Biological Aerating Tower

Submitted in partial fulfilment of the requirement

For the award of degree of

Master's in technology

in

Environmental Science and Technology

Submitted by

Ayush Seth

601601005

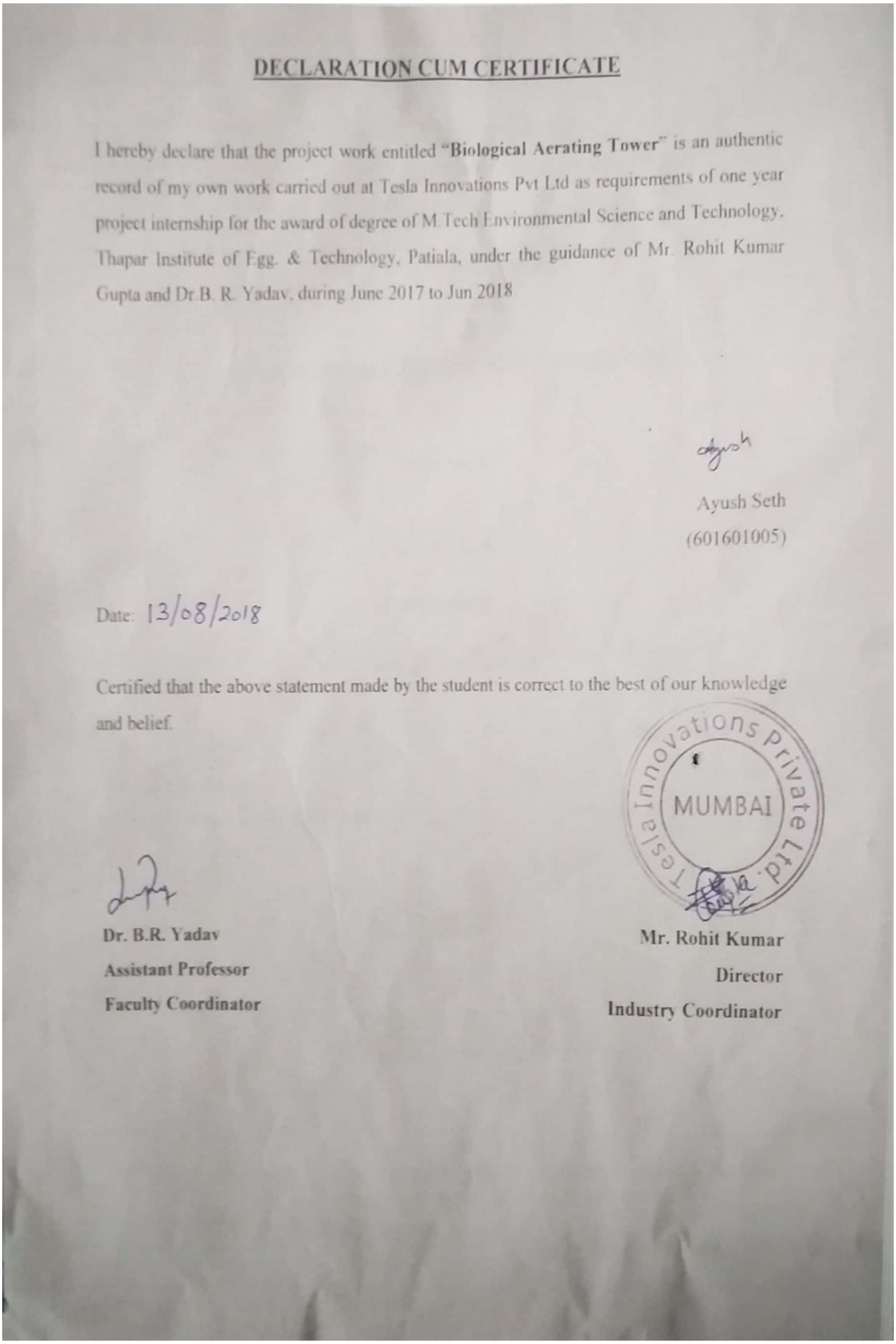
Under the Guidance of

Dr. B.R. Yadav
Assistant Professor
SEE, TIET, Patiala

Mr. Rohit Kumar
Director, Tesla Innovation Pvt Ltd
Mumbai

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

SCHOOL OF ENERGY AND ENVIRONMENT,
THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY, PATIALA
(Deemed to be University)



DECLARATION CUM CERTIFICATE

I hereby declare that the project work entitled "**Biological Aerating Tower**" is an authentic record of my own work carried out at Tesla Innovations Pvt Ltd as requirements of one year project internship for the award of degree of M.Tech Environmental Science and Technology, Thapar Institute of Egg. & Technology, Patiala, under the guidance of Mr. Rohit Kumar Gupta and Dr.B. R. Yadav, during June 2017 to Jun 2018.

Ayush

Ayush Seth
(601601005)

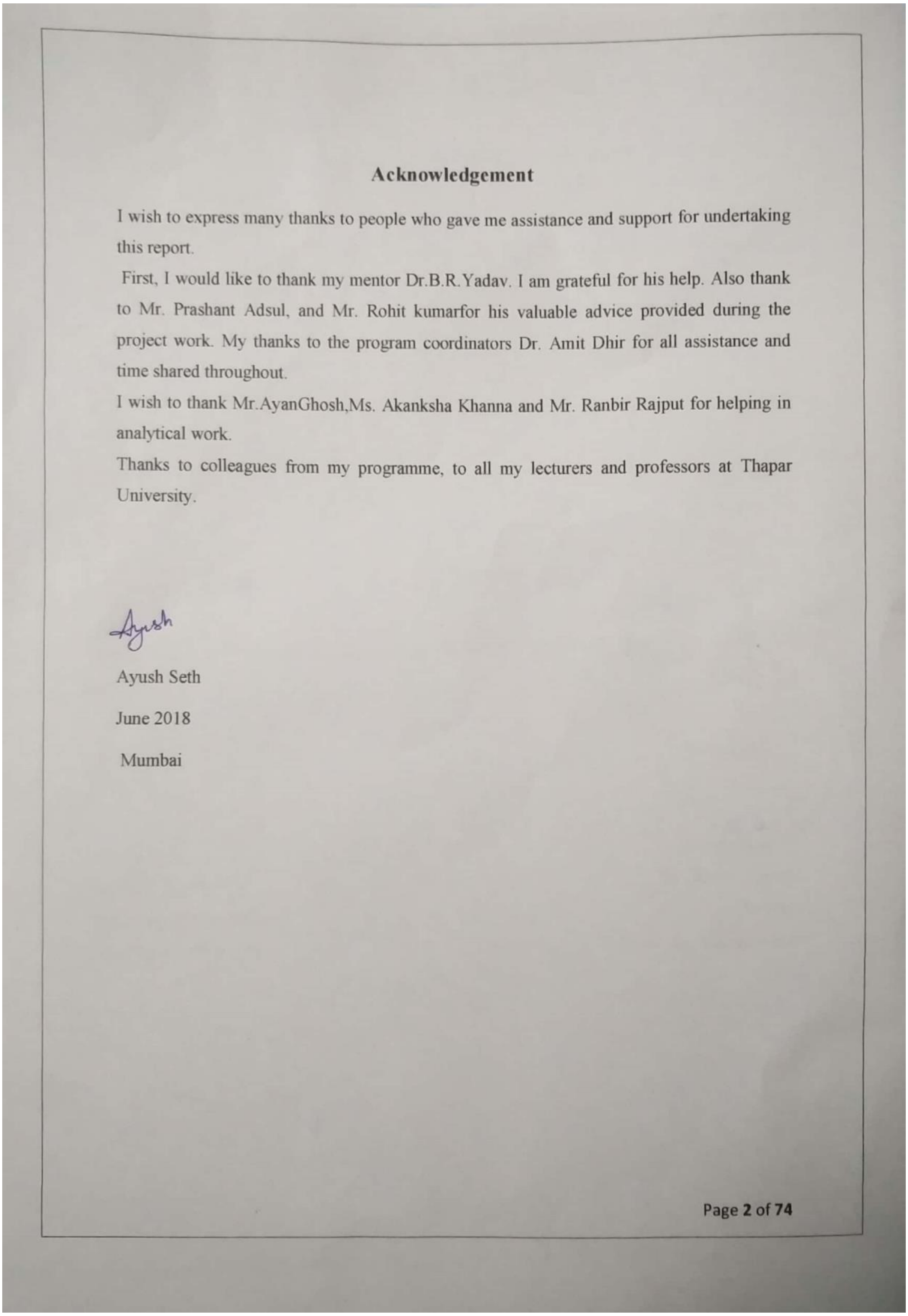
Date: 13/08/2018

Certified that the above statement made by the student is correct to the best of our knowledge and belief.

Tesla Innovations Private Ltd.
MUMBAI

Dr. B.R. Yadav
Assistant Professor
Faculty Coordinator

Mr. Rohit Kumar
Director
Industry Coordinator



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Ayush

Ayush Seth

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Mumbai

Abstract

Nutrient removal from the waste water is essential to prevent eutrophication. This study explains about the designing of the nutrient removal system. Study mainly comprises of the nutrient removal, different methods available, designing of such systems and a case study.

Study is conducted to obtain the suitability of biological aerating tower (a system for nutrient removal). Experiments results were analysed and hence used to obtain the suitability of biological aerating tower. Along with above mention aim another aim to conduct study is to have full exposure of Design, fabrication, procurement, selection of materials, quality inspection and commissioning.

The system consists of unique method of treatment in which large microbial mass was supported by the polystyrene media. Within the biological reactor effluent was first fed into the anoxic zone after that it was allowed to flows into the aerobic zone. The effluent has given sufficient recirculation in order to obtain the sufficient reduction in the nitrate nitrogen.

Result shows that biological aerating tower can be used as a treatment process for total nitrogen removal from the waste water. The result shows that reactor can be operated at an HRT of 8 hrs with more than 92% COD removal and 93% total nitrogen removal is achieved.

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Abbreviation

BAF	Biological Aerating filter
BAT	Biological Aerating tower
BOD	Biochemical Oxygen demend
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
ETP	Effluent Treatment Plant
HRT	Hydraulic Retention Time
LPH	Litre per hour
LPD	Litre per day
MOC	Material of construction
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
PPM	Parts Per Million
RAS	Return activated sludge
SRT	Solid retention time
SOP	Standard Operating Procedure
SVI	Sludge Volume Index
TKN	Total Kjeldhal Nitrogen
TSS	Total suspended solids
TDS	Total Dissolved Solids
TSS	Total Suspended Solids

Chapter 1: Introduction

Total Nitrogen removal is mostly required before discharging treated wastewater to sensitive water bodies for the prevention of eutrophication, it is also necessary before reuse applications like ground water recharge.

Nitrogen comes from different sources like municipal, industrial. Urine contains about 90% of nitrogen which is excreted by humans, mostly from amino acids which comes from food. Food wastes and different industrial processes can also contribute significant amounts of nitrogen to municipal wastewater influents. Nitrogen in food comes from amino acids in protein and from purines, pyrimidines, free amino acids, vitamins, creatine, creatinine, and amino sugars . Under ammonification process urea and organic nitrogen which are present in waste water within the sewer system gets converted to ammonia.

Nitrogen compounds are used in several different industrial processes and used in the many products. Most nitrogen is applied to synthesize of ammonia by the Haber-Bosch process. Nitric acid, urea, hydrazine and amines are other products from nitrogen industries. Nitrogen compounds are by-products of coloring and synthetic agent production.

Contaminated water supplies with nitrate and nitrite will relate to several diseases such as methemoglobinemia in infants, also known as blue baby disease.Some of the major sources or transportation of nitrogen from sewage include:

- Direct discharge of the sewage.
- Leaching fields
- Leachate from septic tank moves into the ground water.

Hence the many industrial as well as municipal waste water contains high amount of ammonia in there effluent so before discharging it into river or any other water body proper treatment is required.

Chemical methods can be used to oxidize ammonia. But chemical methods produce hazardous by-product and introduce other recalcitrant compounds into the produced water. The biological process is always preferred for wastewater treatment, to degrade ammonia, organic matter, and other potential pollutants. Nitrogen removal can be either an integral part of the biological treatment system or an add-on process to an existing biological removal of nitrogen requires an anoxic stage for the denitrification of nitrates and nitrites where nitrate or nitrites are reduced to nitrogen gas under anoxic conditions. Different biological nitrogen removal process is

- Pre-anoxic denitrification.
- Step feed anoxic/aerobic process.
- Intermittent aeration.

Biofilm process are very useful in case of slow growing microorganisms like Nitrosomonas and Nitrobacter, which are believed to be responsible for the degradation of nitrogenous compounds in waste water. The decreasing substrate concentration with depth in the bio film offers the potential for degradation of compounds that would otherwise not be degraded in a suspended culture [40]. However beside environmental condition such as dissolved oxygen, pH, temperature, and alkalinity, nitrification is sensitive to inhibition by a wide variety of organic and inorganic chemicals.

This dissertation work focuses on the details of nitrification, denitrification and designing of the biological aerating tower for total nitrogen removal.

1.1. Objective

- Literature review about the nitrification and denitrification.
- To design and execute the pilot plant which includes fabrication, selection and commissioning of the plant.
- To perform a case study
- To assess the TKN reduction efficiency with respect to bio mass concentration and hydraulic retention time for primary treated effluent of the existing wastewater.
- To determine the optimum HRT required in order to treat the pre-treated effluent for highest TKN reduction.
- To formulate detailed conclusion and results from the whole study.

1.2. Scope

1. Detailed design of pilot plant including basic design, fabrication, selection of instruments.
2. Detailed study of about the nitrification and denitrification.
    a) Stage wise: Aerobic and anoxic zone analysis for following parameters

        1. pH
        2. Chemical Oxygen Demand (COD)
        3. Total Suspended Solids (TSS)
        4. Total kjeldahl nitrogen
    b) Testing of all key operational and quality parameters for temporal variations.
    c) Determination of treatment efficiency of the biological aerating tower.
3. Preparation of report along with compilation of the observations, recommendations and conclusions.

1.3. Methodology

- The study was initiated with the literature review about the nitrification and denitrification includes;
    1. Nitrogen in the atmosphere
    2. Various forms of nitrogen
    3. Nitrification and denitrification process
    4. Factors influencing nitrification and denitrification.
- After the literature review the basic design was prepared according to that a process flow diagram and instrumentation drawing was prepared.
- List of material required for the pilot plant is prepared and given for procurement.
- After obtaining the size of the reactor fabrication drawing was prepared.
- Once the drawing is prepared fabrication of reactor is done.
- After completion of fabrication and procurement of material, erection of the pilot plant is done.
- Once the plant is fully set up, a case study was performed for the removal of nitrification and denitrification according to different HRT.
- After detailed study formulation of the report.

1.4. Structure of the Report

- **Chapter 1:** Description about the Objective scope and methodology.
- **Chapter 2:** Description of Fundamentals about the nitrification and denitrification and various factor influencing them.

- **Chapter 3:** Overview of the different technologies available for nitrification and denitrification.
- **Chapter 4:** Describes about the Biological aerating tower and its application
- **Chapter 5:** Describes about basic design of biological aerating tower design
- **Chapter 6:** Describe about the fabrication details, selection of the instruments along with the standard operating procedure for the biological aerating tower.

- **Chapter 7**: Describes bio reactor, bio reactor set up and conclusion from the case study

Chapter 2: Fundamental

Nitrogen is an essential element. It is a part of most of the cellular components like proteins, nucleic acids (DNA and RNA), vitamins, etc. It is also a very important for chlorophyll in plants. Plants obtain their nitrogen from micro nutrients which are present in the soil while animals obtain it from plants. A cycle of processes helps in maintaining the concentration of nitrogen in the atmosphere which helps in meeting the requirement of every organism. This cycle of nitrogen is called the nitrogen cycle.

The nitrogen cycle consists of recycle and reuse of nitrogen in different forms to meet the demand for different environmental activities. It happens because of different processes with the help of certain microorganisms. In the atmosphere, nitrogen is available in a diatomic form i.e. N_2. Plants and certain organisms can't use nitrogen in this form. Therefore, N_2 is converted into nitrogen oxides like NO, NO_2, NO_3. Various processes like lightning; industrial combustion, forest fire etc. contribute to these oxides.

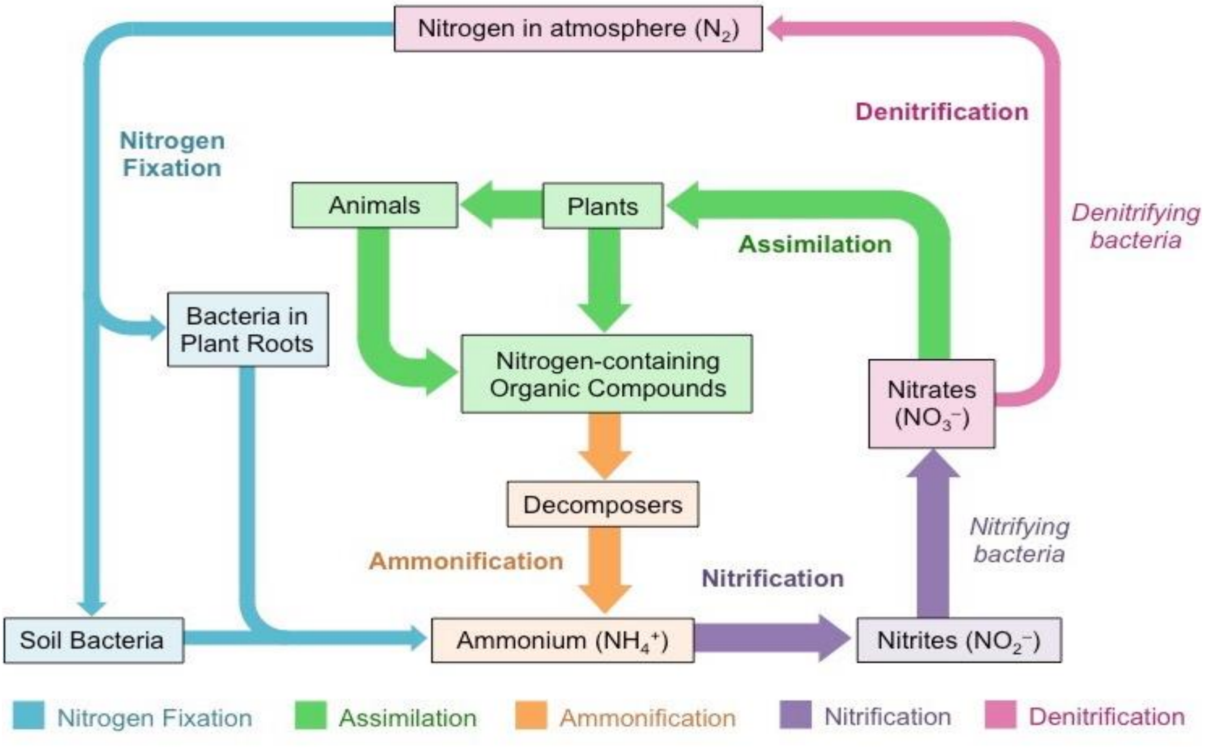

Figure 1 Nitrogen Cycle[1]

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[1] http://ib.bioninja.com.au/options/option-c-ecology-and-conser/c6-nitrogen-and-phosphorus/nitrogen-cycle.html

2.1. Different forms of nitrogen

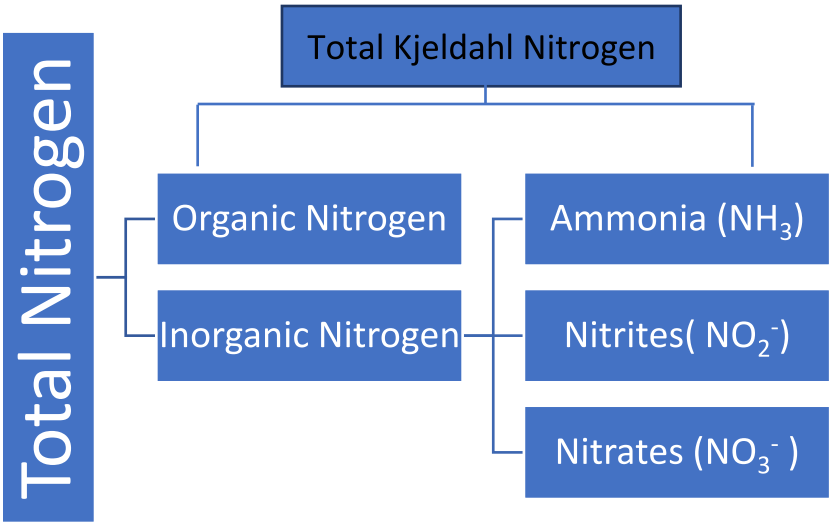

Figure 2 Flow chart showing Different form of nitrogen

Total-N = NH_3 + org-N + NO_3 + NO_2

TKN = NH_3 + org-N

Organic-Nitrogen (org-N). Composing of amines, peptides and proteins, the remnants of life forms make a small fraction, typically one or two milligrams per litre, of the organic-Nitrogen, is not amenable to biological treatment and passes through the treatment facility untreated as organic-Nitrogen.

Ammonia (NH3 or NH4). When the pH of the wastewater is acidic or neutral, the majority of the nitrogen is ammonium (NH4 +). When the pH increases over 8.0, the nitrogen is mostly ammonia (NH3). A municipal wastewater treatment plant with an effluent containing more than 2 or 3 mg/L NH3 is not fully nitrifying.

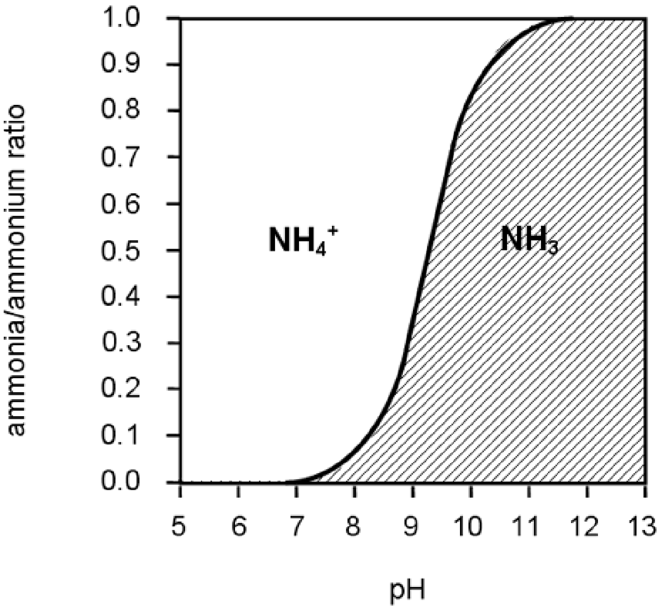

Figure 3 Graph showing the relationship of ammonia and ammonium ion over pH[2]

Total Kjeldahl Nitrogen (TKN). TKN includes Ammonia and organic-Nitrogen.

Nitrate (NO_3). Full decomposition of ammonia i.e. first ammonia gets oxidised to nitrite than into nitrates.

Nitrite (NO2). Ammonia after getting oxidised gets converted into nitrite hence it is more harmful than nitrates.

Nitrogen Gas (N2). The air we breathe is 78% N2 and only 21% oxygen. The remaining one percent is argon and other inert material.

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[2] http://www.nico2000.net/analytical/ammonium/NH4lib.html

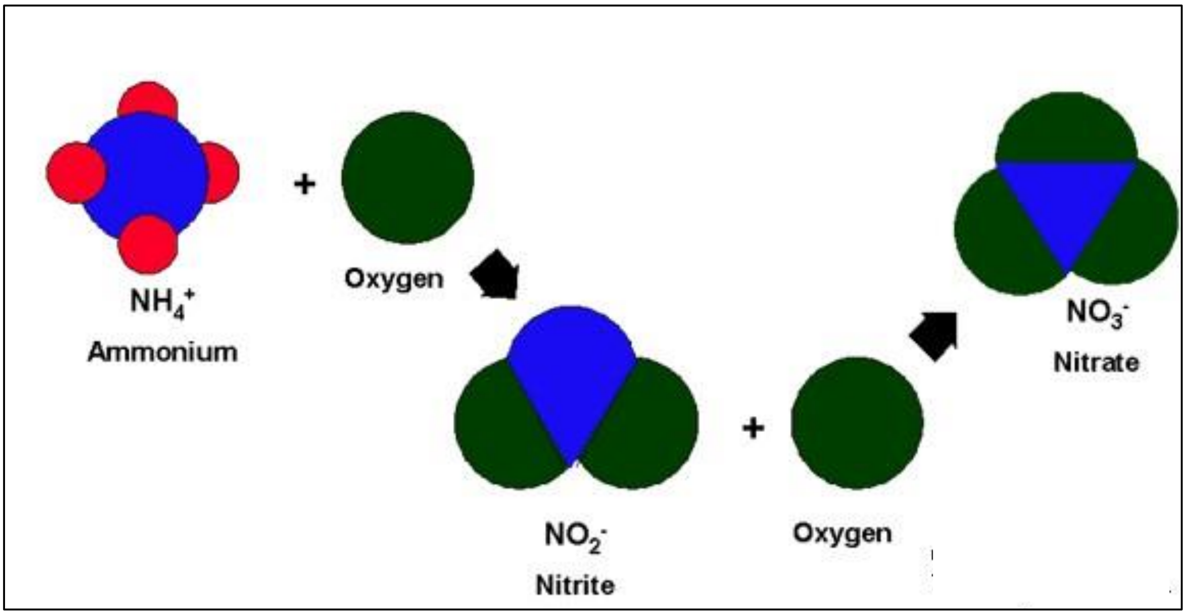

Figure 4 Nitrification Process

2.2. Nitrification

Nitrification is the term used to describe the two-step biological process which includes ammonia (N-NH_4^+) gets oxidized to nitrite (N-NO_2^-) and nitrite gets oxidized to nitrate (N-NO_3^-), under aerobic conditions and using oxygen as the electron acceptor. The importance of nitrification in effluent arises from its quality concerns and these are:

- Consequence on waste water by ammonia in respect of dissolved oxygen concentration.
- Nitrogen removal for control of eutrophication.

For the reference, drinking water maximum contamination level nitrate nitrogen should be 45 mg/l as nitrate and 10 mg/l as nitrogen.

Similar to BOD removal, nitrification is accomplished in both suspended and attached growth biological processes. In suspended growth common approach is to achieve nitrification along with BOD removal in that same single- sludge unit.

For attached growth system used in nitrification, enough quantity of BOD should be removed before nitrification process is established. As heterotrophic bacteria have a higher growth rate which can influence over surface area of fixed film system over nitrifying bacteria.

Aerobic process under which autotrphic bacteria oxidize ammonia or nitrite for energy generation is nitrification. Nitrification is a two-step process involving two different strains of bacteria. In the first step, ammonia is oxidized to nitrite, Eq. (1) by autotrophic strain bacteria called Nitrosomonas-bacteria or Ammonia Oxidizing Bacteria (AOB).

In the second stage, nitrite is oxidized to nitrate, Eq. (2) by another group of autotrophic bacteria called Nitro-bacteria or Nitrite Oxidizer Bacteria (NOB). Nitrification is aerobic oxidation of ammonia by nitrifying bacteria.

Equation 1

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

Equation 2

$NO_2 + 0.5O_2 \longrightarrow NO_3$

Nitrogen removal involves the conversion of reduced nitrogen compounds (ammonia) to more oxidized compounds (nitrate), termed nitrification, followed by the conversion of the oxidized compounds to reduced gaseous products. The oxidation of ammonium to nitrate creates two acid equivalents (H^+) per mole of nitrogen oxidized. Oxygen is used for the oxidation of ammonium and is used as the terminal electron acceptor by the nitrifying bacteria. When sufficient oxygen was present, a drop-in nitrification rate was observed due to competition from the heterotrophic organisms due to the assimilation of the ammonia. With the addition of limited oxygen as a variable, ammonia oxidation was strongly inhibited but not ceased.

2.3. Nitrification Microbial Ecology

Nitrifying bacteria grow slower and have much lower yields as a function of substrate consumed, compared to the heterotrophic bacteria in biological treatment processes. The maximum specific growth rate of the nitrifying bacteria i.e. autotrophic bacteria is 10 to 20 times less than the maximum defined growth rate of heterotrophic bacteria responsible for the oxidation of carbonaceous organic compounds in wastewater treatment . However, genera of microorganisms that scientists believe play roles in nitrification are Nitrosomonas, Nitrobacter, Nitrosospira, Nitrosolobus, Nitrosovibrio, and Nitrosococcus [2]. These genera of organisms are autotrophic, so their carbon source is carbon dioxide (CO_2). Ammonia-Oxidizing Bacteria, such as Nitrosomonas, utilize the reduced nitrogen in ammonia as the electron donor, or energy source. They oxidize it to form nitrate (NO_2) using oxygen (O_2) as the terminal electron acceptor.

Nitrite-oxidizing bacteria, such as Nitrobacter, they use the nitrite as their energy source with oxygen as the terminal electron acceptor to nitrate (NO_3) [3, 4]. Nitrite-oxidizers have a higher growth rate but are dependent on ammonia-oxidizers for a supply of nitrite. Therefore, the amount of time microbial biomass must remain in nitrifying reactors must be longer than treatment systems designed for COD removal in order to provide enough time for the nitrifying bacteria to grow.

2.4. Factors influencing nitrification

2.4.1. PHand alkalinity

The nitrifying bacteria may be more sensitive to temperature and pH [4]. The pH of wastewater should be maintained between 6 and 9 to protect organisms [5]. This is important since a narrow optimal range between pH 6-9 exist for the nitrifying bacteria. The decrease in pH was caused by the reduction of alkalinity and the acid production during nitrification. After completion of nitrification, the pH started to increase. The optimum pH for nitrification was in the range of 7.2-8.6 [6,7]. The nitrification reaction (that is, the conversion of ammonia (NH_4) to nitrate (NO_3) consumes 7.1 mg/L of alkalinity (as $CaCO_3$) for each mg/L of ammonia (NH_4) nitrogen oxidized.

A model developed by Gujer and Jenkins 8.64 mg/L of bicarbonate (HCO_3^-) will be utilized for each mg/L of ammonia-nitrogen oxidized.

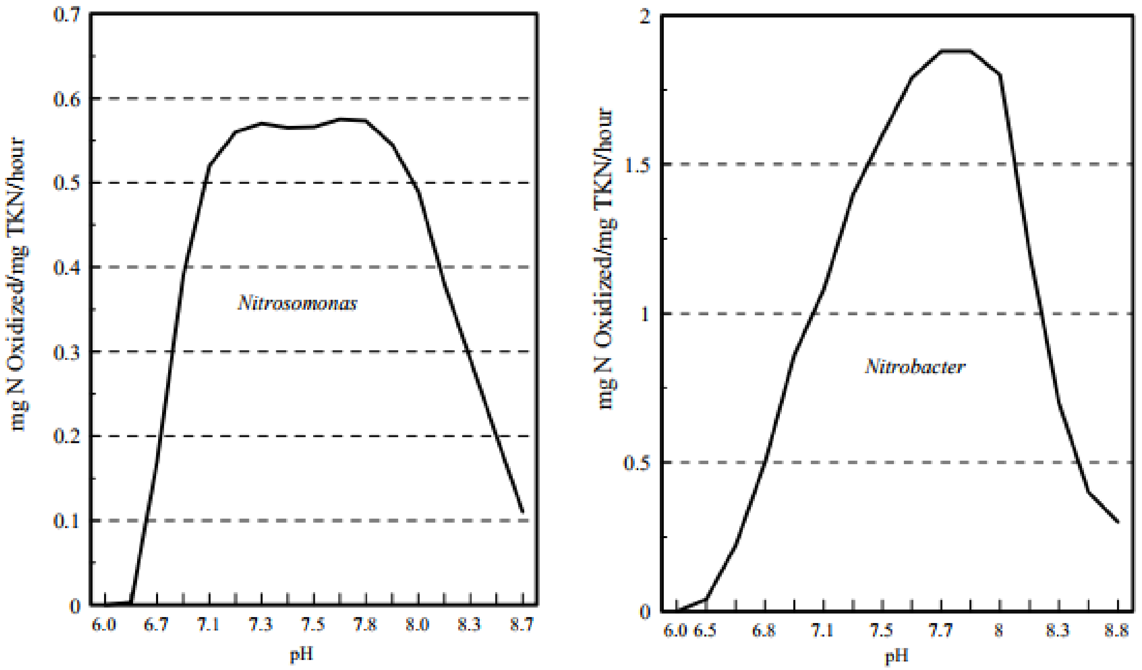

Figure 5 Effects of pH on different bacteria cultures[3]

2.4.2. Dissolved oxygen (DO)

Amount of dissolved oxygen required by the microbes to degrade organic matter it must be equal to the oxygen supplied to the tank, growth rate of microorganisms increases linearly with the dissolved oxygen concentration [9,10]. As for nitrification minimum level of dissolved oxygen required is 2mg/l hence if concentration drop belows 2mg/l growth rate of nitrifiers slows down.

2.4.3. Carbon to nitrogen ratio (C/N ratio)

Biological processes are often used to remove carbonaceous and nitrogenous pollutants from wastewater [11]. Carbon to nitrogen (C/N) ratio of wastewater has been found to impact the distribution of both nitrifiers and heterotrophs population in biological filters [12-14]. An understanding of the impact of C/N ratio on nitrogen removal wastewater is imperative for optimizing biofilm reactor. However, it should be noted that the pre-treatment of raw wastewater for SS removal may cause loss of organic matter and then decrease the C/N ratio of wastewater. Durmaz and Sanin [15]

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[3] Source: Grady and Lim 1980

2.4.4. Temperature

As we all know the biological activity depends rigoursly on temperature of water. Nitrifies also depends upon the temperature of water. Nitrification achieves a maximum rate at temperatures between 30 and 35 degrees C (86^0F and 95^0F). At temperatures of 40^O C (104^O F) and higher, activity of nitrifers falls to near zero. At temperatures below 20^O C, nitrification proceeds at a slower rate, but will continue at temperatures of less than 10 ^{O} C but will not resume if alkalinity is lost until the wastewater temperature increases to almost 15^O C.

2.4.5. Nitrification inhibitors

Nitrifying bacteria are very sensitive to heavy metals and other inorganic compounds in wastewater. From various researches, it has been found Nitrobacter is most suitable species for nitrification in comparison to Nitrosomonas, which can resist harsh condition but the 2,3-Dichlorophenol and 2,4 – Trichlorophenol is toxic to nitrifying bacteria even at very low concentration. Rate of biological activity with heavy metal is shown in figure 2.5

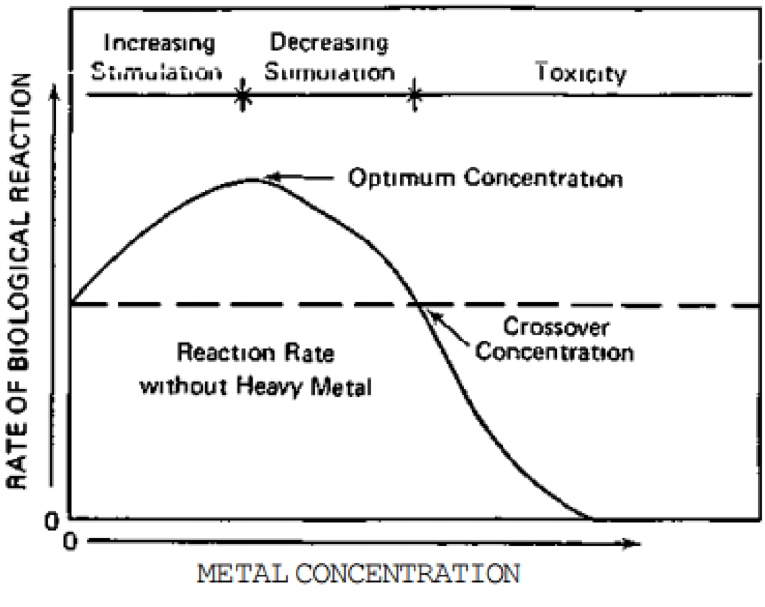

Figure 6 Graph showing effect of metal concentration on biological reaction

2.4.6. Toxicity

Nitrifiers are good indicator of the presence of toxic organic compounds which are present in low concentration. Various compounds are solvent organic chemicals, amines, proteins, tannins, phenolic compounds, alcohols, cynates,ethers, carbamates, and benzene. Because of various compounds it is very difficult to know the exact cause of toxicity for nitrifies.An extensive study of sampling will be required to find the correct source.

2.5. Growth Kinetics of nitrification

Nitrification system which operate at temperature below 28°C ammonia oxidation kinetics versus nitrite-oxidation kinetics are rate limiting, so that designs depends on saturation kinetics for ammonia oxidation is given below, assuming excess DO is available.

$$\mu_n = \left(\frac{\mu_{mn} N}{K_n + N}\right) - K_{dn}$$

Where μn = specific growth rate of nitrifying bacteria, g new cells/g cells day

μm = maximum specific growth rate of nitrifying bacteria, new cells/g cells day.

N= Nitrogen concentration, g/m^3

K_n= half-velocity constant, substrate concentration at one-half the maximum specific substrate utilization rate, g/m^3

K_{dn}= endogenous decay coefficient for nitrifying organisms, g vss/g vss day

Wide range of maximum specific growth rate are being reported as a function of temperature [40]. At temperature 20-degreeCelsius maximum specific growth rate varies from 0.25 to 0.77 g VSS/g VSS. Wide range is there due to the availability of inhibitory compounds in waste water and/or variation in experiment techniques and method analysis.

For fully acclimated system at temperature below 25-degreeCelsius at sufficient DO concentration the concentration of NO_2-N may be less than 0.10 mg/l in comparison to NH4-N concentration in the range of 0.5 to 1.0 mg/l. However, during the initiation of nitrification, concentration of NO2-N is higher than NH4-N it is because the growth of nitrite oxidizing bacteria cannot occur until ammonia gets oxidize by ammonia oxidizing bacteria to generate nitrite.

2.6. Denitrification

Reduction of nitrate to nitric oxide, nitrous oxide, and nitrogen gas is termed as denitrification. Denitrification is the conversion of nitrite and nitrate into nitrogen. Denitrification is performed by the heterotrophic bacterial. Eq.(3). Explains about denitrification. Various factor affecting denitrification are discuss in the below section.

Equation 3

$2\ NO_3 \rightarrow NO \rightarrow NO \rightarrow N \rightarrow N$

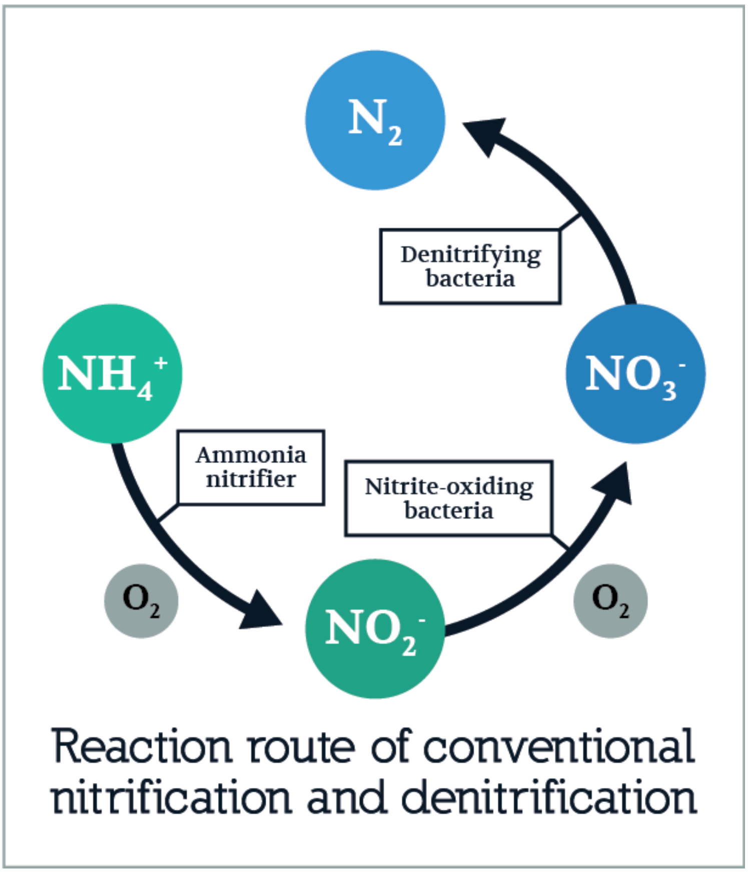

Figure 7 Nitrification and denitrification

2.7. Factors influencing Denitrification

The hydraulic & organic loading patterns, along with reactor arrangement and its condition effect are important for reactor. Various factor affecting the denitrification are explain below

2.7.1. pH and alkalinity

Alkalinity is produced in denitrification reactions and pH is generally elevated, instead of being depressed as in nitrification reactions. In comparison to nitrifying organisms, there has been less concern about pH influences on denitrification rates. Denitrification is an alkalinity producing process. During nitrification, alkalinity is consumed, but alkalinity is produced during denitrification. The best optimum pH range for the denitrification rates is lie between 7 to 8 for different bacterial cultures.

According to Metcalf and Eddy, a pH value near neutral is preferred and below 6.8 the methanogenic activity is inhibited [17].

2.7.2. Dissolved oxygen (DO)

Denitrification occurs when oxygen levels are depleted, and nitrate becomes the primary oxygen source for microorganisms. The process is performed under anoxic conditions when dissolved oxygen concentration is less than 0.5 mg/L, ideally less than 0.2. According to USEPA, oxygen levels must drop significantly for full denitrification to occur in the reactor environment; the USEPA suggests that levels less than 0.3 to 1.5 mg/L for activated sludge systems [18]. Painter also studied denitrification by activated sludge at reduced DO concentration and showed that at DO concentration of 2 mg/L, the denitrification rate was only 10% of the rate under strictly anaerobic conditions [19]. However, two factors which have an influence on the rate of denitrification are the presence of dissolved oxygen, which will inhibit denitrification and the availability of a carbon source [20].

2.7.3. Carbon to nitrogen ratio (C/N ratio)

A few studies discussed BAF system with respect to nitrogen removal by denitrification process. In spite of this, its denitrification efficiency was quite low due to low C/N ratio of influent wastewater [18]. During nitrogen reduction denitrifies require sufficient quantity of carbon in order to completely reduce the nitrite produced during nitrification process [19]. Study has proposed that ratio of carbon to nitrogen needs to be maintained above 5 or equal to 5 to completely remove the nitrogen from waste water [20,21].

Biological aerating tower will require external carbon source which is obtained through methanol to increase the C/N ratio [22,23]. If there is a insufficient amount of carbon source in domestic waste water methanol is used as a carbon source, which maintain the required carbon to nitrogen ratio, which is crucial for the nitrification-denitrification process. Ineffective COD/TKN ratio is not the only problem for nitrogen removal but also short anoxic retention time results in high nitrogen concentration in the effluent. Hence, extra attention needs to be taken for the effective utilization of carbon within the system for treating the low C/N ratio wastewater by supplementary carbon source.

2.7.4. Temperature

Operation of denitrifies gets affected by the temperature of the wastewater temperature. Temperature range over which denitrifies work is35 °C - 55 °C, microbial activityi.e.t their reaction rate decrease at low temperature Denitrification can occur over the temperature range of but the reaction rate slows down for low temperature.

Temperature disturbs the growth rate of denitrifying strains, having the higher growing rate at elevated temperature. Denitrification can occur between 5 and 30^{O} C (41^{O}F to 86^{O}F), and these rates can vary with temperature and different strains. If methanol or acetic acid is used highest growing rate is observed i.e. sufficient quantity of carbon source needs to be present as a food for microorganisms. Some extent of low rate of microbial growth is observed by using raw waste water,It was found out that decrease in growth rate are observed while depending upon endogenous carbon source at reduced water temperatures.

Chapter 3: Overview of the various treatment methods available for nitrification and denitrification

Ammonia nitrogen is one of the most reduced nitrogen compound found in wastewater, it can be oxidised in the presence of oxygen into the nitrate. Most of the wastewater has organic nitrogen and ammonia as major forms of nitrogen. There are different treatment methods available for nitrogen removal from the waste water which are described below

i) Air stripping,
ii) Biologically removal.

3.1. Air stripping

Air stripping, the process comprises of exchanging ammonium into the gaseous phase and then diffusing the liquid into air. Hence transfering ammonia from wastewater into the air. The process has certain limitations as for complete conversion of ammonia greater pH (11) is required thus this pH is greater than the pH of the waste water necessary adjustment of pH is necessary before treating the waste water in the air stripping unit.

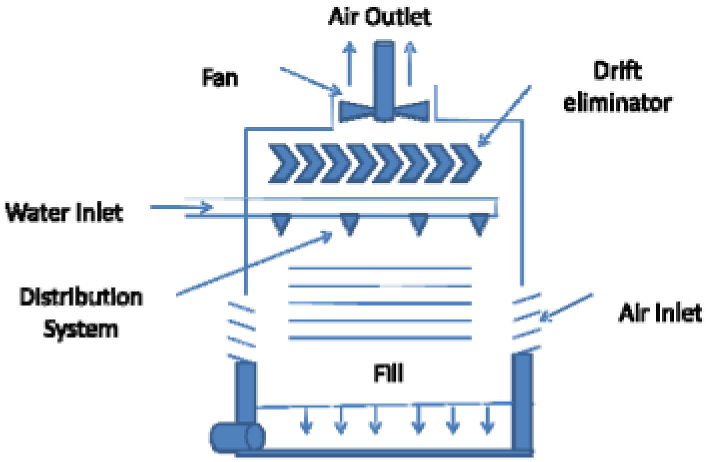

Figure 8 Air diffuser

Limitation to these process areas follows.

- Noise and air pollution along with the scaling of the packing media.
- Unit has odor problem due to diffusion of ammonia gas into the atmosphere because of this unit it is not used at some of the locations.
- Scaling on the packing media is observed.

Biological methods which are available are mostly on suspended growth these are

3.2. Biological Treatment

3.2.1. Pre-anoxic

In pre- anoxic treatment the influent was first fed into the anoxic tank than afterwards it was fed into the aerobic tank. The Process relies on the nitrate which is formed in the aerobic zone is returned along with the activated sludge into the anoxic zone. In the anoxic tank heterotrophic bacteria are present and in the aerobic tank autotrophs are present. The Denitrification mainly depend upon the RAS recirculation ratio. As the heterotrophic bacteria require BOD for their growth hence in the pre-anoxic tank if the influent contain sufficient BOD than there is no need to provideexternal source of BOD. This process doesn’t require any BOD as whatever the BOD is required by the microorganisms is required in the first process i.e. in anoxic process

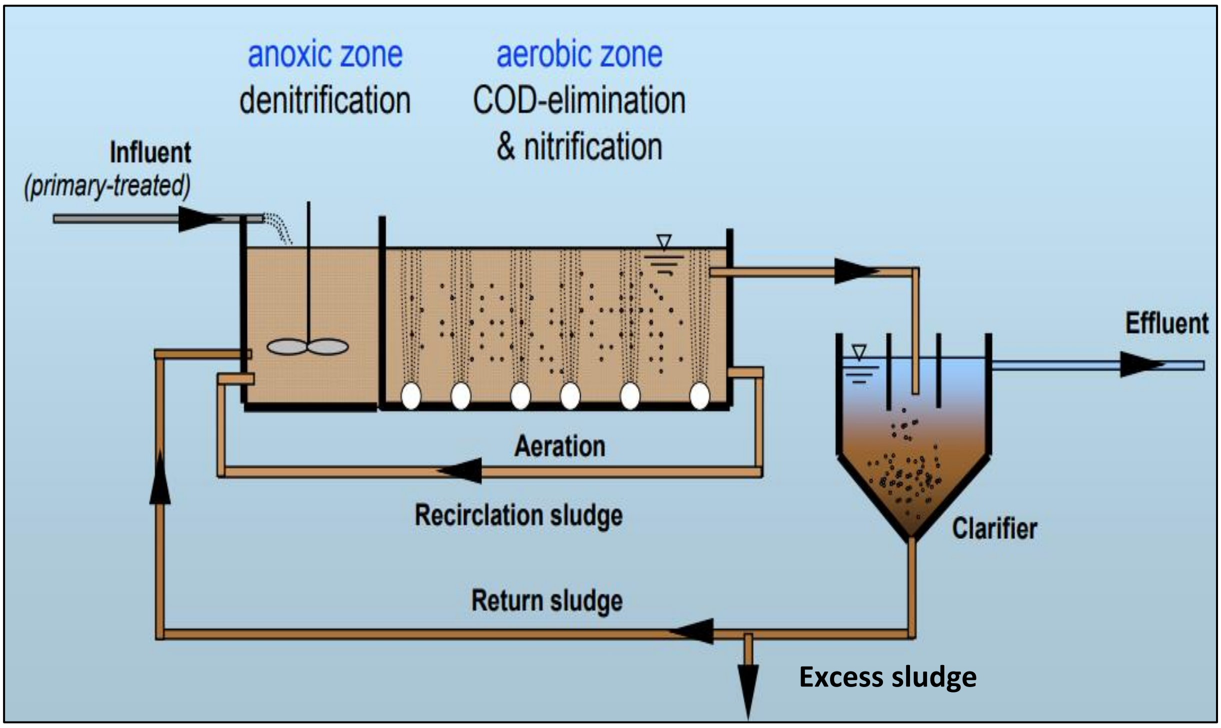

Figure 9 Pre- anoxic Process[4]

3.2.2. Post anoxic

In the post anoxic treatment influent is first fed into the aerobic zone than into the anoxic zone. In this process nitrate which is formed in the aerobic zone is fed into the anoxic tank. In anoxic tank nitrate gets reduced into the nitrogen gas which will not dissolved in waste water and escapes out from the waste water. As after aerobic process most of the carbon gets utilized by the heterotrophic bacteria present in the aerobic zone. hence the bacteria present in

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[4] Dipl.-Ing. S. Rettig TU Berlin, Department of Urban water management Gustav-Meyer-Allee

anoxic tank require carbon source for their growth hence this process requires external carbon source. Methanol is generally used as a carbon source as it is more effective and cheap.

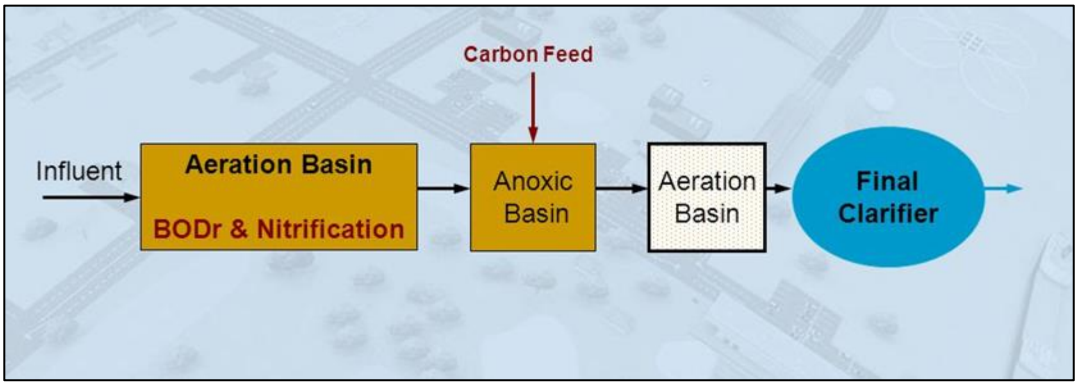

Figure 10 Post anoxic Process[5]

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[5] https://www.google.co.in/search?q=Post+anoxic+treatment&rlz=1C1CHBD_enIN788IN789&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjRr9S-18PbAhUxE6YKHY-lAOkQ_AUICigB&biw=1920&bih=974#imgrc=mTxL3lKXP_2-iM:

Chapter 4: Biological aerating tower

Biological aerating tower (BAT) is amodification to BAF,where total foot print area is decreased by using a tower like structure. BAT is an attached growth system which can be operated continuously, It consist of media which can't clog and had a low head loss, having a high specific biofilm surface area, and no requirement for backwashing. The reactor can be able to work under aerobic environment and anoxic environment i.e. able to nitrify and denitrify. 50 to 55% of the reactor volume is occupy by the media. A higher percentage fill of the media result in reduction in the mixing of the efflluent, which further decreases the overall nitrogen removal efficiency of the reactor. The media is kept within the reactor volume by a strainer.The media[6] most often used is made up of high-density polyethylene(density0.95g/cm3) and which shape like cylinder having lined on the inner wall as well as lined in the inside suface to provide more specific surface area as shown in fig 11

Figure 11 Polystyrene media

BAT is an upflow process which uses polystyrene beads as the media that has a specific density less than water. Packing depth ranges from 1.5 to 3m according to Metcalf and Eddy. The bed is divided into two zones-anoxic and aerobic. Nitrified effluent is recycled for anoxic operation. Typical key design parameters are shown in the table.1

Based on attached growth process, treatment capacity is a function of the specific surface area of the media. This is often reported as the specific surface area of the reactor, equal to the total surface area of the media divided by the volume of the reactor, or the media specific surface area multiplied by the fraction of the total reactor volume that the media occupies. In some cases, the total surface area of the media that is available for biofilm development

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[6] Pleaserefertheannexure1fortheselectivityofmedia.

divided by the volume of the reactor is used, reflecting the significant abrasion of biofilm off the outer surface of some media types.

Autotropic bacteria help in nitrification and heterotrophic bacteria help in denitrification. Nitrification by autotropic bacteria achieves maximum rate in the reactor at dissolved oxygen concentration at 2 mg/l or above. The rate decreases to zero as the dissolved oxygen concentration decreases to zero. In contrast, while denitrification by

Process flow diagram about the biological aerating tower is shown in figure 11

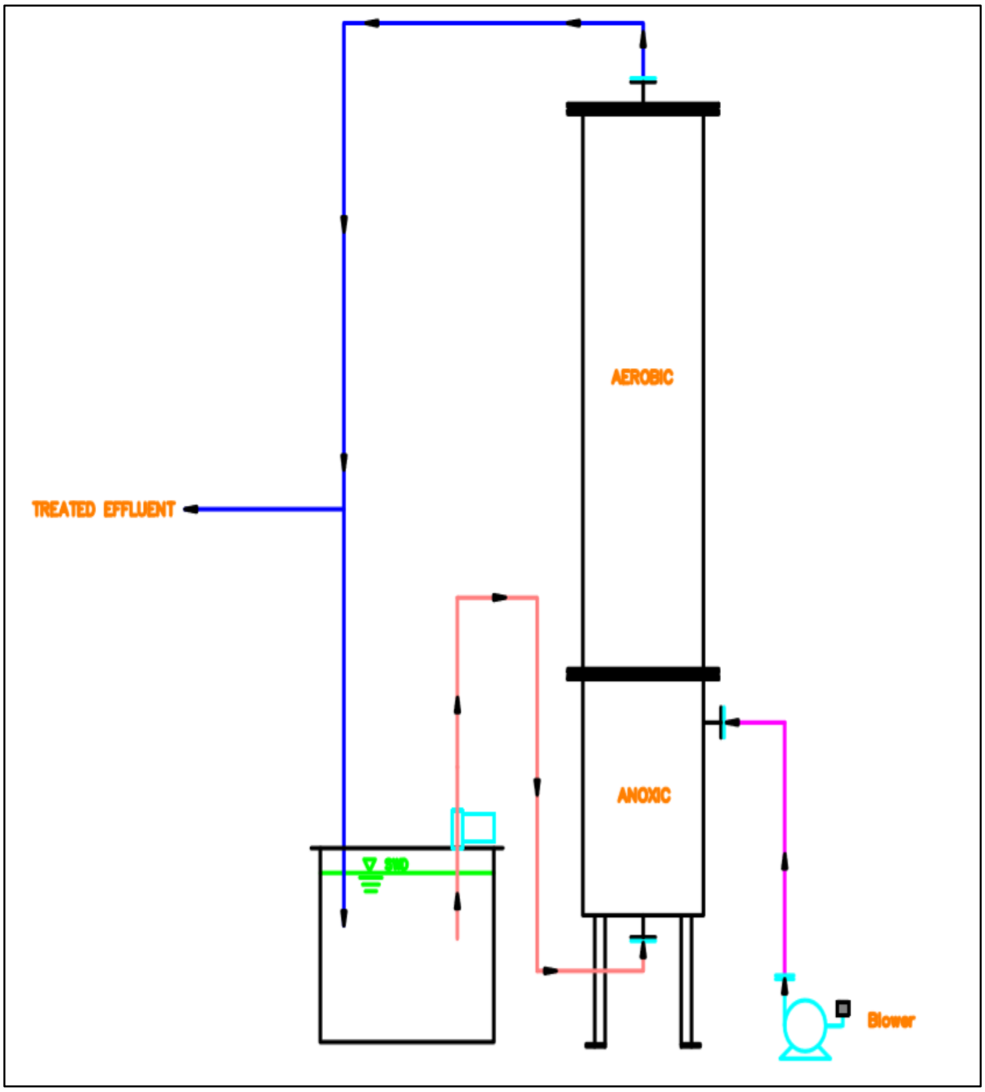


Figure 12 Biological Aerating Tower

.

Table 1 Typical Design Parameters

Parameter	Value
Diameter of Tower	250mm
Aerobic zone	1200mm
Anoxic Zone	400mm
Flow rate	2-6 LPH
Nutrient Loading rate Nitrification	0.5-2.5 g NH_4- N/ m^2day
Nutrient Loading rate denitrification	2g NH_4- N/ m^2day
BOD Feed (maximum)	200 /l

4.1. Advantages

As this system contains both suspended and attached growth hence this system is called as hybrid system. Hybrid reactor is system which treats organic matter and remove nutrients hence it will increase the capacity of the system and helps in increasing the overall efficiency.

The advantages of the system are as follows

- Require less space than most conventional systems
- As the media surface provide more area for development of bacteria hence this will help in increase in capacity of the system.
- Greater process stability
- As this is the attached growth system hence lower sludge production.
- System can handle high biomass concentration
- Compact system with small area requirement.
- Increased treatment capacity

Operation at higher suspended biomass concentrations resulting in higher sludge retention time.

- Improve stability for the process
- Reduced sludge production and no problems with sludge bulking.

In the literature, useful information on the advantages of the Polypeptide media system has been clearly outlined.

Some important features that are highlighted out by Loukidou and Zouboulis [25]. According to them, MBBR has the advantage of higher biomass concentrations, less acuity to toxic compounds and the absence of long sludge settling periods.

Moreover, Horan et al [26] come to the conclusion, that both organic and ammonia removal are efficient and could be achieved in a single stage through the MBBR.Also, the Biological aerating tower has an advantage over small foot print area in comparison to conventional nutrient removal tank, they just occupy approximately one fifth to one third of area require for conventional system.

4.2. Disadvantages

- Diffusion is the rate limiting step for bacterial growth rate, therefore high oxygen concentrations are necessary for high nitrification rates in nitrifying BAF.
- To obtain the best results bio reactor loading should be relatively constant, therefore buffer and equalization tanks are necessary.
- Bio logical aerating tower had very low buffering capacity against peak load.

4.3. Application areas

4.3.1. Fertilizer industry

Fertilizer is a synthesis of chemical compounds which are directly available for utilization by plants, these compounds are either mined or manufactured. Industry uses a variety of nitrogen-based compounds in there manufacturing. Still after maximum retrieval and minimum wastage, the various number of nitrogen-containing compounds comes in the effluent. Hence there is need for the nutrient removal from the effluent.

4.3.2. Tanneries

Bating process in the tanneries is the main source of nitrogen wastes [27]. A process done to reduce swelling is bating, it is done at lower pH. Bating reopen the hidden structure to allow removal of the protein degradation products. Henceit requires ammonium sulphate and ammonium chloride salts. Hence the residue comes out from the tannery contains ammonia in their waste water.

4.3.3. Steel manufacturing

A process in which nitrogen is diffused into the metal surface for creating the hard surface is Nitriding. This process is most commonly used in low-carbon, low-alloy steels. Residue of nitrites comes in the effluent of steel manufacturing plant.

4.3.4. Sewage

Ammoniacal nitrogen is the nitrogen found in the ammonia (NH_4) part of the sewage - mainly from urine. Nitrogen is a major plant nutrient and too much nitrogen in the watercan causegreater plant growth and algae bloom in water surface of lakes, and pond this can result in the death of fish and other aquatic life due to lack of oxygen as the plants which grow over the surface of water reduce light penetration in the water body which further reduce the DO concentration in the water body. The removal of nitrogen from sewage effluent has become a essential requirement for the treatment of sewage and other wastewaters as to maintain the biodiversity.

4.3.5. Dyes &dye intermediates

Processes which use urea as a raw material, are mostly the source of high ammonia. Excess urea is added to increase the reaction rate i.e. it helps in moving the reaction in forward direction. Like in the case of phthalocyanines.

Ammonia vapors are collected in the scrubber. Water from scrubber unit if found suitable i.e. if it be able to produce 15% ammonia concentration this can be sold as a byproduct. If scrubbing water was not a possible product than all the waste water is send to effluent treatment plant of the industry, hence adding huge amounts of ammoniacal nitrogen in the effluent.

4.3.6. Pharmaceutical Industry

Ammonia is used in many extraction operations of pharmaceutical industry because in various process it is necessary to control the pH of water. Ammonium salts are used as buffering agent, aqueousor anhydrous ammonia is used as an alkalinizing reagent. Ammonium salts are highly soluble in water hence they prevent precipitation of different salts, and they do not react chemically with animal or plant tissue. Some basic materials as hydroxides and carbonates of alkali metals do not have these advantages. Ammonium salts are used for pH control during the extraction operations.

4.3.7. Textile Industry

The total nitrogen and ammonia nitrogen come from dyes and raw materials, which is not very high, about 10 mg/L. But the urea is needed while using batik techniques, its total nitrogen is 300 mg/L, residual nitrogen compounds come in theeffluent of Batik technique [28].

4.4. Limitations

- Sensitivity to solids loading and limited solids storage capacity.

Chapter 5: Basic design of biological aerating tower

1. The solid loading rate is measured in $Kg/m^2/day$. It varies from 0.5-2.5 NH_4-N g/m^2 day for Nitrification and 2g NH_4-N/m^2day for Denitrification.
2. Specific surface area (SSA) is a property of solids defined as the total surface area of a material per unit of mass, (with units of m^2/kg or m^2/g) or solid or bulk volume (units of m^2/m^3 or m^{-1}).

Step 1 To obtain feed per cubic meter

- Feed per cubic meter = Media Specific surface * Feeding rate
- The volume of reactor= Influent Ammonia Load/ Feed per cubic meter
- Tower height generally (1.5 to 3 meter)

Step 2 Find the Diameter of the reactor

- Volume = $\pi r^2 h$
- R^2(radius)= $V/(\pi h)$

Step 3 Oxygen requirement for Nitrification

Oxygen requirement is 4.6 times to ammonia loading rate for nitrification.

- Density of air = 1.22 kg/m^3
- The efficiency of mixing of air is affected by tank geometry, hence a correction factor α is introduced whose value varies from 0.3-1.2.
- The correction factor β is used to correct the test system oxygen transfer rate for differences in oxygen solubility due to constituents in the water such as salts, particulates, and surface-active substances. β varies from 0.7-0.98.

$$AOTR= SOTR\ ((\beta\ C_{s,T,H} - C_L)/C_{s,20})\ (1.024^{T-20})\ (\alpha)(F)$$

AOTR = actual oxygen transfer rate kg O_2 /h

SOTR = standard oxygen transfer rate in tap water at 20 °C kg O_2/h.

β = Salinity surface correction factor

$C_{s,T,H}$ = Average dissolved oxygen saturation concentration in clean water in aeration tank

C_L = Operating oxygen concentration, mg/l

$C_{s,20}$ = Dissolved oxygen saturation concentration in clean water at 20^O C

T= Operating temperature

α = oxygen transfer correction factor for waste

F = fouling factor

5.1. Design example

- Flow rate = 2 LPH (50 LPD)
- Inlet NH_4-N = 200 mg/l
- Media Specific surface area = 500 m^2/m^3
- Influent ammonia Load = 200 *50 = 10g/day

Step 1 Calculation for volume of tank required for Nitrification:

Feeding Rate (assumed) = 0.5 NH_4-N g/m^2 day

Feed per cubic meter = 0.5 g/m^2 day *500 m^2/m^3

= 250g/m^3day

Volume of tank required = 10g/day / 250g/m^3day

=0.04m^3

Step 2 Calculation for volume of tank required for Denitrification:

Feeding Rate (assumed) = 2g NH_4-N/m^2day

Feed per cubic meter = 2*500

= 1000g/m^3 day

Volume of reactor= 10/1000

= 0.01 m^3

Step 3 Total volume required for nitrification and denitrification:

Take height of tower = 1.5 m

(Height for nitrification + Height for denitrification = 1.0 m + 0.5 m)

Accommodating for fluctuations in the influent, excess volume is considered.

Taking the volume of reactor = 0.05 m^3

Diameter of reactor:

$= (3.14*d^2*1.5)/4 = 0.05\ m^3$

d = 206 mm

Height from which aeration need to give = $0.01*4/(\pi*0.206^2)$ = 300 mm from inlet refer fig 0-1

Step 4 Air requirement

Influent ammonia load = 10g/day

Oxygen require= 4.6*10= 46g/day

α correction factor = 0.7

β correction factor = 0.9

F= fouling factor 0.9

SOTE percentage for membrane diffuser = 5.5% per meter of depth= 5.5*1.5=8.25%

Air density = 1.22 kg/m^3

Air requirement =46/ (0.7*.9*0.9*0.0825*0.23*24*1.22*10^{-3}) = 117.46 l/hr

Now that we have obtain the size of the reactor we need to select the MOC of the reactor given below are the following points need to be in mind before choosing the material:

- Strength
- Corrosion and Chemical resistance
- Chemical Compatibility
- Ease of Fabrication
- Costs

By considering the above points MOC of reactor is selected to be mild steel epoxy coated reactor.

After selection of MOC of reactor required flow rate pump is required in this case we have chosen peristaltic pump. Next chapter explains the fabrication of the reactor along with its process of inspection.

Chapter 6: Fabrication of Biological aerating tower

Before Proceeding for fabrication, require material List along with instrument list was prepared and the material list is given for procurement. List of material to be procured for making the biological aerating tower is shown in table 2

Table 2 Material required along with specifications

S.NO	Material required	Specifications
1.	**Biological aerating tower**	
2.	**Bio-tower Feed Pump**	Flow rate - 6 LPH
		Head - 10 MWC
5.	**Diffuser**	Type: Vertical membrane diffuser
		Diameter: (100mm)
		Length: 220mm
		MOC of Membrane: silicon
		Process Connection: 20 NB (BSP M)
6.	**Media**	Diameter: 22mm
		Length: 16mm
		MOC: PP
		Specific Surface area: 400m2/m3
		Density: 0.93 gm/cc
7.	**Feed water collection tank**	Operating Volume -50 litre
		Diameter: 410 (Bottom dia)
		HOS: 440 mm
		MOC: HDPE
8.	**Blower**	Capacity: 1 m3 per day
		Head:5 MWC
		Suction pressure: Atmospheric
		Fluid to be handled: AIR
		MOC: CI
9.	**Instruments**	Length: 1000 mm
	Watch glass	Width: 50mm
		Fluid:Waste water

		Operating pressure: Ambient
		Operating temperature: Ambient
		MOC: Toughened glass, MS frame
	Watch glass	Length: 300mm
		Width:50mm
		Fluid: Waste water
		Operating pressure: Ambient
		Operating temperature: Ambient
		MOC: Toughened glass, MS frame
8.	**Rotameter**	Line size: 10 mm(ID)
		Flow rate- 0- 6 LPH
		Panel mounted
9.	**Air flowmeter**	Line size: 10 mm(ID)
		Flow rate- 0- 40 LPM
		MOC- Acrylic
		Float MOC- SS 304
		With air regulator
		Panel mounted
10.	**Stack diffuser**	Male threaded: 63 NB (Nominal bore)
		Length of threading: 35mm
11.	**Valve**	Line size: 15NB
		Type: Needle valve
		MOC- SS
		Female threaded ends
12.	Cables, Glands & Switchboard	
	Three-way switch	Current: 6 A
	Three-way switch	Current: 12A

The material of construction of reactorwas Mild steel along with the epoxy coat to prevent it from corrosion was chosen. Effluent feeding rate into the reactor is very low along with no pressure requirement, so the peristaltic pump was chosen for feeding the effluent into the reactor. Blower with required air volume is selected.

Before fabrication, material required for fabrication is needing to be selected material list shown in table 3

Table 3 Fabrication Material List

S. No	Fabrication Material	Quantity	Weight
1.	250 NB pipe	Length 2 metre	27.78 x 2= 55.6 kg
2.	250 NB Blind Flange	2 no	32.0x2 = 64 kg
3.	250 NB slip on raised Flange	4 no	19.5 x 4 = 78 kg
4.	40 NB SS304 socket	2 no	1.06 x2 = 2.12
5.	40 NB SCH 10 pipe	Length 100 mm	3.11x1= 0.3 kg
6.	20 NB, SCH 10. SS304 pipe	Length 230 mm	1.28x0.23= 0.3 kg
7.	20 NB, BW, 90degree short rad elbow	1 no	0.08 kg
8.	20 NB, SS 304 Coupling	2 no	0.21x2= 0.42 kg
9.	40 NB, SS 304 coupling	2	1.06x2= 2.12 kg
			Total weight= 202.94 kg

Before starting the full weld, tack weld has been done fig 13 and 14 shows the tack welded anoxic zone and aerobic zone reactor. After tack welding, inspection is done, whether dimensions are matching as to the design dimensions. After inspection, the full weld has been done and again the inspection has been done for any error. After full weld whole reactor needs to be painted before painting surface of the reactor is made rough. After that red oxide paint is applied to the reactor and then two coats of epoxy smoke grey paint have been applied on the reactor for preventing the reactor from any corrosion.

Figure 13 Fabricated reactor anoxic Part

Figure 14 Fabricated aerobic part

As reactor require skid on which it has been supported within which pump, blower, reactor and feed tank is placed. Skid material is chosen to be stainless steel. Instrument plate also has been installed on the skid. Instrument plate consist of rotameters and switches. Fig 6.3 shows the fabricated skid.

Rotameters are installed for maintaining the flow within the reactor, airflow metre is installed to vary the air supply within the reactor. By varying the air flow, we can measure the effect on efficiency of total nitrogen removal.

After Completion of fabrication work inspection is done, list of the things need to be covered are:

- Visual inspection
- Dimensions and weight
- Calibration
- Surface finish
- Fabrication quality
- Hydro test

Once the full welding is done the buffing of the skid is done to obtain smooth surface. To prevent the reactor surface from corrosion and rusting proper prevention must be taken care of for that epoxy paint has been done. To make the surface for accepting the paint surface is prepared by brushing. After proper brushing paint coating should be done in order to obtain 200 DFT (dry film thickness) of the paint.

Figure 15 Tack welded skid

After complete inspection plant installation need to be done stages of installation includes:

- Erection of fabricated tanks
- Installation of Pump, Blower, rotameter, blower.
- Piping
- Service test

Figure 16 Flanges for reactor base and top

6.1. Selection of pump

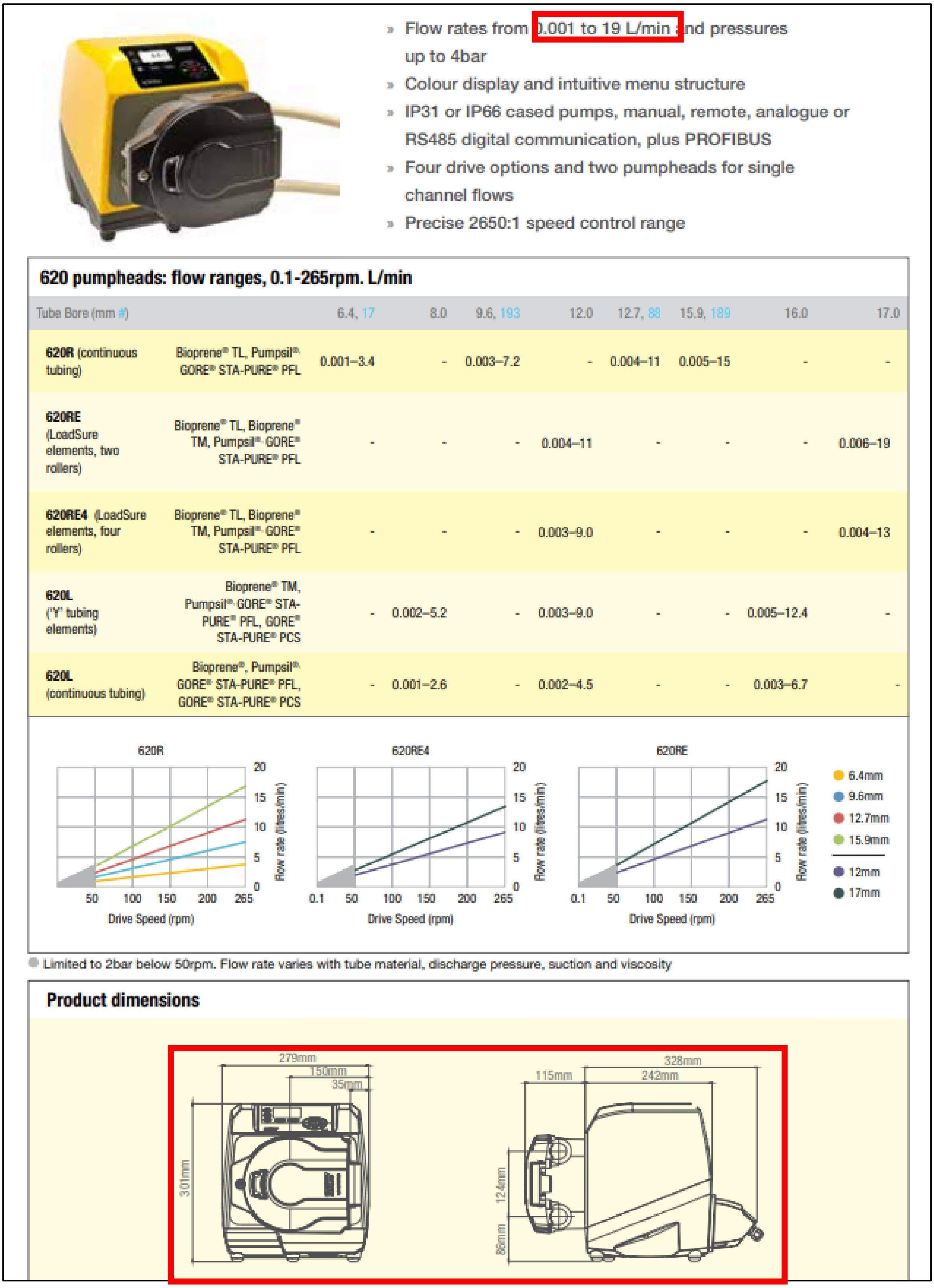
Depending for your choice of pump, find a respective power rating for the required discharge and required head, from best efficiency performance curve, i.e. do not choose exactly the same head or flow as calculated, leaving margin for flow variations as shown in figure.

As the required flow rate for pilot plant setup is 2-6 LPHi.e. (0.033-0.1 LPM) and required pressure is 10 metre water columns considering the entire major and minor loses. Hence the below mentioned figure shows the selection of pump according t mention parameters. Product dimensions mentioned in the figure17 are useful in fabrication accordingly to find out the space required by the pump which further help in giving specific space to the pump in the skid.

6.2. Selection of blower

Depending for your choice of blower, find a respective power rating for the required air flow rate and required head, from best efficiency performance curve, i.e. do not choose the same head or flow as calculated, leaving margin for flow variations as shown in figure.

Like for 2000mm water column we require 120 m3/hr of air flow rate hence select blower as shown in fig 18



- Flow rates from 0.001 to 19 L/min and pressures up to 4bar
- Colour display and intuitive menu structure
- IP31 or IP66 cased pumps, manual, remote, analogue or RS485 digital communication, plus PROFIBUS
- Four drive options and two pumpheads for single channel flows
- Precise 2650:1 speed control range

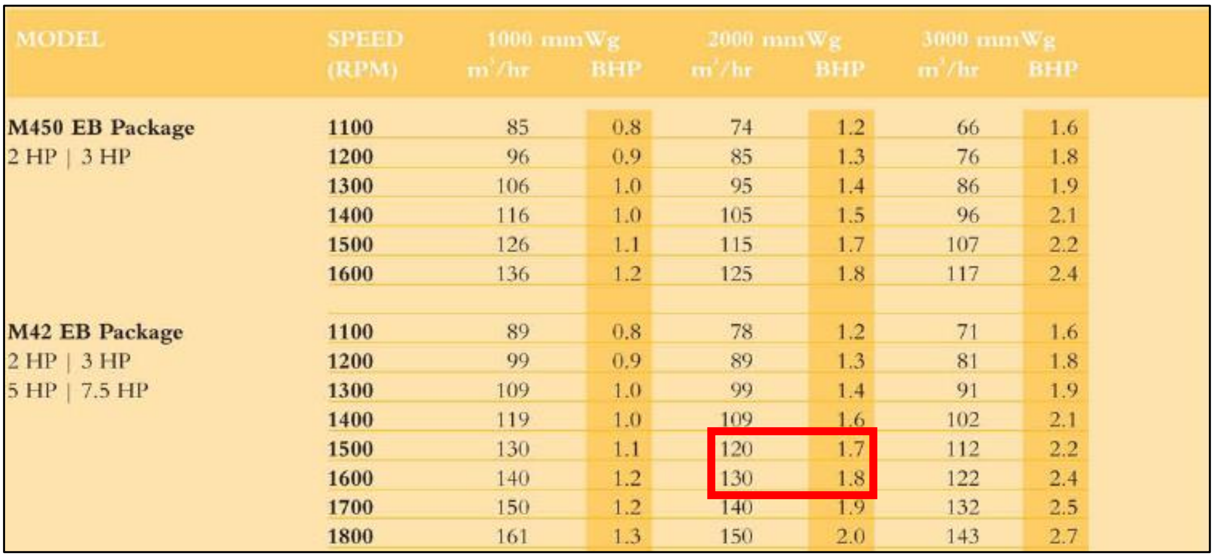
620 pumpheads: flow ranges, 0.1-265rpm. L/min

Tube Bore (mm #)		6.4, 17	8.0	9.6, 193	12.0	12.7, 88	15.9, 189	16.0	17.0
620R (continuous tubing)	Bioprene® TL, Pumpsil®, GORE® STA-PURE® PFL	0.001–3.4	-	0.003–7.2	-	0.004–11	0.005–15	-	-
620RE (LoadSure elements, two rollers)	Bioprene® TL, Bioprene® TM, Pumpsil®, GORE® STA-PURE® PFL	-	-	-	0.004–11	-	-	-	0.006–19
620RE4 (LoadSure elements, four rollers)	Bioprene® TL, Bioprene® TM, Pumpsil®, GORE® STA-PURE® PFL	-	-	-	0.003–9.0	-	-	-	0.004–13
620L ('Y' tubing elements)	Bioprene® TM, Pumpsil®, GORE® STA-PURE® PFL, GORE® STA-PURE® PCS	-	0.002–5.2	-	0.003–9.0	-	-	0.005–12.4	-
620L (continuous tubing)	Bioprene®, Pumpsil®, GORE® STA-PURE® PFL, GORE® STA-PURE® PCS	-	0.001–2.6	-	0.002–4.5	-	-	0.003–6.7	-

● Limited to 2bar below 50rpm. Flow rate varies with tube material, discharge pressure, suction and viscosity

Product dimensions

Figure 17 Peristaltic pump catalogue



MODEL	SPEED (RPM)	1000 mmWg m^3/hr	1000 mmWg BHP	2000 mmWg m^3/hr	2000 mmWg BHP	3000 mmWg m^3/hr	3000 mmWg BHP
M450 EB Package	**1100**	85	0.8	74	1.2	66	1.6
2 HP | 3 HP	**1200**	96	0.9	85	1.3	76	1.8
	1300	106	1.0	95	1.4	86	1.9
	1400	116	1.0	105	1.5	96	2.1
	1500	126	1.1	115	1.7	107	2.2
	1600	136	1.2	125	1.8	117	2.4
M42 EB Package	**1100**	89	0.8	78	1.2	71	1.6
2 HP | 3 HP	**1200**	99	0.9	89	1.3	81	1.8
5 HP | 7.5 HP	**1300**	109	1.0	99	1.4	91	1.9
	1400	119	1.0	109	1.6	102	2.1
	1500	130	1.1	120	1.7	112	2.2
	1600	140	1.2	130	1.8	122	2.4
	1700	150	1.2	140	1.9	132	2.5
	1800	161	1.3	150	2.0	143	2.7

Figure 18 Blower catalogue

Figure 19 Stack Diffuser

Once all the fabrication work is completed,then plant is assembled i.e. first the reactor is mounted on the skid than the flanges are mounted in the reactor. As flanges contain barrel nipple on which stack diffuser is mounted. Above anoxic zone arrangement has been done to provide vertical diffuser. Pipe fittings are done as required. Rotameter are installed on the instrument plate. Separate air flow metre is installed for the measurement of air flow rate within the system. Fig 6.7 shows the stack diffuser which is installed at inlet and outlet of the reactor to retain the media. For electrical connections seprate BOX is provided to carry the cables for the pump and blower.

Figure 20 Erected biological aerating tower

After complete erection of the biological aerating tower hydro test is performed to find any leakage or to make sure the reactor can work under high pressure conditions. if any leakage in joints and pipe is found is arrested . It is to be make sure that the biological aerating tower should be at stable postion hence four screws are adjusted according to leveling tube. Above mentioned fiqure 20 shows the back view and fig 21 front view of the reactor.

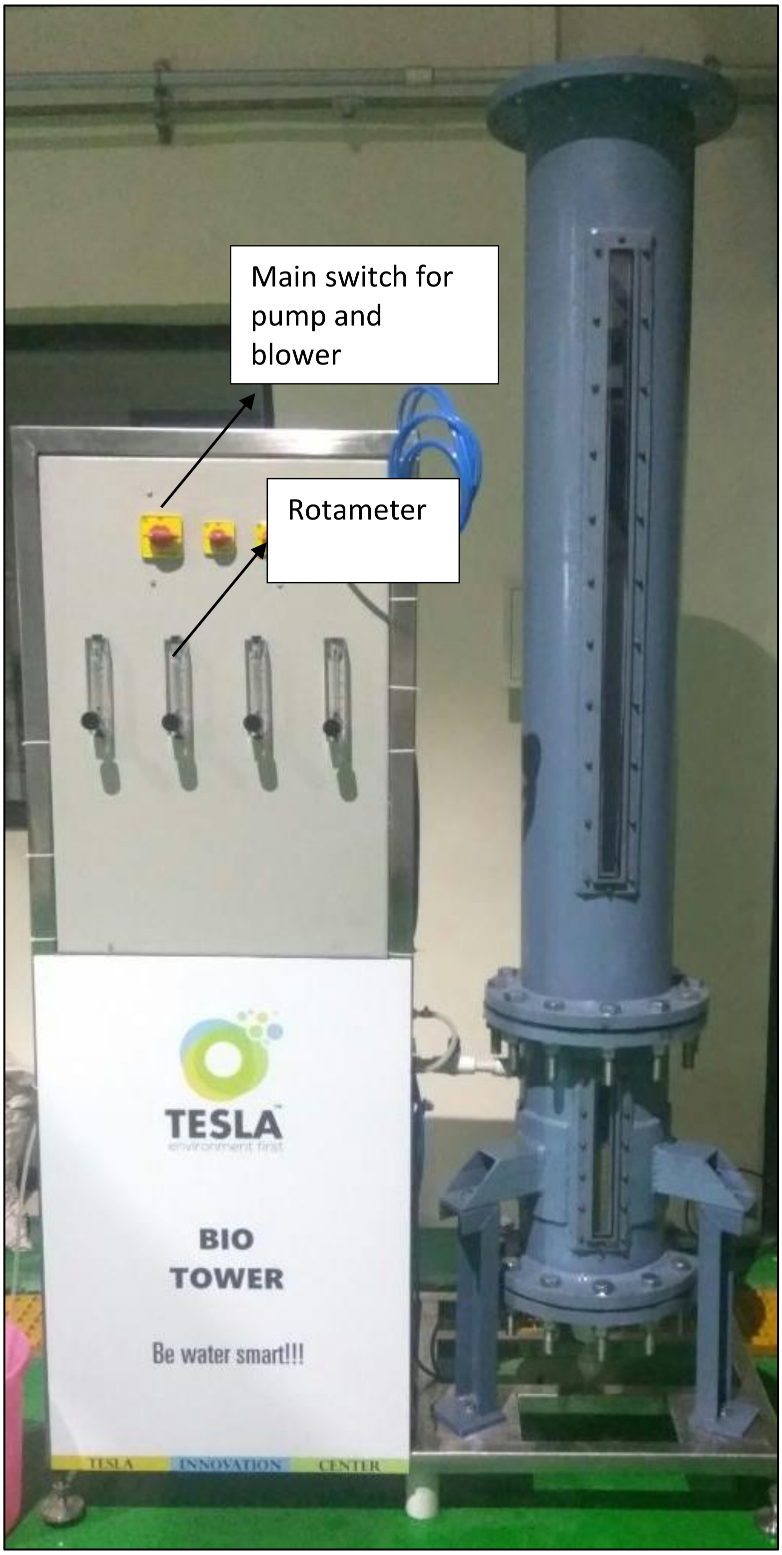


Figure 21 Front view of the BAT along with instrumentation

After hydro test there are certain leakages in the BAT. Major leakage found in the watch glass, silica gel is applied to arrest the leakages

6.3. Standard Operating procedure

Normal Operating Parameters:

Normal Operating Flowrate	
Tag No.	**Value (in LPH)**
Rotameter-1	2-6
Rotametre-2	2-6

1. Check effluent level in the effluent storage tank and if the level is considerably above the suction valve then the plant is ready for start-up.
2. Ensure all the valves are in service mode. Incorrect valve adjustment may lead to reduced flow or cause damage to the equipment and piping due to sudden increase in pressure.
3. After ensuring the water level, switch on the bio-tower feed pump (P-01) and throttle the valve to adjust the discharge to give the desired flow rate.
4. Switch on the blower (B-01); Maintain dissolved oxygen level in Aerobic zone by regulating the required air flow rate.
5. Ensure Dissolved oxygen level should be 2 to 3 mg/ lit in aerobic zone Bioreactor tank(BT-01).
6. The fine bubble must be uniformly distributed & No dead zones must be formed. Coarse bubble indicate that diffuser has got damages & needs replacement
7. Ensure air vent valve always remains open, so that no pressure can be build up inside the bio tower.
8. By throttling the valve and, maintain the appropriate flow rate for recirculation so that effluent gets a sufficient retention time.
9. For denitrification Process, the effluent needs to be recirculated after determining the retention time for nitrification and denitrification
10. Collect intermittent samples, then test & note the pH, TDS & COD

Do's

1. Ensure the proper microbial growth inside the tank for satisfactory BOD/COD/TKN removal.
2. Add jaggery/Urea as required.

3. Maintain the blower flow rate within defined range.
4. Be sure to unplug the machine before moving it.
5. Make sure air is diffused uniformly throughout aeration tank.
6. If service is required, contact an authorized Service Technician.

Don’ts

1. Do not turn off any air supply device during operation.
2. Do not cover or move any system components without prior approval of authority.

Chapter 7: Case study

Up flow partially filled biological aerated toweris used to remove totalnitrogen which present in the form of ammonia ions by a nitrification and denitrification process that comprises of biological, physical and chemical processmanaged by a variety of parameters such as dissolved oxygen concentration, pH, and alkalinity. Dissolved oxygen (DO) and pH were shown to have effects on the nitrification process in this study. Total nitrogen removal was observed at different hydraulic retention times within the reactor.

The Biological aerating reactor used in the study was cylinders 2.0 m in height which is divided into 1.5 meter for aerobic zone and 0.5 meter for anoxic zone hence the total volume of the reactor approximately is 100 liters (75 lit for aerobic zone and 25 lit for anoxic zone). Almost 50 to 60 % of the reactor volume is fill with the media and the system is not operated under any pressure. Set up comprise of a biological reactor, one feed tank an inter connecting tubing network, pumping facility blower, diffuser and the sensor for pH and DO. Peristaltic pump is used for effluent transfer in the biological reactor. A stack diffuser was installed at the inlet and outlet of the reactor, stack diffuser prevent media to block the pipe. A schematic set up is shown in the figure 22.

The study was performed for 30 days on the industrial sewage waste water, waste water need to be given specific retention time for the treatment. Effluent at various time intervals was obtain from the reactor and send for its characteristic analysis.

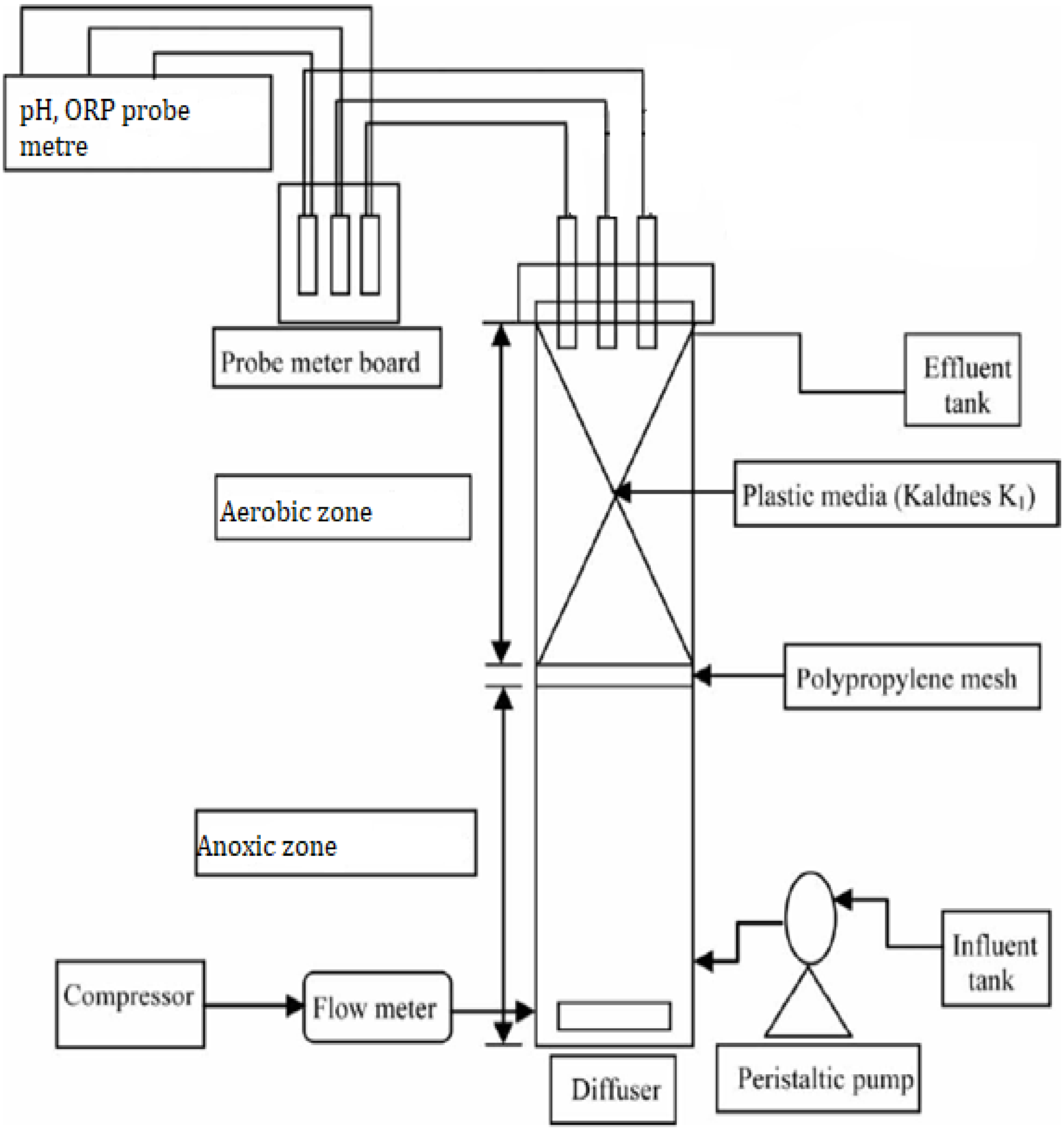


Figure 22 BAT Reactor

Effluent Inlet parameters are analyzed as shown in table 4. Designed MLSS for nitrification and denitrification are calculated below

Table 4 Inlet Parameters

pH	Alkalinity (mg/l)	BOD (mg/l)	COD (mg/l)	TKN (mg/l)
7.25	380	84.5	146	39.14
6.5	360	78.8	140.12	34.5
7.2	390	75.5	138.6	45.3
8.4	420	85	148	38.7
Average value	387.5	80.95	143.18	39.41

Average value of TSS = 90 mg/l in the influent

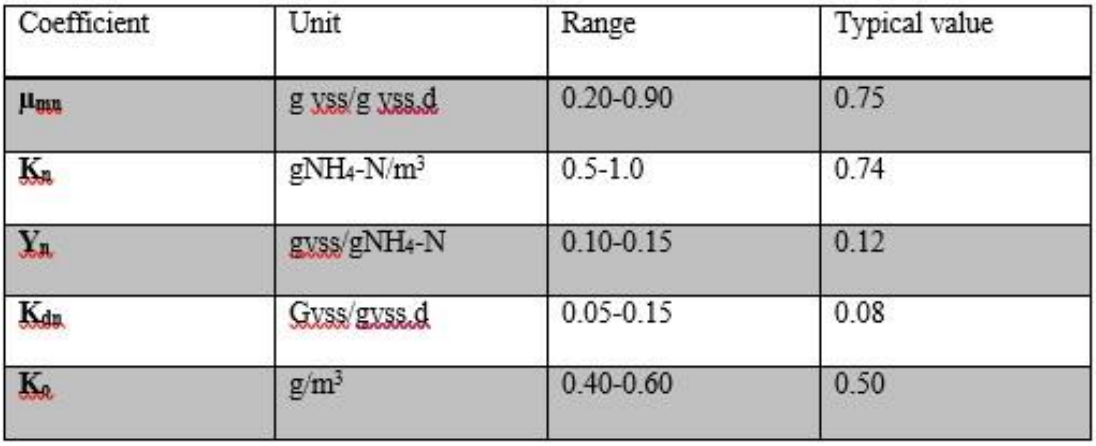
Average value of VSS = 70 mg/l in the influent

Table 5 depicts the Operating parameters for biological aerating tower

Table 5 Operating parameters of Biological aerating tower

Parameter	Value
Diameter of Tower	250mm
Height of Aerobic zone	1200mm
Height of Anoxic Zone	400mm
Flow rate	5 LPH
Nutrient Loading rate Nitrification	0.5-2.5 g NH_4- N/ m^2day
Nutrient Loading rate denitrification	2g NH_4- N/ m^2day
Organic loading rate	0.3gBOD/m^2/day

Table 6 Activated -sludge nitrification kinetic coefficients at 20^{O} C



Coefficient	Unit	Range	Typical value
μ_{mn}	g vss/g vss.d	0.20-0.90	0.75
K_n	gNH$_4$-N/m^3	0.5-1.0	0.74
Y_n	gvss/gNH$_4$-N	0.10-0.15	0.12
K_{dn}	Gvss/gvss.d	0.05-0.15	0.08
K_o	g/m^3	0.40-0.60	0.50

TSS = 90 mg/l

VSS= 70 mg/l

A. Calculation of specific growth rate for nitrification

$$\mu_n = \left(\frac{\mu_{n,m} N}{K_n + N}\right)\left(\frac{DO}{K_o + DO}\right) - k_{dn}$$

Where

μ_n = Specific growth rate for nitrification (T^{-1})

μ_{nm} = Maximum specific growth rate of nitrifying bacteria. (T^{-1})

N = Nitrogen concentration in the effluent (mg/l)

DO = Dissolved oxygen concentration (mg/l)

K_o = Oxygen inhibition coefficient (mg/l)

K_n = half velocity constant, substrate concentration at one-half the maximum specific substrate utilization rate, (mg/l)

Usual working temperature is 20 to 25-degree Celsius

Considering the values from above table 4 and taking value for dissolved oxygen concentration to be 2.0 mg/l and considering the effluent NH$_4$-N concentration in the effluent be 0.6 mg/l

$$\mu_n = \left(\frac{0.75 * 0.6}{0.74 + 0.6}\right)\left(\frac{2}{0.5 + 2}\right) - 0.08$$

$$\mu_n = 0.188 \text{ g/g. d}$$

B. Determination of SRT

1. Finding theoretical SRT

$$SRT = \frac{1}{\mu_n}$$

Where
SRT = Solid retention time, (T)

$$= \frac{1}{0.188} \quad = 5.319 \text{ d}$$

2. Determine the design SRT

Factor of safety = TKN peak/TKN average

= 1.5

Design SRT = FS* theoretical SRT = 1.5* 5.319 = 7.97 day

C. Determination of Biomass Production

Equation 4

$$P_{X,bio} = \frac{QY(S_o - S)}{1 + K_d SRT} + \frac{f_d k_d QY(S_o - S)SRT}{1 + K_d SRT} + \frac{QY_n(NO_x)}{1 + K_{dn} SRT}$$

Where

$P_{X,,bio}$ = Biomass as VSS (Kg VSS/day)

Y = biomass yield rate (gVSS/g substrate)

S_o = Influent substrate concentration (mg/l)

S = Concentration of growth- limiting substrate in solution, (mg/l)

K_d = endogenous decay coefficient (T^{-1})

F_d = fraction of biomass that remain as cell debris, (gvss/gvss)

Y_n = yield rate of nitrifires (gVSS/g NH_4-N)

K_{dn} = endogenous decay coefficient for nitrifying organisms, (T^{-1})

NO_x = Concentration of NH_4- Nin the influent flow that is nitrified, (mg/l)

Input data

Q= 0.12 m^3/day

Y = 0.40 vss/gbCOD

S_o= 81 mg/l

K_d =0.088 g/g.day

μ_m = 3.6 g/g.day

Determining S

$$S = \frac{K_s[1 + (k_d)SRT]}{SRT(\mu_m - K_d) - 1}$$

$$S = \frac{20[1 + (0.088)7.97]}{7.97(3.6 - 0.088) - 1}$$

= 0.57 gbCOD/m^3

Assuming NO_x approximately as 80% as nitrogen balance cannot be done yet.

NO_x = 0.80*39.4 = 31.52 g/m^3

Substituting all the values in equation 4

$$P_{X,bio} = \frac{0.12 * 0.4(81 - 0.5)}{1 + 0.088 * 7.97} + \frac{0.15 * 0.088 * 0.12 * 0.40(81 - 0.5) * 7.97}{1 + 0.088 * 7.97} + \frac{0.12 * 0.12\ (31.52)}{1 + 0.08 * 7.97}$$

= 47.59+ 0.2389+0.277

= 48.1059 gm VSS/day

D. Determine the concentration and mass of VSS and TSS in the aeration basin.

1. Calculate the concentration of VSS and TSS in the aeration basin

$P_{X,\ VSS}$= 48.1059 kg/d + Q (nbvss)

= 48.1059 + 0.12 *20

= 50.506 gm/day

$P_{X,\ TSS}$ = (50.506)/0.85 + Q (TSSo – VSS_o)

Where

$P_{X, TSS}$ = Net waste activated sludge produced each day, measured in terms of total suspended solids, kg/d

TSSo =Influent waste water TSS concentration, (mg/l)

VSS_o= Influent waste water VSS concentration, (mg/l)

Nbvss = non-biodegradable VSS in influent (mg/l)

= 59.418 +0.12 (10)

= 60.618 gm/day

2. Calculation of mass of VSS and TSS

Mass of MLVSS

$(X_{VSS})*V = (P_{X, VSS})$ SRT

Where

V = Volume of the tank

= 50.506 * 7.97

= 402.532 gm

Mass of MLSS

$(X_{TSS})*V = (P_{X, TSS}) * SRT$

= 60.618 *7.97

= 483.12 gm

E. Calculation of the required MLSS based on the reactor volume

a. Determination of the MLSS

X_{TSS} V = 483.12 gm

$$= \frac{483.12*1000}{75}$$

MLSS = 6441.6 mg/l

F. Check Alkalinity

Amount of nitrogen converted to nitrate: NO_x = 31.52 mg/l

Alkalinity required for nitrification = 7.14 g calcium carbonate /g NH_4-N) (31.52gm/m^3)

= 225.05

No alkalinity is required in the waste water as influent waste water has average alkalinity of 350mg/l hence no alkalinity is required.

Anoxic specifications

SDNR = 0.2g/g day at 20 degrees Celsius

$NO_x = (V_{nox})$ (SDNR) (MLSS)

Where

NO_x = Nitrate removed, (grams/day)

V_{nox} = Anoxic tank volume (m^3)

SDNR = specific denitrification rate, (g NO_3-N/g MLSS.d)

MLSS = Mixed liquor volatile suspended solids concentration, (mg/l)

0.12* 31.52 = (0.025) *0.22*MLSS

MLSS = 700 mg/l

As found above MLVSS for both nitrification and denitrification are used for pilot trials and based on that

$$5CH_3OH + 6NO_3^- \longrightarrow 3N_2 + 5CO_2 + 7\,H_2O + 6\,OH^-$$

One gram of nitrate requires 0.43 g BOD hence the effluent contains sufficient amount of BOD so that denitrifies can grow

For nitrification and denitrification MLVSS is considered separately for aerobic zone and anoxic zone as shown in table 7

Table 7 Actual values taken for MLVSS

Parametrs	**MLSS (mg/l)**
Nitrification	6000
Denitrification	1000

Fig 23 shows the Raw effluent, this raw effluent is obtained from equalization tank of industrial sewage treatment plant. Details about the reactor set-up are explained below

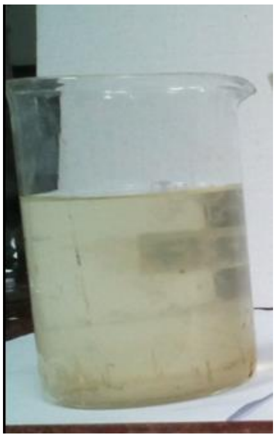


Figure 23 Raw effluent

7.1. Bio reactor Set up

Reactor is first needed to be sterilized along with the media. This is usually done by hypochlorite bleach. After disinfectant usage, bioreactor must be drained out with sterile water before inoculation with the process microbes. If the raw or used water is the source of influent as well as for bio reactor set up, then sterilization may not be necessary.

Water is filled up-to 50% of the volume of the reactor keeping air supply for continuous for 24 hrs so that DO concentration within the water reaches up to the 8-9 mg/l or desired concentration. Activated sludge or desired microorganisms are brought and fed into the system as per the required MLSS. As this the attached growth system media along with the activated sludge or desired microorganisms are fed into the reactor now along with the sufficient air flow rate and sufficient retention time i.e. about 24-48hrs need to be given so that the microorganisms get attached to the media surface.

Very high air flow rate is not recommended as microorganisms get sheared off from the media surface. Than start dosing the effluent in the biological aerating tower along with the suitable urea, jaggery and DAP dosage based on C N P ratio i.e. (100:5:1). As denitrifies they mostly required methanol i.e. carbon as energy source generally methanol dosing vary from 3to 3.6 mg/mg of nitrate nitrogen

After bio film formation over the media, feeding should be initiated at dilution rate equivalent to at least 80%[7] of the microbe’s maximum growth rate.

Microorganisms gets attached to the media surface and their colonies grow to form a bio film. Hence it results in the increase in particle size and decrease in overall density of the media.

---

[7] Above value is as per engineer’s experience

Despite of this initial difference in density, overall biomass supporting media shows a similar specific gravity as the thickness of biomass increases. As the microorganisms grow over the media surface size of the media increases and its density decreases. Bed continues to grow as the design height is achieved.

As this plant is a pilot plant, we have grown the microorganisms on the media than the media is transferred within the reactor for intially 2-3 days is given for the media to get attached on the media surface.

As the influent BOD = 81 mg/l

Influent TKN = 39.4 mg/l

Suggested BOD/N ratio = 100/5 = 20

Nutrient needed = 81/20 = 4.05 mg/l

As nutrient which is coming in influent is more than the required hence there is no requirement of nutrient addition in the influent.

A photograph for bio reactor set up was shown below.

Figure 24 Preparation of Microorganisms

Based on the trails conducted table 9 shows the results obtained at different time interval for the BOD, COD, N-NH_4. As to obtain the working efficiency of the reactor sample was taken at different time intervals.

Table 8 Outlet parameters

pH	Alkalinity (mg/l)	BOD (mg/l)	COD (mg/l)	TKN(mg/l)	HRT (hours)
7.35	120	5.2	10.7	1.65	8
6.3	140	6.5	18.5	5.6	6
7.3	160	4.7	40.6	2.3	6.5
8.4	155	8.9	65.2	6.7	5.5
7.4	187	-ND-	-ND-	14.5	5
6.8	197	-ND-	-ND-	22.3	4
8.2	220	-ND-	-ND-	30.4	3

Based on parameters analysis reduction efficiency is calculated and is shown in table 10.

7.2. Rate of Nitrification

It is expected that the longer the residence time of the sewage in the reactor in contact with the microorganisms the larger the proportion of the incoming nitrogen that will be oxidised.

However, the residence time increase it was found that rate of nitrification is decreased. Table 7.1 depicts the total nitrification at8, 7, 5.5 and 5hrs are constant after acclimatisation of bacteria. 3 and 4 hrs show more value because denitrification bacteria need to be acclimatized.

There is marked change in total nitrification at 4 and 5 hrs reason for this can be, as denitrification started simultaneously hence after 5 hrs, denitrifies acclimatized and it can be seen in table 7.6.

Table 9 Influence of residence time on nitrification

HRT(hr)	Total Nitrification (NO_2 +NO_3) (mg/l)	Nitrification Rate (mg/hr/gMLVSS)
8	18.6	0.38
7	18.7	0.44
6.5	15.6	0.4
5.5	19.1	0.57
5	20.3	0.67
4	30.1	1.25
3	31.1	1.67

Rate of conversion is calculated as shown:

For eg NH_4-N converted to NO_3-N = 30.2mg/l

Residence time = 8 hrs

MLVSS = 6.0 g/l

Nitrification rate = $\frac{30.2}{8*6}$

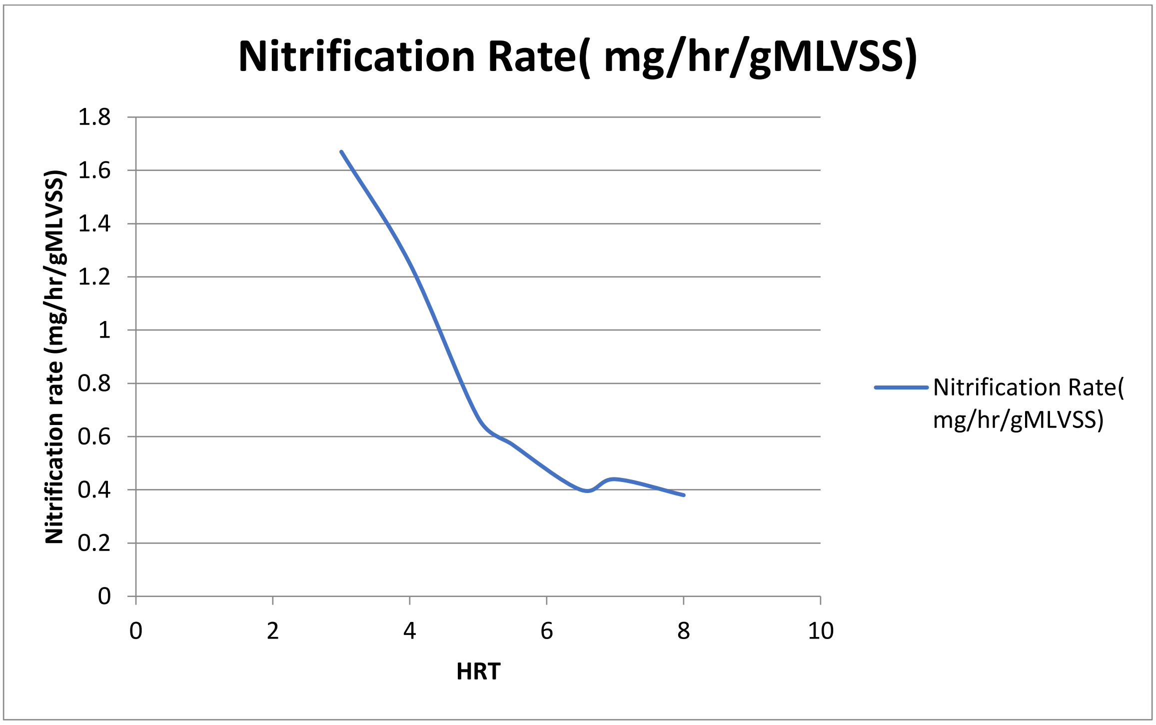


Figure 25 Nitrification rate Graph

However, it is hard to calculate the denitrification rate because the system comprises of anoxic and aerobic condition within the same reactor.

Table 10 Removal Efficiency

Removal efficiency	HRT
93.23	8
83.77	7
94.92	6.5
75.6	5.5
62.95	5
35.36	4
32.89	3

A graph between total nitrogen removal and hydraulic retention time is prepared as shown in fig 26

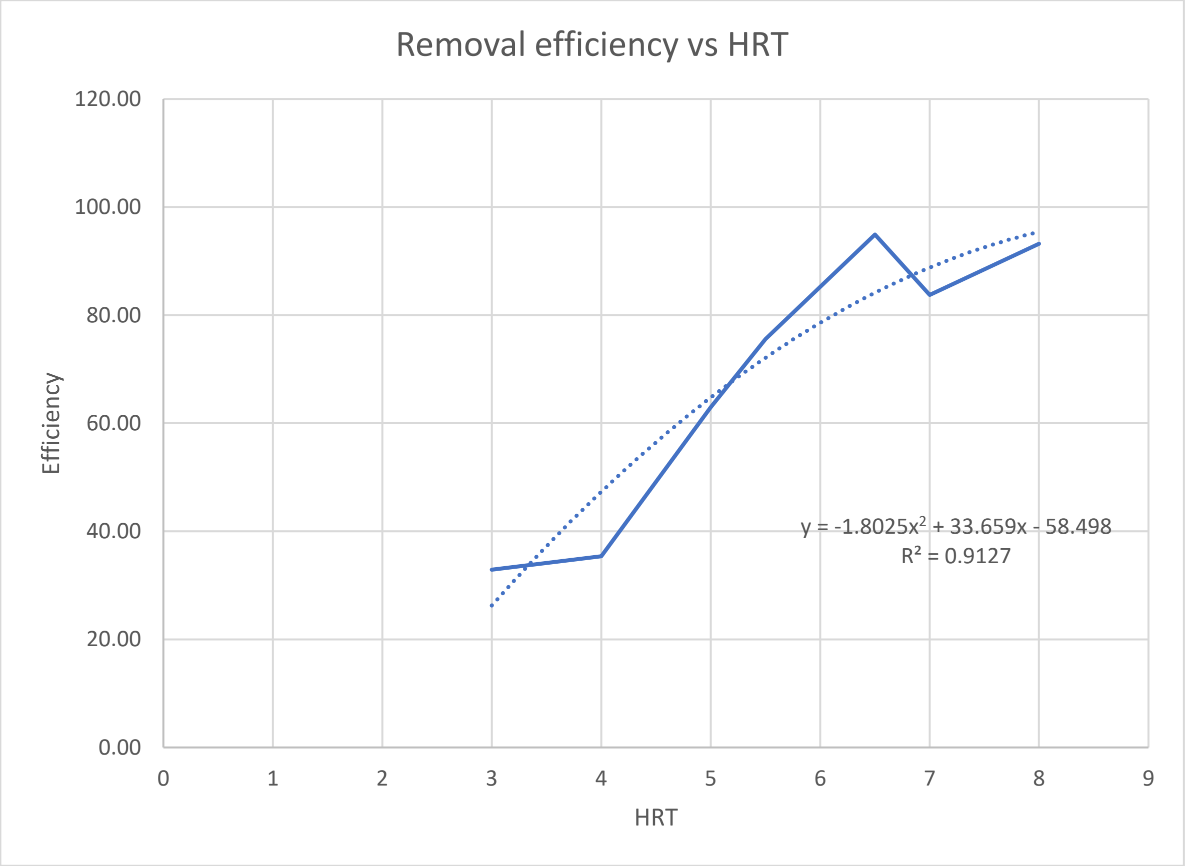


Figure 26 Graph between Efficiency and HRT

Chapter 8: Conclusion and future scope of work

8.1. Conclusion

1. In the secondary (biological) treatment, the optimum HRT value was found to be 8 hrs with an MLSS value of 6000 mg/lit for aerobic zone and 1000 mg/lit for anoxic tank.
2. Maximum reduction for TKN was found to be 93% at 8 hrs HRT there is also 95% reduction in the TKN at 6.5HRT but the value is not reliable as it can be seen there may be some error in the finding out the parameter.
3. As polynomial graph is most correlated to the actual curve, hence we can suggest that with maximum desired HRT to obtain maximum reduction efficiency is between 6-8 hrs.
4. While carrying out the case study it was observed higher overloading rates to the reactor shows less efficiency in the total nitrogen removal.
5. It was found that as the residence time increases, rate of nitrification is decreased.

8.2. Future scope of work

1. Better understanding in the approach can be, the analysis the growth kinetics in depth with mathematical modelling.
2. Different industrial effluent can be tested within the reactor for obtaining the suitability of the pilot plant.

Annexure

Method Used for analysis of ammoniacal nitrogen

Ammonical Nitrogen

a) Nesslerization method,

b) Phenate method,

c) Titrimetric method,

d) Ammonia selective electrode method.

Preliminary Distillation Step

The two major factors that influencetheselection of the method for determination of ammoniaare concentration and presence of interferences. Where interferences are present and greater precisionis necessary, a preliminary distillation step is necessary.

1. Add 500 ml water and 20 ml of borate buffer solution to a distillation flask and adjust pH to 9-5 with 6N sodium hydroxide solution. Add a few glass beads and use this mixture to steam out the distillation apparatus until distillate shows no trace of ammonia.
2. Use 500 ml of dechlorinated sample or a portion diluted to 500 ml with water. Removeresidual chlorine by adding, at the time of collection, dechlorinating agent equivalent to chlorine residual. If necessary, neutralize to pH 7 with dilute acid or alkali. Add 25 ml of borate buffer andadjust pH to 9'5 with 6N sodium hydroxide solution using a pH meter.
3. To minimize contamination, leave distillation apparatus assembled after steaming out anduntil just before starting the sample distillation - Disconnect steaming out flask and immediately transfer sample flask to distillation apparatus. Distil at the rate of 6 to 10 ml/minute with the tip of the delivery tube below the surface of acid receiving solution. Collect distillate in a 500·ml Erlenmeyer flask containing 50 ml plain boric acid solution for nesslerization method. Use 50 ml indicating boric acid (see 2.5.3.2) solution for titrimetric method. Distil ammonia into 50 ml of 0'04 N sulphuricacidfor the phenate method and for the ammonia selective electrode method. Collect at least 200 ml of distillate. Lower the collected distillate free of contact with the delivery tube and continue distillationduring the last minute or two to cleanse condenser and delivery tube.

Dilute to 500 ml withwater.When phenate method is used, neutralize the distillate with 1 N sodium hydroxide solution.

Titrimetric Method

Principle: -

The method is used only on samples that have been carried through preliminary distillation. Use the following values for selecting sample volume for the distillation and titration method:

NH3-N in Sample, mg/I	Sample Volume, ml
5 - 10	250
10· 20	100
20 - 50	50.0
50 – 100	25.0

The ammonia in distillate is titrated with standard sulphuric acid.

Apparatus

Distillation assembly - Borosilicate glass flask of 800 to 2000 ml capacity attached to a vertical condenser so that the outlet tip may be submerged below the surface of the receiving acid solution.

Reagents

Mixed indicator solution - Dissolve 200 mg of methyl red indicator in 100 ml of 95 percent ethyl or isopropyl alcohol. Dissolve 100 mg of methylene blue in 50 ml of 95 percent ethyl or isopropyl alcohol. Combine these two. Prepare monthly.

Indicating boric acid solution - Dissolve 20g of hydro boric acid in ammonia free water,add 10 ml of mixed indicator solution and dilute to 1 litre.

Standard sulphuric acid titrant – 0.02 N (1 ml = 280µg of nitrogen).

Procedure

- Proceed as prescribed in Preliminary distillation using indicating boric acid solution as absorbent fordistillate.
- Titrate ammonia in distillate against standard sulphuric acid until indicator turns a palelavender. Carry a blank through all steps of the procedure and apply the necessarycorrection to the

Calculation

Ammoniacal nitrogen, mg/I = ((A - B) x 280) /V

where

A = volume in ml of sulphuric acid used for sample,

B = volume in ml of sulphuric acid used for blank, and

V = volume in ml of sample taken for test.

Vertical Membrane Diffuser VMD-250

General Specification :

Type : Fine bubble tbe diffuser-vertcal mounting design

Size : 90mm dia X 250mm length.

Construction : Robust support made of fiber glass reinforced polypropyleneWith 3/4" inner thread couplingDiffusing tube with special perforationFixing elementLow buoyancy constructionFloodable

Bubble Size : 1.0 - 4.0 mm

Tube material : EPDM / Silicon

PLASTIC MEDIA

TUBE SETTLER MEDIA :

AIRFIN-TS-750 clarifier media provides a large setting surface area within the specified volume thus giving high flow rates.

- Near laminar flow.
- No moving parts - No energy cost.
- Avoid transfer of liquid between tubes.
- Distribution and entry velocity are minimum resulting in maximum efficiency and better effluent quality.
- Efficient design minimizes space requirements.
- Sturdy and easy to transport and install.
- Increases the capacity of clarifier due to increase in area. Enhances the agglomeration of particles by settling.

Technical specifications : (AIRFIN-TS-750)

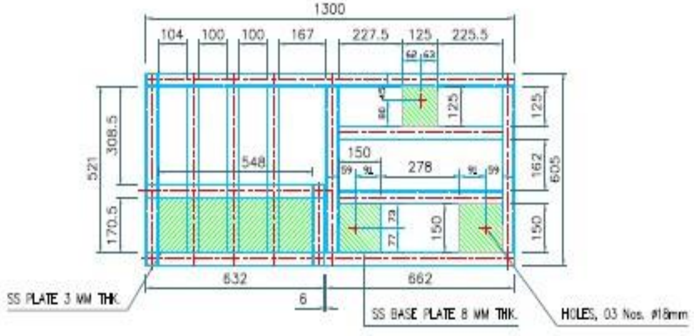
1	Material of Construction	PVC
2	Shape of Tube	Chevron - Unequal Hexagonal
3	Surface Area	$12\ m^2/m^3$
4	Laying Angle	55 or 60 from horizontal
5	Thickness	1 mm (± 0.1mm)
6	Color	Black
7	Distance between Horizontal	120mm
8	Adjacent Tubes	Vertical - 44mm
9	No of tubes per square meter	200 nos
10	Vertical Height	750 mm
11	Weight per Cubic meter	60-65 kg. Approx
12	Maximum Working Temperature	55 C
13	Fitting of Tube	Easy to fit with a tongue and groove arrangement
14	Storage	Media must be stored in a covered place with adequate ventilation
15	Surface Loading Rate	$4 - 5\ m^3/m^2/h$

MBBR Media :

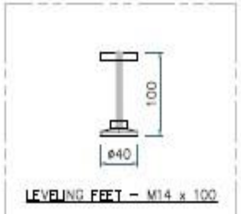
We are offering MBBR Media to our clients by our professional and expert techinicians. They are made of the polymeric materials with the promoted additions of bio-enzyme. It improves the enzyme catalysis. It is an advanced kind of suspension carriers. They are very easy to clean and require low maintenance. We serve them in lots of models and designs. It has a thermo form biofilm reactor and has strong ability to contaminant

Technical Details

Effective Specific Surface Area of Media	$400M^2/M^3$
Colour	Black
Media Height	16 MM
Media Diameter	22 MM
Type of Media	Fluidized Bio Media
MOC of Media	Virgin PP UV Stabilized
Structure	Cylindrical with External Fins
PSA / TSA Ratio (%)	75
Specific Weight (kg/m2) Surface Area	0.37
Specific Gravity	$0.90-0.95\ gms/cm^3$
Max Continuous Operating Temperature	80°C
Voltage	>98%
Density (gm/cc)	0.93
Media Fill Rate Range, % Fill of V	25-55



PLAN

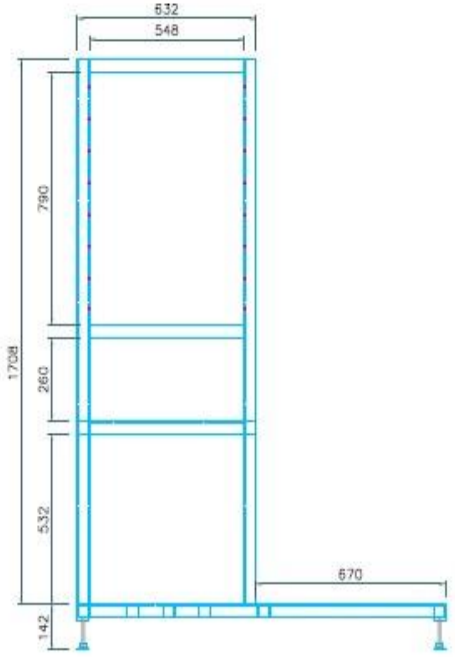


LEVELING FEET – M14 x 100

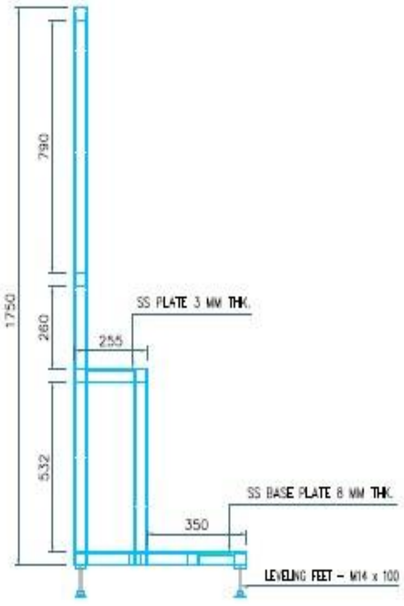
SR NO.	DESCRIPTION	QTY.	MOC
01	SQ PIPE 42mm X 42mm X 3 mm Thk.	14 Mtr.	SS304
02	PLATE 548mm X 170.5mm X 3 mm Thk.	01 No.	SS304
03	BASE PLATE 150mm X 150mm X 8 mm Thk.	02 Nos.	SS304
04	BASE PLATE 125mm X 125mm X 8 mm Thk.	01 No.	SS304
05	LEVELING FEET (M14 x 100) FOR SKID	04 Nos.	–

FABRICATION NOTES :–

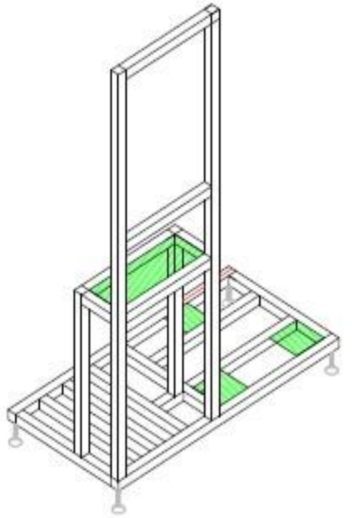
1. ALL WELDINGS ARE OF 5MM. ALL WELDS ARE FILLET WELDS UNLESS OTHERWISE STATED. ALL CORNERS ARE TO BE REMOVED. ALL WELDS MUST BE SMOOTH. THOROUGH CLEANING IS REQUIRED.
2. FABRICATOR TO SUPPLY:
   A) ALL FACILITIES AND MATERIALS FOR TESTING AND INSPECTION BY TPL
3. ALL MATERIAL INCLUDING PLATES, FLANGES, PIPES, NUTS, BOLTS – AND GASKETS MUST BE AS PER MENTIONED M.O.C.
4. ALL DIMENSIONS ARE IN mm. UNLESS OTHERWISE STATED.
5. FOR TRUE ORIENTATION REFER PLAN VIEW.



ELEVATION



SIDE–VIEW (R.H.S.)



ISOMETRIC–VIEW

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