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A STUDY ON REDUCTION OF NITRATE FROM INDUSTRIAL CUM MUNICIPAL WASTEWATER USING MBBR TECHNOLOGY

SAURABH YADAV[1], Dr. J.K .SRIVASTAVA[2]

M.Tech scholar, Department of chemical engineering,Ujjain engineering college,Ujjain(456010), Madhya Pradesh , India[1]

Professor, Department of chemical engineering,Ujjain engineering college,Ujjain(456010), Madhya Pradesh , India[2]

Abstract - Now- a –days, Nitrate in water become a big concern for human society .Since the age of industrialization, Nitrate concentration in municipal & industrial wastewater is increasing day by day,

Due to its high level in water bodies , eutrophication process is growing at high rate , due to eutrophication, algal bloom is covering the upper surface of water bodies , it has adverse effect on marine ecosystem .

Besides this , due to high concentration of Nitrate in waste water many harmful diseases is threating the human race ,diseases like METHEMOGLOBINEIA (BLUE BABAY SYNDROME) in infants , indirectly it helps the carcinogenic elements to cause cancer . due to high concentration of nitrate in aquatic plants , phytoplankton etc , its enters into fishes , prons etc bodies & get accumulated , when humans consume such types of infected aquatic animals , the Nitrate enter into their gastrointestinal system & accumulated, causes coloractel cancer, this cancer may sometimes cause fatal .

So, we have chosen to study a cheap and feasible Nitrate removal process , we have decided to work on MBBR technology , in our work we have selected a cheap PU(polyurethane) sponge based bio - carriers , our PU based bio- carrier have high porosity and low density (28 kg / m^3), large specific surface area per unit weight (0.846 m^2 / g).

Our bio-carrier filling fraction is 20% by volume, at this filling fraction we get satisfactory removal of Nitrate form effluent / wastewater , we have decided to mix municipal wastewater and industrial wastewater (50:50 v/v), it help us to remove Nitrate without chemical & biological entity doping .

We have used a spontaneous Nitrification & Dinitrification process(SND) , this make our work economically feasible . In our study it has been, analyzed that the high concentration of Nitrate ceases the bacterial colony growth in bio-carriers .

It has been recommended by us , while using MBBR use mixture of municipal wastewater & industrial effluent for nitrate removal .

Key Words: MBBR, PU , SND.

1. INTRODUCTION

Introduction-

Nitrates and nitrites are composition of N_2 and O_2 that present naturally in our environment due to the Nitrogen Cycle.

• Nitrogen is a vital nutrient to plants and animals i.e. amino acids, which is key raw material for protein systhesis in animal as well as plants body.

• The wastes from animals & humans i.e. faecal & urine and fertilizer products i.e. NPK , ammonium nitrate , ammonium sulphate etc are degrade to form nitrates(NO_3 and nitrites(NO_2).

There are different types of nitrates that act differently once enters into the body. Generally the presence of inorganic nitrates in contaminated well water are oftenly overlooked as a environment of nitrate exposure that can result in serious health effects in infants **like Blue baby syndrome etc** . Usually nitrates that enter the body by eating or drinking leave the body without harm. Sometimes when we get affected by water borne diseases such as diarrhea and dehydration (condition of low level of fluid in body) can make nitrates change to nitrites in greater amounts. These nitrites in the blood cause changes in haemoglobin coordination composition, or the proteins that help move oxygen in the body. Nitrates can make it so that less oxygen is available for the body to function properly. People who drink water from ground/shallow rural domestic wells that are not tested for the presence of nitrate concentrations are at above the permissible limit. Infants younger than 4 months of age are the highest risk group for harm from exposure to nitrates.

• When nitrate containing well water is mixed with baby formula and fed to infants, it can cause serious health effects.

• Because the gastrointestinal system/track of infants is still developing i.e in pre-mature condition after birth, they are at higher risk for serious health effects resulting from nitrate exposure. Infants with diarrhea and vomiting form more nitrites inside the body that place them at higher risk for health effect.

During pregnancy, women are more prone to nitrate exposure, due to its toxic affect the foetus gets seriously affected especially during 30th week of pregnancy.

MBBR stands "moving bed biofilm reactor", in this technology a bed of bio-carriers has been provided for the growth of bio film (i.e autotrophs and heterotrophs), these autotrophs causes nitrification and heterotrophs causes denitrification .

Till now, the MBBR has been victoriously planted to treat municipal as well as industrial wastewater and upgrade medium size wastewater treatment plants (Andreottola et al., 2000; Loukidou and Zouboulis, 2001; Yang et al., 2009,Libing chu et al., 2011). Di Trapani et al. (2010a) compared the traditional activated sludge system and the MBBR for treating sewage

wastewater.

Some salient features of the MBBR system are the less head loss, no packing bed channelling problem, periodic back washing and sludge recycle is not required , and a large surface area for colonization and high specific biomass activity (Odegaard, 2006; Guo et al., 2010).

A typical & conventional MBBR system is following—

Anoxic Oxic[Aeration zone]

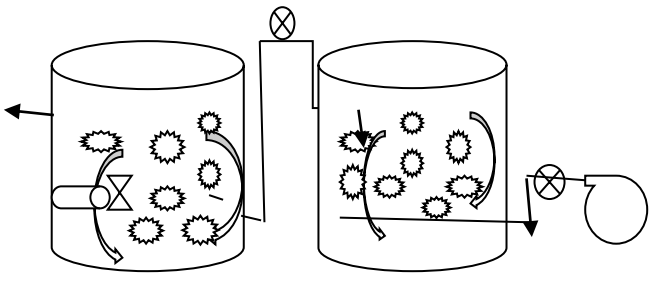

Figure 1

The first tank is oxic and adjacent one is anoxic one, in first tank autotrophs has been developed and in later on tank heterotrophs has been grown , both of them make a cover of fine biofilm over biocarrier.

Generally, in use bio carriers are made of polyethylene, granular activated carbon, sand and diatomaceous earth. The polyurethane (PU) carrier(i.e sponge) is an ideal growth medium with high porosity, light weight for microorganism immobilization, good mechanical strength and economical cost (Chae et al., 2008; Kim et al., 2009). It has been reported that the rate coefficients for nitrification and denitrification of the PU (polyurethane) suspended biological growth reactor were 1.5 and 1.6 times, respectively, higher than those of a conventional activated sludge reactor.

Generally, polymer carriers have low density and excellent processability due to high porosity , and expansion can be obtained easily as the water circulates. However, the poor hydrophilicity and biocompatibility of plastic carriers often lead to some deficiencies in the rate and amount of biofilm culturing, and the adhesion extent of biofilm.

It have unique advantages which counters the conventional two reactor vessel nitrification and denitrification.

1. In continuous processing wastewater plant , due to the SND process the costs of the second (anoxic) tank get reduced .

2 Reduction in reactor size .

It is widely useful when we want to treat biological nitrogen and phosphorus along with their derivatives from wastewater at low C/N ratio.

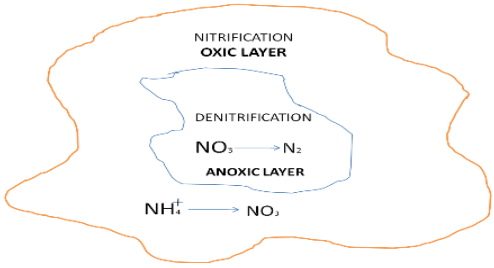

Figure 3

[SND FLOC WITHIN BIOCARRIERS]

In SND based bio-carriers the autotrophs & heterotrophs develops side by side , the heterotrophs concentrated in the inner cavity of the bio - carriers the reason behind this type of behaviour is heterotrophs like anoxic condition to develop or say they generally like to live actively in low oxygen zone or regime.

But on the other hand, in case of autrotrophic bacteria's ,oxic zone is favourable for their growth and activity, that's why they like to grow on the outer cavity of bio - carriers as shown in figure 3.

One more advantage of autotrophic bacterial layer on outer surface , reduces the oxygen diffusion rate via its layer , indirectly help in maintaining anoxic zone at inner side of its layer.

2. Literature review

Libing Chu et al,.(2017)

Based on study, it has been observed that the types of biocarriers have significant effect on the reduction of many undesirable contents of wastewater .in their they has compared biogradeable (polycaprolactone (PCL)) and polyurethane foam – a non biodegradable biocarriers for the removal of organic as well as nitrogen based impurities i.e. ammonium, nitrite, nitrate with low C/N ratio with the help of moving bed biofilm reactor(MBBR).

The reactor with polyurethane (PU) has shown efficient TN removal (59%) at low level of nitrate i.e. < 5 mg/l in effluent this is because of simultaneous nitrification and denitrification (SND) on the other hand reactor with polycaprolactone (PCL)has shown less TN removal in initial stage because it is a solid carbon source, its degradation rate is very slow due to which the microbial assimilation rate gets lower down, which causes low denitrification rate .

As per their conclusion, it has been finded by me that if we want to use biodegradable biocarriers then we have to increase its porosity meanwhile we can develop improvised PU biocarriers (i.e PU biocarriers impregnated with solid carbon substitutes).

Xinbo zhang et al.,(2016)

Their study has been based on the effect of packing fraction on the working and efficiency of sponge based moving bed biofilm reactor(MBBR).Their experience has shown us that the simultaneous nitrification and denitrification (SND) increases with increase in the filling percentage i.e SND were 85.5 ±8.7%, 91.3±9.4%,93.3±10.2% in 10%,20%,30% filling fraction reactor respectively.In their study it has been observed by me that as per their experiment result ,if a 12 l reactor fill upto 12% by sponge (15×15×15)mm biocarriers then the process would achive maximum biomass accumulation per gram of sponge.

In comparison with other MBBR biocarriers like polyethylene plastics, polyurethane sponge, polyvinyl alcohol gel, biodegradable polymer, granular activated carbon ,polymer foam pads, nonwoven media etc.(Rouse et al., 2010, Bertin et al., 2010, Guo et al., 2010, Nguyen et al., 2010, Chu and wang., 2011a, Wu et al ., 2012), the sponge biocarries are very efficient and economical due to its high porosity , light weight ,easily & cheaply availability in market , pores of sponge provide sites for biomass accumulation for microbial immobilization (Guo et al., 2010).

Nguyen et al .,(2016)

They has performed an experiment to study the effect of size and type of sponge biocarriers on the removal of micronutrients and other organic components from wastewater under aerobic conditions. Their observation has revealed there has been no effect on removal efficiency of reactor with respect to variation in filling fractions i.e we need to worry about the specification of sponge biocarriers like in the case of other biocarriers .

Chu and Wang (2016b).,

Use of polyurethane sponge (PU) based biocarriers (20% filing fraction in MBBR) in case of low C/N ratio, has shown that TOC and ammonium removal has been 90% and 65% at HRT of 14 hrs respectively.

Luo et al.,(2016).

Their study has revealed that there has been a variation in sorption capacity of polyurethane (PU) sponge based moving bed biofilm reactor (MBBR) for micropollutants like removal efficiency of carbamazepine -22.9%.

Wang ,.xia,.chen,.zhao et al., (2016)Their experiment has showed that Nitrogen-removal from municipal wastewater through SND was successful in the MBBR single - reactor. Chemical dosing onto the MBBR using ferrous sulphate heptahydrate was a highly effective method for the removal of phosphorus from wastewater. The general performance of the MBBR, with respect to COD, BOD, TN removal, was not significantly affected by the chemical addition. To meet the EC phosphorus discharge standards, the optimum dose of iron(II) is 1:1.3 (P:Fe). The combined chemical precipitation and moving bed biofilm system is a very effective process for complete nutrient removal, with average TN and TP removal efficiencies of 89.1% and 90.6%, respectively, during optimum and economical conditions.

A.A.L.Zinatizadeh et al (2015)

The MBBRs filled with two types of carriers with different geome-try, Ringform and Kaldnes-3 ,at packing rate of 50%(v/v) showed good performances in COD removal(>85%). The system with Ringform media could achieve more TNremoval efficiency than that of the pro-cess with Kaldnes-3, indicating that anoxic condition is favoured with Ringform.

Feng Quan, Wang Yuxiao et al;(2015)

The MBBRs filled with PUF carriers at packing percentage of 20%,30%,& 40%(v/v) showed good efficiency in COD

removal.the prosequencing analysis, predicted that the proteobacteria,Bacteriodetes and Verrucomicrobia were the three most abundant phyla.

Bo Fu, Xiaoyi Liao,Lili Ding et al;(2015)

FISH(fluorescence in situ hybridization) analysis shows that dominanace of both Betaproteobacteria ammonia-oxidizing bacteria & Nitrospira – like nitrite- oxidizing bacteria were negatively correlated to C/N ratios.

Sequence analysis of DGGE bands has predicted the presence of anoxic denitrifying bacteria Agrobacterium tumefaciens and Rhizobium sp. There observation predicted that oxygen gradient is a responsible factor for SND process .

Eva M. Gilbert et al;(2015)

Their observation has revealed that along with decrease in ammonium conversion dropped from an average of 40g_N m^{-3} d^{-1} at 20 ^oC to 15 g_N $m^{-3}d^{-1}$ at 10 ^oC.

Andreottola et el. (2015)

Present an experimental study to evaluate the application of an MBBR system for the upgrading of an overloaded municipal wastewater treatment plant (MWWTP). The MBBR solution was considered to offer several advantages including good

Potential in nitrification process, easiness of management and the possibility to use theexisting tank with very few modifications. A pilot-scale experiment was undertaken todevelop the design parameters for the full-scale upgrade. The final configuration was a twostageMBBR system. The upgraded was able to handle a 60% increase in flow rate with good performance. (Andreottola et al., 2015)

Rodgers &) Zhan (2015)

Present a review of four types of moving medium biofilm reactors

For the treatment of wastewater. Their review is based on published case studies and covers:

1. The rotating biological contactor (RBC);

2. The moving bed biofilm reactor (MBBR);

3. The vertically moving biofilm reactor (VMBR); and

4. The fluidized-bed reactor (FBR).

They conclude that the MBBR is a good process for upgrading existing wastewater treatment systems.

Weiss et al. (2015)

Present an evaluation of the use of an MBBR system for the enhancement of nitrogen removal in a secondary treatment wastewater plant. They conclude that the

MBBR process is capable of achieving desired nitrogen removal requirements in a smaller overall bioreactor volume. However, the advantages of the MBBR system have to beweighed up against the capital cost of purchasing the proprietary MBBR attached growthmedia and the increased energy costs for the aeration. (Weiss, Alvarez, Tang, Horvath &Stahl, 2015).

Verma et al. (2015)

Present a survey of aerobic bio-filtration processes for wastewatertreatment. They assess a range of conventional and advanced bio-filtration systems, including

MBBR systems. They conclude that the MBBR process is a good one for upgrading existingwastewater treatment systems. However, they note that for fluidised systems generally(including MBBR systems), while capital costs arecomparatively low, operating costs are higher due to pumping/aeration requirements. (Verma, Brar, Blais, Tyagi&Surampalli, 2015)

Brinkley, Johnson & Souza (2015)

Note that many existing wastewater treatment facilities are being upgraded to cater for increased effluent flows, and that many such existing facilities have constraints on space for expansion. They identify MBBR as one wastewater treatmenttechnology that has been developed which addresses both of these issues. They suggest thatMBBR systems provide more treatment capacity within a given reactor volume compared to aconventional activated sludge (AS) process. They present a case study of a full-scale MBBR system that was installed on a space-constrained site to treat a planned increase in wastewaterfrom a pharmaceutical production facility. They state that the MBBR system was the mostcost-and space-effective treatment solution. The MBBR system is smaller than the existingaeration basin and can treat wastewater with a significantly higher organic load. They expect good performance from the MBBR system and less operator invention than the original AS process. They conclude that the MBBR process is ideal for expanding or upgrading existing treatment plants that have space constraints. (Brinkley, Johnson & Souza, 2015)

Di Trapani et al. (2012)

Present a pilot-scale comparison between a conventional AS treatment system and a MBBR treatment system. The aerobic reactor in both systems was the same size. The MBBR system was able to treat twice as much waste water

as the AS system while maintaining similar performance in organic and nitrogen removal. They conclude that the higher treatment capacity of the MBBR system demonstrates that it is an effective technology for the upgrading of overloaded wastewater treatment plants.

(Di Trapani, Mannina, Torregrossa & Viviani, 2012).

McQuarrie & Boltz (2012)

Provide an up-to-date overview of MBBR process design considerations. They observe that MBBR systems can be used for a wide range of wastewater treatment applications, and that they offer a range of benefits, including similar treatment performance as AS systems, and being a continuous flow process that does not require a special operational cycle. (McQuarrie & Boltz, 2012)

KompetenzzentrumWasser Berlin (2011).

This extended summary report provides detailed operational performance data for all12 wastewater treatment plants included in the trial, including energy consumption. Based on kWh/(PE.a), a wide range of energy consumption was reported across the 12 plants, with the moving bed plant performance being mid-range. (KompetenzzentrumWasser Berlin, 2011).

Kermani M., et al (2011)

Conducted the study to evaluate the organics, phosphorus and nutrients removal from synthetic wastewater by a laboratory scale moving bed biofilm process. For nutrients removal, moving bed biofilm process had been applied in series with anaerobic, anoxic and aerobic units in four separate reactors. Moving bed biofilm reactors were operated continuously at different loading rates of nitrogen and Phosphorus.

Delnavaz *et al.*, (2011)

Suggested that MBBR is a suitable alternative for common activated sludge reactors in treating domestic and industrial wastewaters in commercial scale. Three moving bed biofilm reactors were used to treat synthetic wastewater of aromatic amine compounds. The reactors with cylindrical shape had an internal diameter and an effective depth of 10 and 60 cm respectively. The reactors were filled with light expanded clay aggregate as carriers and operated in an aerobic batch and continuous conditions. Evaluation of reactor's efficiency was done at different retention time of 8, 24, 48, 72 hours with an influent COD from 100 to 3500 mg/L. the filling ratio was 50%. The maximum obtained removal efficiency was 90% (influent COD= 750 mg/L), 87% (influent COD= 1000 mg/L), 75% (influent COD= 750mg/L).

Research gap-

We have observed that earlier authors have use plastic based biofilm carrier so we have decided to use low cost easily available Polyurethane foam based cubiodal bio film carriers. Meanwhile we have also examined that if we mix municipal sewage as doping to reduce bacterial culture growth time to hasten the process.

Findings-

The process is simple, effective, low maintenance cost, compact size ,highly efficient for removal of nitrate from effluent.

Questions-

First queri is whether we can make it low cost meanwhile retaining MBBR reactor efficiency.

3. CONCLUSIONS

After reading previous literatures related to MBBR technology , we come to know the advantages of this technology, but we notice that the bio- carriers generally has been using in MBBR to treat wastewater are expensive and have less surface area for bacterial growth or say biofilm generation . So we have decided to do our Nitrate removal study using a cheap and feasible bio-carrier, for this we have chosen to use cubical shaped polyurethane (PU) sponge bio- carriers as a moving bed.

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