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Evaluation of Nitrate Removal in Aquatic System: A General View

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Abstract—

Nitrate is one of the most common wide spread contaminant in groundwater and originating primarily from fertilizers, septic systems, manure storage, human and animal sewage and uncontrolled discharge of industrial wastewater. Nitrate is a potential human health threat especially to infants, causing a disease known as methemoglobinemia. Chronic consumption of high levels (> 45 mg/l) of nitrate may also cause several health problems which include goiter, birth defects, hypertension, anemia, stomach cancer, oral cancer, colon cancer, gastrointestinal cancer, lymphomia and dipsnia etc. Hence, removal of nitrate is crucial from nitrate contaminated water before being utilized. The possible nitrate remediation methods such as reverse osmosis, ion exchange, ion exchange membrane bioreactor system, catalytic reduction, electrolysis, activated carbon process, land disposal, distillation, chemical denitrification, wetland remediation, phytoremediation and microbial treatment were explained in this article. The effectiveness of physical and chemical processes has been limited due to their expensive operation and subsequent disposable problem of generated nitrate waste brine. The process and results in the literatures point out that microbial treatment proved more acceptable, potential and ecofriendly technique for nitrate removal.

Keywords— ***Nitrates, Effects, blue baby syndrome, Aquatic system, Remediation methods***

I. INTRODUCTION

Nitrate contamination in surface and ground water is a worldwide problem. Nitrate in drinking water is regulated by environmental agencies around the world since it can cause several human health problems at high concentration. Nitrate contamination of aquifers is often linked to agricultural (chemical fertilizer, manure, and animal feed lots) and nonagricultural (wastewater disposal and solid water disposal) sources [1]. Nitrate can also be generated through conversion from atmospheric nitrogen by bacteria, or through the oxidation of the more reduced species of nitrogen, nitrite and ammonia [2].

Nitrate levels have been increased in drinking water supplies in the European Economic Community, the United States, Canada, Africa, The Middle East Australia and New Zealand [3]. Backround nitrate concentration in surface waters are usually below 5 mg l^{-1} of NO_3-N [4]. However, the World Health Organizations discovered that 31.5% of 2000 wells surveyed in Canada had concentration exceeding 20 mg l^{-1} of NO_3-N. Health and Welfare Canada has set a maximum acceptable concentration of 10 mg l^{-1} of NO_3-N [5], which is consistent with the USEPA standards. Only about 2.66% of the earth’s water resources are fresh water and 0.6% is available for drinking water [6].

High nitrate concentrations in drinking water has been blamed for several health problems which includes methemoglobinemia, goiter, birth defects, hypertension, anemia, stomach cancer, oral cancer, cancer of colon, gastrointestinal cancer, lymphomia and dipsnia etc. Due to the detrimental biological effects, elimination of nitrogen compounds such as nitrate nitrogen and ammonical nitrogen in ground water is considered essential. Several treatment process including physical, chemical and biological processes have been developed to remove nitrate from water with varying degrees of efficiency, cost and ease of operation. The objective of this paper is to review sources and effects of nitrate and compare several treatment technologies available for the removal of nitrate from water.

II. NITRATE REMOVAL

The increasing concern with high concentrations of nitrate in drinking water has led to the development of various methods for efficient nitrate removal. Nitrate is a stable and highly soluble ion and has a low potential for adsorption or coprecipitation [7]. These properties are responsible for difficulty in nitrate removal using conventional water treatment processes including lime softening and filtration. There are several technologies developed for nitrate removal from drinking water are reverse osmosis [8], ion exchange [9], ion exchange membrane bioreactor system [10,11], catalytic reduction [5], electrolysis [12], activated carbon process [13], land disposal [21], distillation [22], chemical denitrification [20], wetland remediation [19], phytoremediation [23], microbial treatment and especially for anaerobic treatment [7,24].

2.1. Physical Methods

2.1.1. Reverse Osmosis

In a reverse osmosis process, ionic species present in water are removed by forcing the water across a semi permeable membrane and leaving nitrates and other ionic species behind. Removal of nitrates is achieved by subjecting water in reverse osmosis cells to pressures exceeding its corresponding osmotic pressure. Pressures ranging from 300 to 1,500 psi (2,070 kPa -10,350 kPa) are applied to reverse the normal osmotic flow of water. The membranes used in this procedure are commonly composed of cellulose acetate whereas the membranes made of polyamides or composite membranes are used to a lesser extent. These membranes do not have a preference for any particular ion, but the amount of salt rejected is proportional to the valence of the ions in solution [7]. There are problems resulting from deposition of soluble materials, organic matter, suspended particles, pH variations and chlorine exposure. Therefore pretreatment is a necessary procedure which will often extend the life of the membrane and improve efficiency. Typical pretreatment includes adding sodium hexametaphosphate for carbonate and sulfate control as well as filtration and lowering of pH by addition of acid. Post treatment steps are also required, which include air stripping for stabilization, pH adjustment to control corrosion and chemical addition for disinfection. The semi-permeable membrane can be expected to remove nitrates efficiently for three to five years [8]. Schoeman and Steyn [25] applied reverse osmosis technology for water denitrification in a rural area. The results revealed nitrate nitrogen was reduced from 42 mg l^{-1} to less than 1 mg l^{-1}.

The major disadvantage of this method is the disposal of the super concentrated ion solution that is produced. The disposal options depend on conditions of federal, state and local regulations. The options include discharge to lakes and streams or oceans, deep well injection, lined evaporation lagoons, irrigation and dilution in wastewater systems [8]. About 65% of nitrate separation was observed for influent NO_3^- - N concentrations of 18 - 25 mg l^{-1} [26]. It was also found that 35% of the total influent water became waste brine solution. Compared to ion exchange, reverse osmosis is estimated to be three times more expensive.

2.1.2. Ion Exchange

Ion exchange involves exchange of ions in water and exchange resin. An anion exchange resin consists of a polymer of positively charged sites that are bonded to negatively charged ions. In this case sodium chloride is generally used to charge the column. When sodium chloride is flushed through the resin column, chloride ions bind to the positively charged sites on the resin. Then water containing nitrate is passed through the column and the nitrate ions, which are negatively charged, displace the chlorine ions on the resin [27].

Clifford and Liu [28] conducted a study to estimate nitrate removal from drinking water by ion exchange. The raw water contained 18 to 25 mg l^{-1} NO_3-N, 43 mg l^{-1} sulfate and 530 mg l^{-1} TDS. The process reduced the nitrate level to below 10 mg l^{-1}. The problems associated with ion exchange include disposal of the spent brine containing nitrate and excess sodium chloride. This causes corrosion and negative health effects due to the increase of chloride content in the treated water [7].

Leakovic *et al*. [29] reported a treatment process in fertilizer industry wastewater by an ion exchange process using strong acid cation and weak basic anion exchangers. The wastewater in the investigation period contained a high content of nitrogen in ammonium form (with an average of 325 mg l^{-1} N-NH_4^+) as well as nitrogen in nitrate form (with an average of 201 mg l^{-1} N-NO_4^-). After treatment, the wastewater contained 8.7 mg l^{-1} of ammonium nitrogen and 7 mg l^{-1} of nitrate nitrogen and with the conductivity of 150 µS cm^{-1}. There are several advantages of ion exchange which includes reuse of treated wastewater, utilization of product regeneration for fertilizer and absence of other pollutants [29]. This method has disadvantages of unsatisfactory anion resin conditions due to the production of nitric acid and unsatisfactory vacuum evaporation conditions. Another problem was that the resin can be often fouled due to the presence of organic matter in the influent [7]. However, the resin can be restored, however, with the addition of bentotnite clay to backwash water. Precipitates of iron and silica can reduce the nitrate removal capacity of the resin.

2.1.3. Catalytic Reduction

Horold *et al*. [30] revealed a process that palladium-alumina catalysts were effective in the reduction of nitrate to nitrogen and ammonia in the presence of hydrogen. In addition, the lead, copper and aluminium oxide catalyst showed a complete removal of nitrate from water having an initial concentration of 100 mg l^{-1} nitrate. The process could be easily automated, operated and may be useful for small water treatment system. This process is still in the development stages, and the associated kinetics and long-term performance of catalysts have not been studied [7]. Reddy and Lin [5] reported that catalytic process has a potential to remove nitrate from groundwater in small agricultural communities for treatment of drinking water. This technique has a potential for field application because rhodium can be coated onto fiberglass mesh and a photovoltaic cell can supply the redox potential. This method can become quite inexpensive since sunlight can be used as an energy source.

2.1.4. Electrodialysis

Electrodialysis (ED) is similar to reverse osmosis in many ways. In electrodialysis, ions are transferred from a solution of lower concentration to a solution of higher concentration due to application of a direct current. Electrodialysis selectively removes undesired ions as water flows through a semi-permeable membrane. Similar to reverse osmosis, the water must be pretreated. In electrodialysis reversal (EDR) process, the polarity of two electrodes is reversed two to four times an hour to change the direction of ion flow. This process reduces scaling and chemical usage compared to conventional ED and has been used for the production of drinking water from brackish and seawater [7] Menkouchi Sahli *et al*. [31]. Nitrate removal efficiency is similar to that of reverse osmosis, but electrodialysis is limited to treat soft water with less acid dosages and higher water recovery rates. This process is currently considered too expensive [7]. Miquel and Sahli [31] also developed a selective nitrate removal process based on electrodialysis. They achieved effective in reducing nitrate concentrations from 50 to less than 25 mg l^{-1} without the addition of any chemicals. In other experiment Menkouchi Sahli *et al*. [31] conducted an electrodialysis operation for technical optimization of nitrate removal from ground water using a pilot plant having a capacity of 24m3/d and found. They observed nitrate level below the admissible limits from the concentration of 70 mg l^{-1} of nitrate.

2.1.5. Activated Carbon Process

Sison *et al*. [13] proposed a denitrification process using granular activated carbon (GAC) column with dynamic modes of external carbon addition. This process is suitable for water or wastewater containing NO_3 but not for organic matters. It was demonstrated that 87% of nitrate was removed by adding the organic matters once a day with continuous inflow of 20 mg l+ nitrate. Ozturk and Bektas [14] reported a nitrate removal study from aqueous solution using sepiolite, sepiolite activated by HCl, slag and powdered activated carbon were used as adsorbent with a particle size between 71 and 80 µm. Influence of contact time, pH and adsorbent dosage were also investigated using the adsorbents except slag. They found that sepiolite has good nitrate adsorption properties due to its channel structure, high surface area and sorption capacities. The maximum removal for nitrate was observed at pH 2 for activated carbon. pH did not affect nitrate removal significantly for other adsorbents.

2.2. Chemical Methods

2.2.1. Chemical Denitrification

Reduction of nitrate can also be induced under basic conditions according to the following reaction [7]:

$NO_3^- + 8\,Fe\,(OH)_2 + 6\,H_2O \rightarrow NH_3 + 8\,Fe\,(OH)_3 + OH-$

It has been demonstrated that a Fe: NO3- ratio of 15:1 is needed in the presence of copper catalyst for the reaction to occur. Use of iron, however, has some disadvantages such as generation of large amount of iron sludge and production of ammonia that requires removal by air stripping. Aluminum has also been used to reduce nitrate. Ammonia was found to be the principal reaction product (60-95%) which should be removed by air stripping. The optimum pH level was found to be 10.25 [15]. Water treatment plants can effectively use lime, which reduces additional costs of raising the pH, for the process of reactions. Experimental results showed that only 1.16 g of aluminum was required for the reduction of 1 g of nitrate, making this process more economical than that with iron. However, this process is still too expensive to implement in a large scale [7].

Chemical reduction of nitrate and nitrogen oxide using ferrous iron as bulk reducing agent has been investigated. Using Fe^{2+} produces voluminous amount of sludge since eight moles of ferric hydroxide is generated per mole of nitrate reduced [16]. In recent years, zero valent iron has been intensively studied for its ability to reduce chlorinated solvents and has been successfully applied to remediate groundwater [17]. Huang *et al.* [18] developed a denitrification process from aqueous solution using metallic iron at the pH 2 to 5. Rapid nitrate reduction from 50 to 48 mg l^{-1} was observed only at pH 2. Acidity is the principal factor which controls the rate and the extend of nitrate removal by Fe0. The quick reduction of nitrate at low pH was most likely due to either direct reduction by Fe^0 or indirect reduction by surface hydrogen derived from proton.

2.3. Biological Methods

2.3.1. Wetland Remediation

Various biological technologies have been established in order to solve the problem of nitrate in drinking water and groundwater. One method to treat a large quantity of groundwater through denitrification is to use wetlands. Wetlands are efficient in removing nitrate from water because of two environmental characteristics that promote denitrification, which are anoxic sediments and a healthy supply of carbon from plant growth [19]. Wetlands have been constructed for several different pollutants from various sources such as sewage effluent, mine drainage and urban runoff [32].

The majority of the organic carbon required for denitrification of wastewater in wetlands is supplied by the wastewater itself. However, in some cases where dissolved organic carbon (DOC) of groundwater is very low, plants are needed to supply the carbon required. Therefore carbon supply would be a limiting factor in wetlands constructed for nitrate removal from water with low DOC [19]. Ingersoll and Baker [19] showed that the limiting ratio of carbon to nitrogen is approximately 5:1. It was also discovered that nitrate removal efficiency increased as the C: N ratio increased to 5 : 1. A key finding was that the reaction rate constant for nitrate was directly dependent upon the addition rate of carbon. These findings suggest that the performance of the nitrate-treatment wetland would be enhanced by promoting plant growth and consequently the carbon supply. This can be achieved by optimizing the habitat for maximum plant productivity such as fertilizing the plants with phosphorus or cutting the plants and leaving the clippings. Constructed wetlands can be used for remediation of nitrate-polluted aquifers. The wetland would remove the nitrate through denitrification but produce elevated DOC. This method would be the most cost-effective where the groundwater is shallow and the wetlands are situated in a temperate climate. Robins *et al.* [33] developed a denirification study from synthetic ground water using a constructed wetland model. They found adverse nitrate removal from the synthetic feed concentration of 30 mg l^{-1} with starch and cellulose mixture as the carbon source.

2.3.2. Nitrate Uptake by Terrestrial Plants

In soils nitrogen is available as dissolved nitrogen (eg. amino acids), NH_4, NO_3 or any combination of these for absorption by plants [34]. The relative amount of these forms of N depends upon a number of biotic and abiotic factors which determine the rates of mineralization, nitrification, denitrification, leaching, relative uptake of different N forms by plants and microorganisms etc. [35, 36]. Min *et al.* [37] have used the terrestrial plants Trembling aspen and Lodgepole pine for uptake of NO_3 and NH_4 from aqueous solution.

Barley [38], Switchgrass [23], Duckweed [39] and Bluegrass [39], Jiang and Sullivan [40] plants were also used for uptake of NO_3 and NH_4 from synthetic solution. The use of the *Lemna minor* L. species of duckweed is an emergent technology that may be effective for the removal of nitrogen and phosphorus from enriched waters [41].

A few plant species have been noted for their ability to accumulate nitrate in their roots or aboveground parts. The members of the genera Beta, Borago, Chenopodium and Menyanthes are nitrate-storing plants [42]. Borago officinalis (borage) is being increasingly grown since its seed oil is a rich source of gamma-linolenic acid, a compound of rising interest as a natural pharmaceutical [43]. Borage can also be sown in the autumn and persist over the winter. Swiss chard (Beta vulgaris), in addition to being an edible vegetable, also has the virtue of accumulating very high amount of nitrate (up to 3.8 g/kg fresh weight) in its leaves [44].

Several species of grasses have been shown to display increased nitrate reductase activity in the presence of N fertilizers. Timothy (Phleum pratense) increased total N, nitrate N and amino N in leaves and stems which correlated with the amount of calcium nitrate added [45]. At the highest level of fertilization, leaf nitrate was at a toxic level. Switchgrass (*Panicum virgatum*) showed a similar response but to a lesser degree.

2.3.3. Nitrate Uptake by Aquatic Plants

Aquatic plants in natural or constructed wetlands not only reduces the concentration of problematic nutrients from the wastewater but also alter the physico-chemical environment of water, rhizosphere and underlying sediments [46]. Water hyacinth is a floating aquatic plant which has been employed for wastewater in many parts of the world. Water hyacinth has been used successfully to remove organics and heavy metals from chemical wastewater before their discharge [47]. In a study an integrated kinetic model for water hyacinth ponds used for wastewater treatment. Water hyacinth ponds have been found effective in the removal of organic matter, suspended soils, nitrogen and phosphorus as well as the reduction of heavy metals like zinc, chromium, cadmium and trace organics [48].

Orth and Sakota [17] found that the removal efficiencies of COD and suspended solids increased more than 50% in a facultative pond implanted with water hyacinth when compared with those for a control pond. Mitchell [49] selected aquatic plant species for wetland remediation based on the some criteria such as growth rate, ease of propagation, capacity for absorption of pollutants, tolerance under hyper eutrophic conditions, easiness of harvesting and potential usefulness of harvested materials.

Thomas and Kalaroopan [50] used various aquatic macrophytes Eichornia crassipes (Water hyacinth), *Spirodela* sp. (Duck weed) and *Salvinia molesta* (Salvinia) for treatment of septic tank effluent. These aquatic macrophytes were able to transfer oxygen into the bed and thus created aerobic microzones around the plant roots and anaerobic zones away from them. As a result both aerobic and anaerobic bacteria carried out the breakdown of the organic matter and removal of nitrogenous compound through nitrification and denitrification. Larson *et al*. [51] studied effective nitrate removal in aqueous solution using a floating aquatic plant of hornwort. The initial nitrate concentration 350 mg l^{-1} was used and reduced to 75 mg l^{-1} in 9 days, corresponding to a half-life of 4-5 days. It removed on average about 2 mg l^{-1} nitrate per day per gram of plant. Hornwort grew well under higher nitrate concentration along with the other nutrients in the solution.

2.3.4. Ion Exchange Membrane Bioreactor

This technique combines ion-selective membrane dialysis (ion exchange) with biological remediation. A nonporous membrane is an essential part of a bioreactor, which keeps water being treated separated from both the microbial culture and the biomedium where the culture is suspended [10]. The possibility of bacterial transfer between treated water and bioreactor depends on the characteristics of the membrane. The membrane can be selected to facilitate the removal of ionic pollutants from the water and to retard the transfer of other inorganic and organic contaminants in the biomedium. A combined form of an anion-exchange membrane and an anoxic denitrifying bioreactor is used. The removal of nitrate is accompanied by the counter transport across the membrane of a second ion, equivalent in molality, known as the counter ion [10,11].

The advantages of this combined technique include prevention of secondary pollution of the treated water with particulate, dissolved organic and inorganic substances. Microbial contamination is also prevented due to the bacteria segregation in the bioreactor. High nitrate removal (approximately 98% with a current of 20mA) was achieved due to facilitated transport through the membrane with less brine solution to be disposed [52]. Velizarov *et al*. [53] obtained 87% nitrate removal efficiency from polluted water containing nitrate at a concentration of 150 mg l^{-1} using ion exchange membrane bioreactorl. Recently, the authors Ergas and Rheinheimer [54] applied similar technique in drinking water containing 200 mg l^{-1} of nitrate and found 99% removal efficiency.

The major disadvantage of this process is higher hydraulic residence time (HRT = 4.4h) of the water stream compared with other biological treatment processes [10]. In addition, it was observed that a biofilm developed on the biomedium side of the membrane hindered the transport of nitrate from the water to the biological compartment. The impact of biofilm on nitrate degradation rate and the transmission of ethanol to the water stream should be clarified before this technique can be applied to a large scale process [10].

2.3.5. Microbial Denitrification

A great deal of effort has been expended by sanitary engineers to establish empirical methods of tertiary treatment, which will lead to the elimination of much or most of the nitrogenous compounds present in influent/ secondary wastewater. Method of tertiary treatment has been developed over many years along several lines of solution. However, literature on biological nitrification and denitrification for removal of nitrogenous compound is very scarce at present. A review of the published literature on treatment of nitrogenous waste in general biological nitrification and denitrification in particular is made

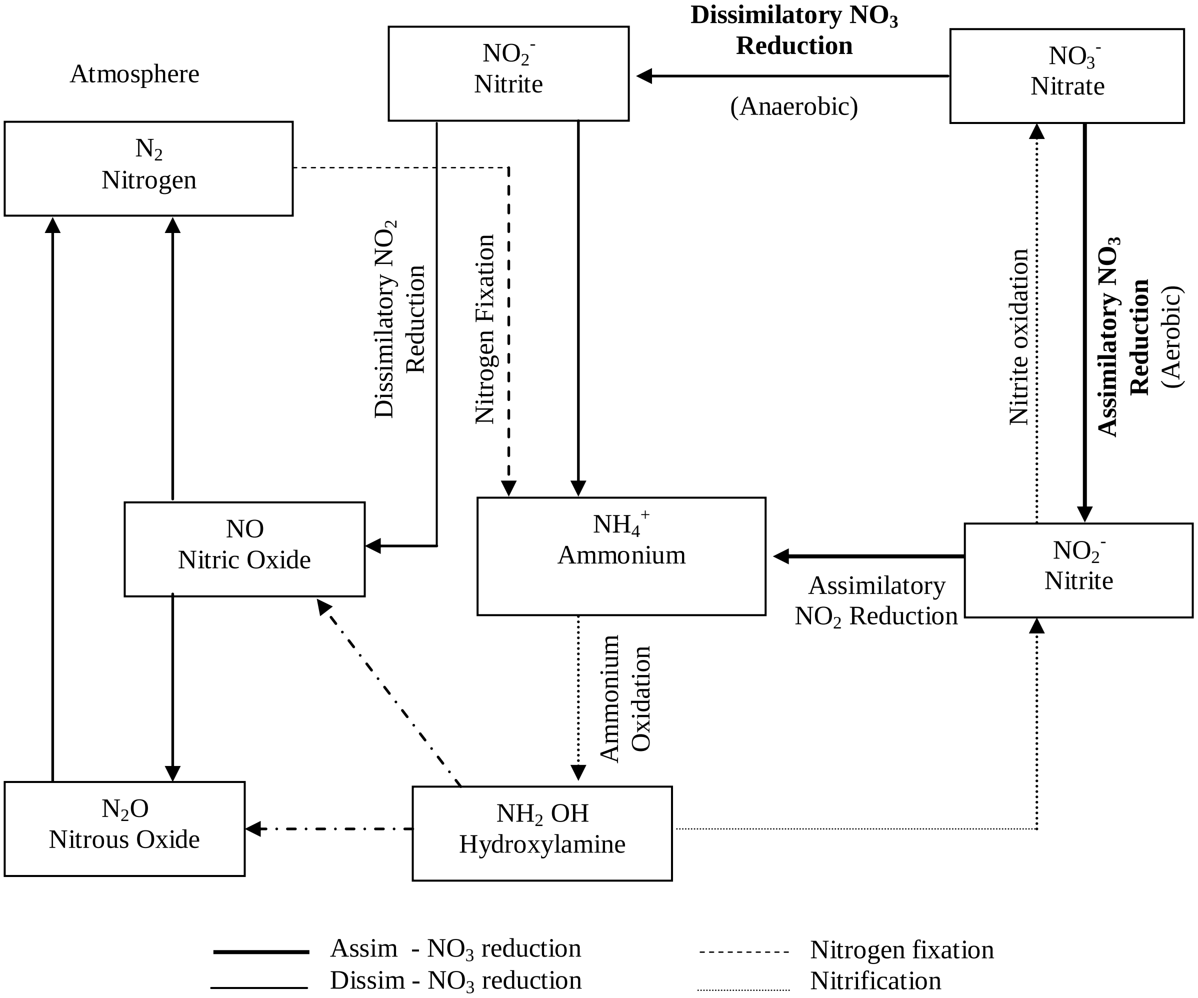

Fig. 1. Pathway of assimilatory and dissimilatory nitrate reduction

Ye and Thomas [55] reported the pathway of microbial denitrification process (Fig. 1). Nitrate is converted to nitrite by assimilatory or dissimilatory nitrate reductases. Assimilatory reduction of nitrate to ammonia via nitrite enables microbes to use nitrate as the nitrogen source. Under oxygen-limiting conditions, nitrite can be reduced to nitric oxide or ammonia. Bacteria with the complete denitrification pathway catalyze the dissimilatory reduction of nitrate to nitrogen. In some bacteria, dissimilatory reduction of nitrate to ammonia via nitrite can support anaerobic growth or dissipate excess reducing power. Ammonia oxidizers oxidize ammonia to hydroxylamine, which is subsequently converted to nitrite. This process also leads to the production of nitric oxide and nitrous oxide. This pathway clearly indicates that the microbes are the major role to metabolize nitrate either aerobic or anaerobic condition. Based on this metabolic pathway, several authors have been achieved nitrate removal from and wastewater using microorganisms.

The two types namely heterotrophic and autotrophic denitrification is commonly used for the treatment of municipal and industrial wastewater. However, increasing knowledge and experience indicates that biological treatment is the most promising, effective and economic for removing nitrate from water and wastewater [7] Kim *et al.* [56]. Biological denitrification is used to achieve the reduction of oxidized nitrogen compounds to gaseous nitrogen. As a result of the reduction, different intermediate and end products are produced: nitrite (NO_2^-), nitric oxide (NO), nitrous oxide (N_2O) or molecular nitrogen (N_2). In the biological step of a wastewater treatment plant, the denitrification process to molecular nitrogen runs usually according to the following reaction [6].

$$4NO_3^- + 2H_2O \longrightarrow 2N_2 + 5O_2 + 4OH^-$$

In nature riparian zones remove nitrate from groundwater and is believed to be due to microbial denitrification [57]. Denitrification requires a sufficient supply of nitrate as an energy source that is often organic matter under anaerobic conditions. It follows the reaction:

$$NO_3^- \longrightarrow NO_2^- \longrightarrow N_2O \longrightarrow N_2$$

These conditions are often met in riparian zones. Therefore a system analogous to this has been proposed for remediation of contaminated groundwater and wastewater. Nitrogen chemistry is complicated due to its numerous oxidation states in its compounds such as NO_3^- (+5), ammonium NH_4^+ (-3) and nitrite NO_2^- (+3) [5].

Denitrification is generally accepted as the reduction process of nitrates, via nitrites, to nitrous oxides and nitrogen gas. However, many denitrifying bacteria have the enzymatic ability to reduce nitrates to nitrites only without further reduction of the nitrites produced [58]. Robertson and Kuenen [58] reported that most of the denitrifying bacteria in aquatic systems are capable of only incomplete denitrification. However, the full effect of this on nitrogen removal during activated sludge treatment has not yet been determined. Recently Fierro *et al*. [59] accomplished a study using an immobilized algal species such as Scenedesmus spp. for the removal of nitrate and found that 70% removal within 12 h of incubation.

Schipper and Vukovic [60] created a porous reactive wall constructed in the polluted plume path to remove the contaminant as the groundwater passed through. Nitrate removal by denitrification is limited by the availability of an energy source. To overcome this, the reactive wall was constructed using 20% sawdust as a carbon source to stimulate denitrification. The wall successfully decreased nitrate concentrations in the groundwater throughout the study period. This removal could be due to denitrification or immobilization of nitrogen. However, immobilization seemed unlikely to be a major sink as the nitrogen removal in the wall, suggesting no net nitrogen accumulation. Denitrification over an extended time depends on nitrate input and a supply of carbon from degrading sawdust. It was predicted that overtime the sawdust would be degraded and nitrate removal would consequently decline. Therefore fresh sawdust needs to be added annually.

The main concern with biological denitrification is that there might be some remnant microbes in the treated water, which then requires post treatment. The major limitations of this process include the rate of substrate diffusion, reaction products through the matrix, loss of cells from the matrix, reduced activity of cells and short life span of the matrix [7]. To overcome these problems, the biofilm reactor was invented, which keeps denitrifying bacteria and the carbon and energy source away from the treated water. The cost for a heterotrophic denitrification plant would be about twice that of ion exchange with equivalent operating costs. The autotrophic biological system would cost approximately twelve times that of ion exchange [7].

2.4. Comparison of nitrate removal methods from water

Physical, chemical and biological processes have been developed for removal of nitrate from water and wastewater. The table 1 compares various treatment processes concerning nitrate removal. Reverse osmosis is applicable without any post treatment in home water treatment process which can quickly treat various contaminants from all major classes of drinking water pollutants such as nitrate, phosphate, heavy metals, bacteria, particulates and other organic and inorganic chemicals. If a water quality problem exists due to the presence of several different contaminants, reverse osmosis could be the most cost effective method for their removal. But a major disadvantage of this process is in particular, the large amount of concentrated wastewater generation [54,61]. The ion exchange process is also one of the adequate technique in all the aspects for the treatment of nitrate wastewater. However, the wastewater treatment by this technique can also be dangerous if a high concentration of HNO3 is used for the regeneration of cation resin at working conditions above 400C (Davies, 1994). Another problem noted by Kapoor and Viraraghavan [7] in ion exchange that post treatment was required due to presence of sulfate, chloride, organic matter and some corrosives. Catalytic reduction and electrodialysis are acceptable process for nitrate reduction in all aspects viz status of the process, start up period, temperature and pH effect, operation and cost. Both of these processes, however, yield concentrated waste brine requiring further treatment or disposal. Similarly activated carbon process is also one of the appropriate technique for removal of nitrate from water system but it creates dumping of more solid waste.

The chemical denitrification is effective only either acetic or alkaline condition and makes secondary pollution due to incorporation of some metals such as ferrous iron and aluminium. Kapoor and Viraraghavan [7] reported chemical denitrification of water using aluminium is effective only in the pH range of 9.1 to 9.3 and can be incorporated in treatment facilities using lime softening as little additional cost will be required for neutralization. Therefore, chemical denitrification is incomplete process due to presence of secondary contaminant in the water system.

Wetland remediation could be used mainly for remediation of nitrate polluted aquifers but produce some elevated DOC. Ingersoll and Baker [19] reported that recharging the treated groundwater through percolation ponds would remove particulates and would probably remove much of the DOC produced in the wetland. Ingersoll and Baker [19] postulated that constructed wetland may also provide a low cost alternative for remediating nitrate contaminated groundwater. Terrestrial and aquatic plants are used because they can absorb and accumulate the nutrients from water for a limited period. Young plants are more efficient in the removal of nutrients than the old plants and hence regular harvesting of old plants is essential. If not harvested at proper time, nutrients from the plants are reaching back to the water and old plants after death cause an anaerobic condition in water. Also phytoremediation process takes more duration for nitrate uptake and increases water loss through evaporation at a far greater rate.

The process ion exchange membrane bioreactor is one of the combined systems of physical and biological technique for the treatment of nitrate wastewater. Fonseca *et al*. [10] was observed a difficulty that a biofilm developed on the biomedium side of the membrane hindered the transport of nitrate from the water to the biological compartment. Due to these above involvedness and limitations for removal of nitrate from the water system, the most adaptable, ecofriendly and widely used technology is microbial denitrification.

Most water treatment systems are designed and operated specially to reduce to an acceptable level of biochemical oxygen demand (BOD) and the suspended solids (SS) concentration. In many countries, disinfection may be used to control the discharge of pathogenic bacteria. An increasing interest is now being shown in the removal of various forms of nitrogen from water and wastewaters. Control of the residual nitrogenous material from the water system is a complex problem. Bacterial nitrification- denitrification is perhaps the most generally promising biological method for N removal because of its moderate cost, reasonable reliability, high potential removal efficiency and economical area requirements.

III. CONCLUSIONS

The present paper provides concurrent evidence concerning sources, effects and remediation of nitrate in the water and wastewater system. Nitrate is wide spread ubiquitous pollutant in groundwater and originated primarily from both natural and anthropogenic system. Natural sources contributed high concentration of nitrate to the groundwater. But, it is usually as a result of anthropogenic disturbance. Natural, mature forests preserve nitrogenous compound but human disturbances can lead to nitrate pollution of the groundwater. However, forests represent a very little source of nitrogen compared to agriculture. Some literatures point out that there are many anthropogenic sources of nitrate that could potentially lead to the pollution of the groundwater with nitrates. The anthropogenic sources are really the ones that most often cause the amount of nitrate to rise to a dangerous level. Many local sources of potential nitrate contamination of groundwater exist such as sites used for disposal of industrial wastes, human and animal sewage. Septic tanks are another example of anthropogenic source nitrate contamination of the groundwater.

Most of the literature indicates high concentration of nitrate in drinking water has been blamed a disease called methemoglobinemia, a blood disorder primarily affecting infants under six months of age. There are reports of other health disorders namely stomach and gastric cancer, lymphatic cancer, goiter, birth defects, hypertension, increased infant mortality, non-Hodgkins lymphoma and thyroid disorder. Apart from that nitrate cause an excessive enrichment of the water, leading to a rapid growth of algae which in turn darkens the water, reduces its oxygen content and created eutrophication. Hence, removal of nitrate is essential from nitrate contaminated water before being utilized.

There are several processes that have been discussed for removal of nitrate include reverse osmosis, ion exchange, ion exchange membrane bioreactor, catalytic reduction, electrodyalysis, activated carbon process, chemical denitrification and biological denitrification. Application of some technologies for removal of nitrates into a water treatment system could substantially increase the cost of water treatment. Kapoor and Viraraghavan [7] have reported reverse osmosis requires a high-energy input in order to overcome the natural osmotic flow and thus, operating costs are much higher compared to the other processes. Research is being completed to develop efficient membranes, which will require lower operating pressures and therefore, reducing operating costs. Also this process is particularly advantageous for removing many dissolved salts. Ion exchange is best suited for a small or medium size facility and for treating groundwater with low dissolved organic matter. Large quantities of dissolved organic matter can cause fouling of the resin in both ion exchange and reverse osmosis [7]. Similarly electrodyalysis are very effective in removing nitrate from contaminated water, they also result in concentrated waste brine, which must still be disposed of [61]. The methods like ion exchange membrane bioreactor system and chemical denitrification currently have limited potential for full scale operation and too expensive [7].

Activated carbon process is also suitable for water or wastewater containing nitrate but it creates disposal problem of solid waste. Due to these above limitations for removal of nitrate from wastewater and groundwater, the most versatile and widely used technology is biological denitrification [61]. Biological denitrification has been studied more extensively in Europe and the literature indicates a wider application of hetertrophic denitrification compared to autotrophic denitrification. This is mainly due to a faster denitrification rate accomplished by hetertrophic bacteria. Many investigators reported that carbon sources and plant residual substrates are the vital role to stimulate bacterial growth and nitrate reduction. Similarly the influence of temperature on denitrification rate is another important feature in the biological process. Normally incubation near $30^{o}C$ is used to grow the microorganisms, but not always favors for denitrification. According to the above literature, the over all process and the results indicates microbial treatment proved more acceptable, potential and ecofriendly technique for nitrate removal than others.

From the over all review it was concluded that, nitrate in drinking water has been blamed for several health and environmental problems. The various physical, chemical and biological processes have been developed for nitrate removal from water and wastewater. Although physical and chemical process are very effective in removing nitrate from contaminated water but currently they have limited potential for full scale operation. Hence the biological treatment of both assimilatory and dissimilatory nitrate reduction can be employed for the nitrate contaminated water and wastewater systems.

Recommendations

From the above literatures concerning sources, health effect and remediation of nitrate in the aquatic system, the following actions are recommended:

1. Do not give the water to infants less than 6 months of age or use the water to prepare infant formula.
2. Do not attempt to remove the nitrate by boiling the water like disinfection. This will only concentrate the nitrate making levels even higher.
3. Seek medical help immediately if the skin of an infant appears bluish or gray in color. Sometimes the color change is first noticed around the mouth, or on the hands and feet.
4. Limit your daily intake if you have chronic health problems that increase your sensitivity to nitrate, or if you are concerned about scientific uncertainty regarding the health effects of long-term exposure to nitrate-contaminated water.
5. Identify the nitrate source and take action to reduce contamination. Remedial actions may include reducing fertilizer use, improving manure handling methods, pumping septic tanks, or upgrading wells.

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