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REMOVAL OF NITROGEN FROM WASTEWATER BY ANAMMOX PROCESS: A REVIEW

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Abstract—*Reducing nitrogen in various effluent discharges should be one of the major goals of wastewater treatment plants. Discharge of nitrogen (ammonium)higher than prescribed standard limit may result in eutrophication in water bodies and impart toxicity. various conventional methods for removal of ammonium from waste water are at current operated, but these techniques are energy consuming and high in cost. With the discovery of anammox bacteria, annamox process has been extensively studies for anaerobic removal of ammonium and its direct conversion into dinitrogen. this process in environment friendly, and cost effective compared to conventional nitrogen removal techniques, anammox wastewater treatment results in significant energy reduction (65%) and greenhouse gas emission (90%). This brings a vision that soon the pollutants in waste water will no longer be seen as a problem, but as a source of renewable energy. This manuscript focuses on summarizing various methods and applications of annamox process and in addition proposes development of new concept in anammox.*

1. INTRODUCTION-

Enormous Increase of population and rapid industrialization has exerted more pressure on water resources. So, an effort to reduce the pressure on existing water resources has always been a keen topic and is being studied extensively by the researchers. Nitrogen pollution in wastewater is the main topic of interest. Various conventional wastewater treatment applications use combination of nitrification and denitrification processes for nitrogen removal from wastewater. These processes do not meet present discharge limits and are not energy efficient. Keeping in mind the energy requirements, researchers have always been keen to find best and alternate ways to remove nitrogen from wastewater.

Use of nitrogenous compounds and nitrogen fertilizer discharges in water are main causes leading to eutrophication of aquatic and terrestrial environments to global acidification [1] [2]. Nitrogen removal based on anammox process is an efficient, economical and low energy alternative to the conventional processes. Anammox bacteria convert ammonium (NH_4^+) and nitrite (NO_2^-) directly into dinitrogen gas. The first evidence of anaerobic ammonium oxidation to dinitrogen gas was obtained from a denitrifying fluidized bed reactor system [3]. These microbes were found related to planctomycetes. These organisms were capable of oxidizing ammonium using nitrite instead of oxygen as electron acceptor and hence reduced cost of aeration.

Discovery of these anammox bacteria changed the view of nitrogen cycle and gave rise to a new concept in wastewater treatment research around the world.

2. LITERATURE REVIEW-

This literature review considers various aspects of anammox based wastewater treatment. We direct this towards enhancing further development of research in this area of wastewater treatment. This area requires extensive study in India as there is no full scale based anammox treatment plant working at present. Development and evaluation of this area of research will result in its commercial scale application.

2.1 Anammox Bacteria -Microbiology and Biochemistry

Anammox Bacteria are related with bacterial phylum planctomycetes. These have been detected from anoxic habitats where nitrogen loss up to 100% is due to these anammox bacteria [4]. Various anammox bacterial cultures by different culturing techniques were enriched as monospieces as there is no pure culture of anammox species. Culturing techniques used were membrane bioreactor-MBR [5], Rotating biological contactors and sequencing batch reactors. Some species such as Ca. Scalindua and Ca. Kuenenia stuttgartiensis were enriched with 90% purity [6] [7].

Although there is a clear understanding of anammox bacteria there are still some challenges associated with their application. The biggest hindrance in their application is their slow growth rate (7-14 days doubling time) that causes slow start up (Schmidt et. al [8].

Mainly two species that carry out the anaerobic ammonium oxidation have been named as Kuenenia and stuttgartiensis [9] and brocadia anammox dans [10]. The working temperature range for these bacteria is 20 and 43°C [10]. with

PH range 6.4 and 8.3 [11]. Possible pathways for anammox process:

- Oxidation of ammonium ion to hydroxylamine, that reacted with nitrite which is further reduced to nitrogen [12].
- Partial reduction of nitrite with formation of hydroxylamine.

$$NH_2OH + NH_4^+ \rightarrow N_2H_4 + H^+$$

Here formation of hydrazine (N_2H_4) results which is further converted to nitrogen.

2.2 Process configuration and Methodology

Various system configurations have been employed by researchers for anammox process. The process can be run in two separate steps- partial reactor in reactor one followed by anammox in reactor 2 or the process can be completed in one single reactor. Bacterial growth type used may be of granular sludge, activated sludge or biofilm. Different reactors are to be used for different bacterial growth types.

For granular sludge Air lift reactor, UASB, Sequencing batch reactor can be used [13], [14].For activated sludge growth type, membrane bioreactor or sequencing batch reactor can be used [15], [16]. For biofilm growth type, Rotating biological contactor or moving bed biofilm reactor can be used [17], [18].

Several full-scale systems already used and applied are DEMON, SHARON-Anammox, Anita-Mox and De Ammon.

SHARON -Single reactor system for High ammonia removal over Nitrite. In this process only 50% of influent ammonia is oxidized to nitrite, the effluent from SHARON is then fed to anammox reactor where they are converted to dinitrogen gas anaerobically [19], [20].This process was developed at university of Delft to stop ammonia oxidation at nitrite (nitration) and operates at a high temperature above 25°C, since it enables high specific growth rate so that no sludge retention is required making the process stable.

In DEMON process nitration and anammox process occur simultaneously. The process makes use of hydro cyclone that separates anammox granules from excess sludge and recirculates back to SBR This process was developed and patented at university of Innsbruck.

DE Ammon and Anita-Mox use a carrier as medium for biofilm growth allowing the anammox organisms to retain in the system. Nitration takes place in outer biofilm layer and anammox are found in inner biomass layer.

2.3 Applications of Anammox-

There are around 114 including 10 under construction and 8 at design phase reported full scale anammox plants around the world [21]. and the number is increasing rapidly. Full scale plants are currently in operation which can treat 134 tons per day of nitrogen load. Application of partial nitrification-Anammox process for leachate is proving promising than conventional methods. This process significantly reduced sludge generation and net emission of co_2 reducing treatment operating cost up to 90% [22]. Anammox and its combined processes have a future in considerable savings of energy and resources.

Challenges-

The biggest challenge in anammox based nitrogen removal is how to accelerate the slow rate of nitrogen removal as the doubling time of anammox bacteria ranges from 7-14 days. Another challenge for anammox based treatment is its application to mainstream municipal wastewater. It is a big challenge because of lower nitrogen concentrations (high C/N ratio) and lower temperatures. The poor effluent water quality of mainstream municipal wastewater is also a hindrance. In this regard post treatment is essential which increases capital cost and energy requirements. Recent studies have shown that the presence of organic compounds in water could lead the dominance of Brocadia lineage. On the other hand, it has been proved some biodegradable organic matter can inhibit the process of anammox. High concentration of humic matter may also deteriorate the working of anammox process. It has been investigated that ammonium concentration up to 1g N L^{-1} does not inhibit the process. Other studies reveal that higher levels of ammonia may inhibit Anammox process. Under different operating modes and experimental conditions the nitrite threshold concentration was reported to lie between 5 and 280 mg N L^{-1}.Dispersed anammox biomass aggregates in a nitrite solution of 100 mg NL^{-1} completely lost anammox activity [15]. Salinity concentration up to 3-15 g NaCl L^{-1} promoted the formation anammox granular sludge and hence increased bacterial retention in reactor but high salinity inhibited anammox.

3. CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

Anaerobic ammonium oxidation (anammox), a process suited for treatment of nitrogen rich wastewater is an evolving and promising biological nitrogen removal technique. Compared to conventional processes is a cost-effective process. Anaerobic ammonium oxidation at present is1 extensively studied for its development. Anammox process finds wide applications in treatment of:

Municipal wastewater

Fertilizer industry

Petrochemical and metallurgical industry

Solid waste treatment (landfills, composting).

Semi-conductor industry

Future research for anammox process lies in the fact of challenges it is facing such as longer start up period of anammox process, mainstream application of anammox

process, poor effluent water quality. This review proposes following development in anammox process: -

Use of appropriate immobilization techniques can reduce the process start up.

Study of capacity of anammox bacteria to grow at mainstream conditions

Changing reactor configurations to make process more sustainable.

Research on one step anammox configuration as well as reducing N_2O emissions is recommended.

Trickling filter based anammox process can be employed to effectively enhance anammox activity.

Study of anammox process on specific wastewater can result in further development of anammox process.

With the methods of molecular ecology inhibition mechanisms need to be studied.

Zeolite -Anammox process used to remove both ammonium and nitrite without substrate regeneration from mainstream WWTP effluent is to be further investigated for monitoring of WWTP gases generated [23]. Use of bio-zeolites and their seeding rates in reactors, supplementation to enhance anammox growth rates is recommended for further research.

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