49**	**4**	**26.7**	**835.7**	**99.69**	**10.49**	**3.67**
		R1	**8.3**	**4.1**	**27.1**	**823.5**	**95.06**	**6.70**	**3.28**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**DO**	**Tempt.**	**HCO3-**	**NH4-**	**NO2-**	**NO3-**
		R2	**8.45**	**4.3**	**27.4**	**854**	**103.27**	**4.63**	**2.53**
		R3	**8.5**	**4**	**27**	**884.5**	**114.46**	**3.08**	**2.99**
11	149	RAW WATER	**8.45**	**6.6**	**20**	**951.6**	**112.01**	**0.12**	**0.38**
		R	**8.5**	**4**	**27.2**	**793**	**92.03**	**5.92**	**2.86**
		R1	**8.67**	**4.3**	**26.9**	**762.5**	**87.85**	**11.01**	**3.74**
		R2	**8.17**	**4.2**	**27**	**884.5**	**101.74**	**6.91**	**1.92**
		R3	**8.35**	**4.1**	**27.1**	**896.7**	**104.23**	**3.20**	**2.27**
12	151	RAW WATER	**8.43**	**3**	**18.3**	**896.7**	**112.33**	**0.36**	**0.62**
		R	**8.74**	**4.1**	**26.8**	**829.6**	**91.68**	**8.26**	**3.76**
		R1	**8.64**	**4.3**	**27.5**	**799.1**	**89.36**	**11.48**	**4.22**
		R2	**8.59**	**4.2**	**27.1**	**847.9**	**100.04**	**6.49**	**3.30**
		R3	**8.53**	**4**	**27.3**	**872.3**	**101.10**	**2.85**	**1.10**
13	153	RAW WATER	**8.2**	**5**	**19.4**	**915**	**128.61**	**0.13**	**0.93**
		R	**8.95**	**4**	**26.5**	**841.8**	**103.60**	**13.33**	**4.07**
		R1	**8.48**	**4.3**	**26.8**	**744.2**	**100.49**	**15.83**	**4.31**
		R2	**8.22**	**4.1**	**26.9**	**878.4**	**108.59**	**7.84**	**3.62**
		R3	**8.17**	**4.6**	**26.8**	**902.8**	**114.55**	**4.03**	**1.33**
14	155	RAW WATER	**8**	**2.9**	**18.3**	**890.6**	**117.18**	**0.27**	**0.93**
		R	**8.59**	**4**	**27.2**	**811.3**	**93.81**	**7.54**	**6.78**

		Sample basic information					Avg. Concentration mg/l		
SN.	Sample	Sample	pH	DO	Tempt.	HCO3-	NH4-	NO2-	NO3-
		R1	8.35	4	27.3	658.8	90.97	13.05	7.70
		R2	8.4	4.2	26.7	823.5	91.86	10.93	3.97
		R3	8.45	4.3	27.3	878.4	102.98	2.84	2.30

3. HRT 0.91 hrs

		Sample basic information					Avg. Concentration mg/l		
SN.	Sample date	Sample type	pH	Tempt.	DO	HCO3- (ppm)	NH4-N	NO2-N	NO3-N
1	175	RAW WATER	7.51	18.5	5.6	915	123.04	0.22	0.47
		R	8.74	27	4.1	689.3	81.33	27.80	7.91
		R3	8.5	26.5	4.2	622.2	70.70	38.70	8.64
		R2	8.32	27.3	4.4	725.9	88.09	24.73	6.40
		R1	8.4	26.9	4	738.1	96.78	16.29	5.23
2	177	RAW WATER	7.54	17.1	3.7	915	140.74	0.38	0.61
		R	8.6	26.2	4.1	732	88.09	41.99	8.52
		R3	8.58	25.8	4	640.5	77.95	53.20	9.16
		R2	8.59	26.1	4.2	725.9	92.34	36.37	5.49
		R1	8.53	26.7	4	866.2	104.03	28.11	4.69
3	179	RAW WATER	7.85	19.2	3.2	896.7	123.05	0.06	0.09
		R	8.88	25.8	4.2	622.2	83.26	35.42	7.37
		R3	8.24	25.6	4.1	524.6	68.48	42.51	8.07
		R2	8.5	26.3	4	732	88.57	30.70	4.46

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-**	**NO3-N**
		R1	**8.55**	**26.4**	**4.1**	**823.5**	**101.71**	**18.98**	**3.39**
4	181	RAW WATER	**7.82**	**18.2**	**2.9**	**915**	**131.40**	**0.51**	**0.90**
		R	**8.2**	**26.6**	**4.1**	**689.3**	**85.09**	**36.28**	**9.59**
		R3	**8.25**	**27**	**4.3**	**610**	**70.89**	**47.23**	**10.01**
		R2	**8.15**	**27.6**	**4.1**	**732**	**95.33**	**30.10**	**7.07**
		R1	**8.3**	**28**	**4**	**829.6**	**108.65**	**13.78**	**5.63**
5	183	RAW WATER	**7.9**	**17.9**	**2.6**	**908.9**	**135.94**	**0.33**	**0.70**
		R	**8.49**	**25.8**	**4.3**	**701.5**	**84.71**	**42.99**	**8.96**
		R3	**8.55**	**26.4**	**4.2**	**549**	**71.18**	**55.97**	**9.41**
		R2	**8.4**	**27**	**4.1**	**713.7**	**93.40**	**32.69**	**5.70**
		R1	**8.36**	**27.1**	**4**	**780.8**	**103.06**	**27.24**	**5.09**
6	185	RAW WATER	**7.92**	**16.6**	**2.3**	**933.3**	**146.53**	**0.72**	**1.53**
		R	**8.72**	**26**	**4.2**	**732**	**85.96**	**42.90**	**10.51**
		R3	**7.92**	**26.4**	**4.1**	**646.6**	**79.30**	**49.74**	**11.06**
		R2	**8.35**	**27**	**4.3**	**713.7**	**95.72**	**38.32**	**7.65**
		R1	**8.39**	**27.3**	**4.4**	**854**	**117.07**	**21.44**	**6.48**
7	187	RAW WATER	**8.12**	**16.6**	**7.3**	**908.9**	**136.87**	**0.17**	**0.38**
		R	**8.84**	**26.4**	**4**	**732**	**87.03**	**36.90**	**8.49**
		R3	**8.35**	**25.9**	**4.3**	**622.2**	**80.36**	**38.58**	**9.27**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-**	**NO3-N**
		R2	**8.39**	**26.4**	**4.2**	**780.8**	**98.91**	**29.01**	**4.46**
		R1	**8.26**	**26.9**	**4**	**854**	**117.94**	**8.38**	**3.39**
8	189	RAW WATER	**8.13**	**18.3**	**2.8**	**933.3**	**137.03**	**0.15**	**0.74**
		R	**8.1**	**27.5**	**4.2**	**713.7**	**88.77**	**38.14**	**7.19**
		R3	**7.9**	**26.8**	**4.2**	**683.2**	**81.42**	**42.58**	**8.11**
		R2	**8.32**	**27.2**	**4**	**847.9**	**101.61**	**25.21**	**3.30**
		R1	**8.4**	**27.4**	**4.3**	**854**	**112.72**	**13.44**	**1.62**
9	191	RAW WATER	**7.97**	**21.3**	**1.7**	**884.5**	**123.44**	**1.42**	**1.13**
		R	**8.6**	**28**	**4.2**	**640.5**	**79.49**	**34.85**	**8.60**
		R3	**8.43**	**27.3**	**4.1**	**622.2**	**70.70**	**41.31**	**10.05**
		R2	**8.5**	**28**	**4.3**	**762.5**	**91.08**	**25.79**	**5.19**
		R1	**8.37**	**26.8**	**4**	**854**	**110.40**	**11.85**	**4.39**
10	193	RAW WATER	**7.7**	**21.3**	**5.8**	**915**	**140.64**	**0.60**	**0.91**
		R	**8.44**	**28**	**4.3**	**756.4**	**85.96**	**47.49**	**7.83**
		R3	**8.38**	**25.4**	**4**	**646.6**	**76.40**	**52.16**	**8.66**
		R2	**8.4**	**27.2**	**4.2**	**732**	**96.78**	**37.71**	**4.79**
		R1	**8.15**	**26.9**	**4**	**884.5**	**122.38**	**12.23**	**3.70**
11	195	RAW WATER	**7.85**	**23.1**	**1.5**	**915**	**153.85**	**1.56**	**1.16**
		R	**8.6**	**26**	**4.2**	**732**	**93.11**	**47.32**	**9.36**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-**	**NO3-N**
		R3	**8.55**	**27**	**4.2**	**713.7**	**81.52**	**56.06**	**10.59**
		R2	**8.53**	**28**	**4**	**854**	**107.04**	**36.37**	**3.70**
		R1	**8.26**	**27.6**	**4**	**915**	**130.61**	**21.88**	**3.34**
12	197	RAW WATER	**7.8**	**20**	**2.1**	**933.3**	**152.78**	**1.11**	**0.93**
		R	**8.4**	**26**	**4**	**713.7**	**94.56**	**51.17**	**7.07**
		R3	**8.57**	**26.8**	**4.2**	**701.5**	**82.49**	**57.09**	**9.10**
		R2	**8.63**	**27**	**4.3**	**847.9**	**109.34**	**36.85**	**3.09**
		R1	**8.3**	**27.5**	**4**	**854**	**122.38**	**23.87**	**2.05**
13	199	RAW WATER	**7.95**	**20.9**	**3.7**	**896.7**	**140.64**	**0.81**	**0.88**
		R	**8.55**	**27.4**	**4.1**	**701.5**	**86.16**	**44.07**	**6.91**
		R3	**8.59**	**25.5**	**4**	**640.5**	**76.30**	**51.73**	**8.30**
		R2	**8.64**	**27.6**	**4.2**	**823.5**	**104.03**	**32.04**	**2.69**
		R1	**8.53**	**25.3**	**4.3**	**844.85**	**112.72**	**22.52**	**1.54**
14	201	RAW WATER	**8.21**	**17.6**	**1.4**	**884.5**	**136.10**	**1.74**	**1.13**
		R	**8.34**	**27.4**	**4.3**	**622.2**	**82.49**	**47.42**	**7.17**
		R3	**8.62**	**25.5**	**4.2**	**610**	**73.70**	**50.37**	**9.12**
		R2	**8.5**	**27.6**	**4**	**793**	**101.71**	**33.82**	**3.59**
		R1	**8.24**	**25.2**	**4**	**847.9**	**110.40**	**22.91**	**2.79**

4. HRT 1.82 hrs

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample date (Days)**	**Sample type**	**pH**	**Tempt.**	**DO**	**HCO3- (ppm)**	**NH4-N**	**NO2-N**	**NO3-N**
1	215	RAW WATER	**8.14**	**24.00**	**0.89**	**814.35**	**90.27**	**1.73**	**3.77**
		R	**7.5**	**26**	**4.1**	**576.45**	**48.36**	**24.33**	**20.71**
		R1	**7.39**	**26.5**	**4.5**	**515.45**	**36.95**	**26.93**	**21.95**
		R2	**7.19**	**26.7**	**4**	**567.3**	**40.51**	**25.32**	**20.56**
		R3	**7.85**	**27**	**4.2**	**613.05**	**51.59**	**16.44**	**15.86**
2	217	RAW WATER	**8**	**25.30**	**1.3**	**838.75**	**89.27**	**0.26**	**3.00**
		R	**7.9**	**27.00**	**4.8**	**610**	**45.35**	**10.98**	**18.03**
		R1	**7.5**	**27.40**	**4.4**	**579.5**	**37.21**	**25.92**	**20.14**
		R2	**7.32**	**28.3**	**4.5**	**646.6**	**45.67**	**24.95**	**17.82**
		R3	**7.4**	**28.5**	**4.6**	**640.5**	**61.63**	**18.10**	**14.41**
3	219	RAW WATER	**7.97**	**28.8**	**0.12**	**857.05**	**97.89**	**0.57**	**2.17**
		R	**7.1**	**26.4**	**4.2**	**610**	**61.63**	**3.33**	**32.64**
		R1	**7.13**	**25.2**	**4.5**	**603.9**	**54.55**	**22.77**	**14.46**
		R2	**7.21**	**25.4**	**4**	**610**	**63.85**	**14.15**	**15.55**
		R3	**7.76**	**25.7**	**4.3**	**689.3**	**67.86**	**15.46**	**12.09**
4	222	RAW WATER	**7.6**	**26.6**	**0.38**	**866.2**	**79.00**	**0.80**	**1.58**
		R	**7.2**	**26.6**	**4.2**	**610**	**53.32**	**12.31**	**13.35**
		R1	**7.3**	**26.5**	**4**	**600.85**	**43.08**	**18.27**	**15.36**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-**	**NO3-N**
		R2	**7.39**	**26.8**	**4.3**	**649.65**	**55.46**	**9.32**	**11.59**
		R3	**7.4**	**27.1**	**4.1**	**680.15**	**64.00**	**8.16**	**8.64**
5	224	RAW WATER	**8.05**	**24**	**1.1**	**869.25**	**85.80**	**1.00**	**1.29**
		R	**7.57**	**25**	**4.6**	**561.2**	**50.38**	**17.20**	**16.30**
		R1	**7.34**	**25.7**	**4.2**	**549**	**46.20**	**24.30**	**16.05**
		R2	**7.37**	**26.4**	**4**	**585.6**	**51.01**	**21.84**	**14.97**
		R3	**7.5**	**25**	**4.1**	**603.9**	**59.95**	**14.36**	**13.40**
6	226	RAW WATER	**7.35**	**26.5**	**0.12**	**869.25**	**93.73**	**0.09**	**0.06**
		R	**7.25**	**26.5**	**4.5**	**509.35**	**48.96**	**20.00**	**17.43**
		R1	**7.65**	**26.8**	**4.8**	**466.65**	**44.46**	**23.21**	**21.99**
		R2	**7.1**	**27**	**4.7**	**564.25**	**56.17**	**16.32**	**20.47**
		R3	**7.3**	**27.3**	**4.4**	**643.55**	**62.75**	**12.11**	**12.32**
7	228	RAW WATER	**7.46**	**29.8**	**0.24**	**857.05**	**92.92**	**0.09**	**0.16**
		R	**7.38**	**26.6**	**4.3**	**634.4**	**49.05**	**25.31**	**7.76**
		R1	**7.1**	**26.8**	**4.5**	**484.95**	**40.33**	**40.71**	**18.85**
		R2	**7.39**	**27**	**4.3**	**658.8**	**51.01**	**29.76**	**10.26**
		R3	**7.4**	**26.2**	**4.2**	**704.55**	**64.89**	**16.21**	**5.90**
8	230	RAW WATER	**7.23**	**20.6**	**0.2**	**875.35**	**95.82**	**0.00**	**0.40**
		R	**7**	**26**	**4.3**	**631.35**	**50.92**	**28.00**	**12.23**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-**	**NO3-N**
		R1	**7.1**	**26.4**	**4**	**585.6**	**41.30**	**35.48**	**10.70**
		R2	**7.13**	**26**	**4.2**	**643.55**	**55.10**	**21.20**	**10.70**
		R3	**7.2**	**26**	**4.4**	**686.25**	**59.10**	**17.31**	**10.66**
9	232	RAW WATER	**7.3**	**21.3**	**0.36**	**847.9**	**108.77**	**0.00**	**0.40**
		R	**7.2**	**26.4**	**5.4**	**613.05**	**41.04**	**18.10**	**41.22**
		R1	**7.1**	**26.8**	**5.3**	**588.65**	**35.16**	**53.04**	**13.75**
		R2	**7.2**	**27**	**3.5**	**637.45**	**49.23**	**40.71**	**12.37**
		R3	**7.3**	**27.5**	**2.9**	**643.55**	**56.17**	**36.00**	**9.82**
10	234	RAW WATER	**7.3**	**21.5**	**0.37**	**844.85**	**102.54**	**0.01**	**0.75**
		R	**7.2**	**26.5**	**4.4**	**570.35**	**31.02**	**49.53**	**16.74**
		R1	**7.15**	**25.8**	**4.3**	**521.55**	**25.59**	**24.98**	**48.58**
		R2	**7.23**	**27.2**	**4.1**	**606.95**	**35.29**	**18.02**	**42.25**
		R3	**7.24**	**27.6**	**4**	**625.25**	**38.12**	**38.39**	**15.32**
11	236	RAW WATER	**8**	**20.4**	**0.23**	**838.75**	**102.18**	**0.05**	**0.70**
		R	**7.5**	**26.5**	**4.2**	**588.65**	**30.89**	**14.47**	**51.96**
		R1	**7.75**	**26.9**	**4**	**579.5**	**25.10**	**0.00**	**91.45**
		R2	**7.8**	**27**	**4.1**	**631.35**	**33.38**	**45.38**	**13.75**
		R3	**7.9**	**27.3**	**4**	**680.15**	**35.89**	**46.28**	**12.37**
12	238	RAW WATER	**7.3**	**20.3**	**0.51**	**850.95**	**102.94**	**0.01**	**0.35**

		Sample basic information					Avg. Concentration mg/l		
SN.	**Sample**	**Sample**	**pH**	**Tempt.**	**DO**	**HCO3-**	**NH4-**	**NO2-**	**NO3-N**
		R	**7.2**	**25.7**	**4**	**610**	**31.51**	**41.42**	**19.58**
		R1	**7.1**	**26.2**	**4.3**	**488**	**25.01**	**48.23**	**18.41**
		R2	**7.15**	**26.8**	**4.2**	**549**	**30.91**	**53.83**	**15.81**
		R3	**7**	**27.3**	**4**	**664.9**	**34.67**	**47.61**	**13.45**

ANNEX-2: Test Procedures

A. Ammonia Analysis by Phenate Method

Ammonium-nitrogen was tested using the UV spectrophotometer and a series of standard solution of NH4-N was prepared from the standard concentration of 1000 mg/l from lab with respective dilutions to a range of 0.05-5mg/l.

Procedure for preparation of reagents:

a. Reagent A was prepared with addition of 5 gm of phenol and 0.025 gm of sodium Nitroprusside to 400 ml of distilled water and diluted to 500 ml.

b. Reagent B was prepared by adding 7.5 gm of sodium hydroxide and 10 ml of sodium hypochlorite solution in 100 ml of distill water and diluted to 500 ml.

Test Procedure

a. 3 ml of samples with suitable dilutions and 3 ml of series of standard concentration were taken in duplicates.

b. 1.5 ml of reagent A was added and gently shaken.

c. 1.5 ml of Reagent B was added and gently shaken after capping

d. Samples and standard solutions were left for 1 hour in room temperature

e. Photometric measurement was done with UV 640nm for all standards and samples

f. Calculation was done by plotting absorbance of standards against NH_4-N concentrations and computing sample concentration from that curve.

B. Nitrite Analysis by Colorimetric Method

Nitrite was tested using the UV spectrophotometer and a series of standard solution of NO_2-N was prepared from the standard concentration of 1000 mg/l from lab with respective dilutions to a range of 0.02-0.5mg/l.

Procedure for preparation of color reagent:

Color reagent was prepared with addition of 10 ml of Phosphoric acid, 1 gm of sulfanilamide and 0.1 gm of N-(1-Naphthyl) ethylene diamine dihydrochloride to 80 ml of distilled water and diluted to 100 ml.

Test procedure:

a. 5ml of samples with suitable dilutions and series of standard concentration were taken in test.

b. 0.2 ml of color reagent was added and mixed and left for 20 min in room temperature

c. Photometric measurements were done at UV 543 nm.

d. Calculation was done by plotting absorbance of standards against NO_2-N concentrations and computing sample concentrations from that curve.

C. Nitrate Analysis by Ultraviolet Spectrophotometer Screening Method

Nitrate was tested using the UV spectrophotometer. A series of standard solution of NO_3-N is to be prepared from the standard concentration of 1000 mg/l from lab with respective dilutions to a range from 0.05 to 5mg/l.

Procedures for preparation of reagents:

10 ml of hydrochloric acid was added to 110 ml of distilled water to make 1 N HCl

Test procedures

a. Samples with suitable dilution and series of standard NO_3-N solution of 5 ml with different concentrations were taken in test tube.

b. 0.1 ml of 1N HCl was added and mixed

c. Photometric measurement was done at UV 275nm and 220 nm and the calculation of $2D_s$ ($2D_s = Abs_{220} - 2 \times Abs_{275}$) will be done.

d. Calculation was done by plotting absorbance of standard $2D_s$ against NO_3-N concentration and computing sample concentrations from that curve.

D. Alkalinity by Titration Method

Procedure for preparation of reagent

a. MR-BCG (Methyl red bromocresol green) indicator was prepared by dissolving of 0.02 gm of methyl red and 0.1 gm of Bromocresol Green in 100 ml of 95 % ethanol.

b. Preparation of 95 % ethanol was done by dissolution of 95 ml of ethanol in 5 ml of water.

Test procedures

a. 10 ml of sample was taken in conical beaker and 1 drop of MR-BCG indicator was added and stirred rapidly, which gives off bluish color.

b. Titration was done with 0.02N H_2SO_4, noting the end point as old pansy color.

c. Calculation of Bicarbonate concentration by:

HCO_3^-(mg/l) = [a (ml)/V(ml)] x 0.02 (N) x 0.02 x F x 61(g/mol) x1000 (mg/g)
Where, a = ml 0.02 N H_2SO_4 used

V = ml of sample

F = Factor of 0.02N H_2SO_4

ANNEX-3: Photographs

Photo 1: Experimental Setup

Photo 2: DO and temperature measurement on site

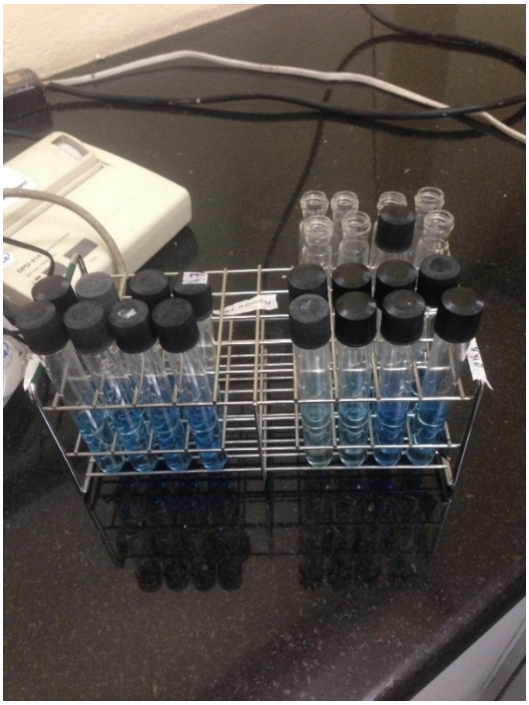

Photo 3 : Analysis of ammonia on lab

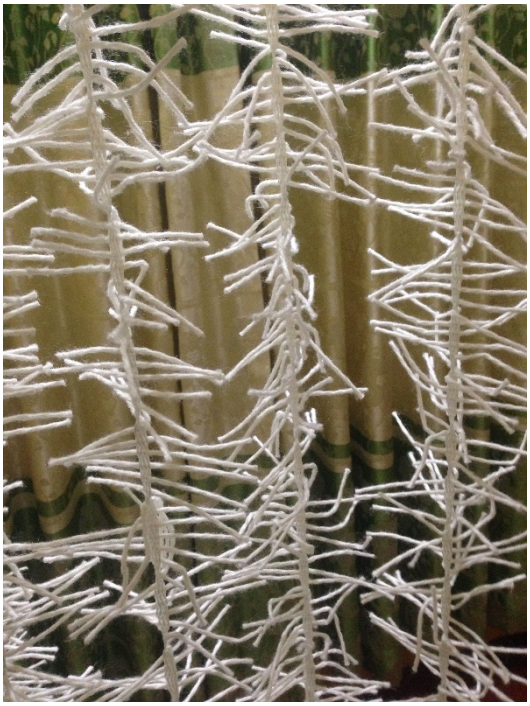

Photo 4: Biofringe Media