The Ecological and Anthropogenic Factors Influencing the Nitrification: A review

Amjed Ginawi¹,², Yan Yunjun¹*

¹Key Lab of Molecular Biophysics of Ministry of Education, College of Life Science and Technology, Huazhong University of Science and Technology, 1037 Luoyu Road, Wuhan, 430074, China. 
²Faculty of Marine Science and Fisheries, Red Sea University, Port Sudan, Sudan.

Abstract
This review focuses on the influence of the environmental factors and the human impact on the nitrification, specifically aerobic ammonia oxidation that is the degree limiting stage of nitrification and is mediated by ammonia oxidizing archaeal and bacteria (AOA/AOB). The understanding the primary drivers of ammonia oxidizing distribution and abundance in sediments are increasing interest around the globe. Many studies evaluated the environmental sediment of the communities' ammonia oxidizing, but a few issues are known about sediments ammonia oxidizing. The sediment characteristics that have significant control in determining ammonia oxidizing communities include ammonia substrates, pH, temperature, carbon, and oxygen, these environmental parameters represented reasons the AOA higher than the AOB in various sediments and numerous ecological, as they can inhabit possibility specialized that are unavailable to the AOB.

Keywords: Ammonia-oxidizing, environmental factors, anthropogenic.
INTRODUCTION

The nitrification where the ammonia is oxidized to nitrite under aerobic status this first step. This step can be performed by two communities of microbes ammonia oxidizing archaeal (AOA) and ammonia oxidizing bacteria (AOB) who are phylogenetically different bacteria but execute the same function, in Figure 1 (Kozlowski et al., 2016; Suzuki et al., 1974).

The AOA and AOB communities were supported nitrous oxide effluence in different ways. However, excessive Nitric oxide (NO) distributes into the atmosphere or water and natural hybridized with H2O to form nitrite Figure 1 (Kozlowski et al., 2016). The numerous different species of microorganisms are responsible for mediating these compounds (Osburn et al., 2016). The ammonia and ammonium are transformed to nitrate (NO3-) using nitrification by a one or two-step process. Nitrate does not adhere to soil or sediment particles as well as ammonia/ammonium (NH3/NH4+), and so nitrate can leach further down into the sediment to the anoxic layer. Dinitrogen is either lost to the atmosphere, or it can be assimilated back to ammonia and kept within the biologically available lake of nitrogen. Finally, NO3- and NO2 can also be converted to NH4+ using the dissimilatory nitrate reduction to ammonium (DNRA), one of the least understood nitrogen processes. The DNRA is found in sediments with high organic content in the biologically available lakes Figure 2 (Dang et al., 2010a; Smith et al., 2015).

Fig. 1. Schematic design of the nitrification steps through (i) AOA and (ii) AOB along with nitrous oxide formation. Nitrification composed of 1: ammonia oxidation and 2: nitrite oxidation. Dashed arrows indicate gaseous distribution from sediments into the atmosphere. Capital letters above bolts refer to enzymes. AMO – ammonia monooxygenase; HA0-hydroxylamine oxidoreductase; Cu-novel enzyme – reduces NO and NH2OH; NIR – nitrite reductase; NOR – nitric oxide reductase; NXR - nitrite oxidoreductase.

The nitrifying microorganisms are common in sediment and aquatic environments (freshwater and marine). Nitrification is two-stage processes that carry out two various groups of bacteria, AOB and nitrite-oxidizing bacteria (NOB). Currently, no autotrophic microorganism is known to oxidize ammonia straight away to nitrate Table1 (Koops and Pomerening-Roser, 2001; O'Mahony and Papkovsky, 2006). The Nitrospira and Nitrospinae form their species of bacteria because they are only related to other nitrifying bacteria in a metabolic sense (Lucker et al., 2013; Off et al., 2010).

The nitrogen is the important component in primary productivity (Howarth, 1988). While the increased or decreased nitrate environments are challenging and suffer from primary productivity as it headway to hypoxia, eutrophication, and pollution of water sources (Vitousek and Howarth, 1991). Water sources pollution can produce physical condition problems similar to methemoglobinemia in children and the compounds that promote carcinogenesis such as nitrosamines. Additionally, the nitrous oxide attends a greenhouse gas, which has a global warming potential specifically 265–298 times more than CO2 (van Groenigen et al., 2011). The aquatic ecosystems are especially sensitive to surplus nitrogen abundances, where territory, streams, and lakes. These waters are extraordinarily loaded with nitrogen arising from aboveground and anthropogenic sources (Rolston et al., 2017). Effectively, it is approximated that more than 60% of anthropogenic dissolved inorganic nitrogen (DIN) loads to aquatic ecosystems are removed by microorganisms transformations of the nitrogen cycle (Fan et al., 2015). The importance of nitrification can be recapitulated in the points: (1) the conversion of ammonium to nitrate, with consequence for the nitrogen available for living plants.

Fig. 2. Schematic representation of the nitrogen cycle in sediments. Various steps in the nitrogen cycle are numbered 1 – 5, dashed line.

The nitrogen is the important component in primary productivity (Howarth, 1988). While the increased or decreased nitrate environments are challenging and suffer from primary productivity as it headway to hypoxia, eutrophication, and pollution of water sources (Vitousek and Howarth, 1991). Water sources pollution can produce physical condition problems similar to methemoglobinemia in children and the compounds that promote carcinogenesis such as nitrosamines. Additionally, the nitrous oxide attends a greenhouse gas, which has a global warming potential specifically 265–298 times more than CO2 (van Groenigen et al., 2011). The aquatic ecosystems are especially sensitive to surplus nitrogen abundances, where territory, streams, and lakes. These waters are extraordinarily loaded with nitrogen arising from aboveground and anthropogenic sources (Rolston et al., 2017). Effectively, it is approximated that more than 60% of anthropogenic dissolved inorganic nitrogen (DIN) loads to aquatic ecosystems are removed by microorganisms transformations of the nitrogen cycle (Fan et al., 2015). The importance of nitrification can be recapitulated in the points: (1) the conversion of ammonium to nitrate, with consequence for the nitrogen available for living plants.
Environmental characteristics affecting ammonia oxidizers within controlling ammonia abundance and function variation

The numerous environmental parameters might be determined nitrification ratio in several ecosystems. They have involved the descriptions of things that influences geobiological processes in the worldwide, strongly those particular to the metabolism of nitrifiers: oxygen concentration, substrate (ammonium and nitrite) concentrations, temperature, light, salinity, pH, and organic matter concentrations. The differences environmental parameters that affect ammonia oxidizing in sediments are presented with samples from ecosystems. Obviously, the several of the bio-physiochemical environmental factors and correlations among them complexly affect nitrification of sediments (Behrendt et al., 2017). The metabolic variations between AOA and AOB are environmental indicators in observing the deterioration of the ecosystems. Moreover, AOA and AOB have a specified metabolism, one that depends on substrate concentration but can be dedicated to environmental dynamics whether physical, chemical, or biological (Yan et al., 2018). As the effect of ammonia oxidizers sensitivity to both identified and potentially unknown parameters in the environment, ecological challenges by with in situ based field studies or experiments combined with relationships community composition with activity and function of AOA and AOB. The enables our get one moves closer to determining their activity under particular states. The investigations have shown that the microorganisms composition, abundance, distribution, and the activity of ammonia-oxidizing groups are influenced by the numerous environmental factors, including pH, ammonia substrates, DO, temperature, salinity, and inhibitors. Sewage specifics and treatment procedure management also affect the structure and abundance of ammonia oxidizing in sewage treatments.

Ammonia Substrates

The concentrations of NH$_4^+$ to NH$_3$ is significant due to increased ammonia concentrations might be toxic while decreased ammonia concentrations might be substrate limited to ammonia oxidizing archaeal and bacteria (Martens-Habbena et al., 2009; Nakagawa and Stahl, 2013). There are varieties of parameters that indicators NH$_3$ appearance such as temperature and pH that can vary considerably in the ecosystem (Christman et al., 2011; Puthiya Veettil et al., 2015). The AOA was allowed for utilizing and grow ammonia with urea as a substrate. In this report, they presented that AOB was not determined in sediments among pH (3.75 - 5.4), while the Crenarchaea 16S rRNA genes and archaeal amoA are higher in ratio 5.4), while the Crenarchaea 16S rRNA genes and archaeal amoA are higher in ratio to NH$_3$ (Christman et al., 2011). The concentration in the environment habitats (Christman et al., 2011). The concentration in the environment habitats.

pH

The pH is the environmental parameter that directly influences ammonia accessibility due to the effect pH has on the NH$_4^+$ - NH$_3$ concentration; as mentioned above the increased in the pH the more NH$_3$ is attainable for ammonia oxidation (Martens-Habbena et al., 2009). The nitrification

Table 1.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Phylum</th>
<th>Genera</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidize ammonia</td>
<td>Gamma-proteobacteria</td>
<td>Nitrosooccus</td>
<td>Freshwater, Marine</td>
</tr>
<tr>
<td>Oxidize ammonia</td>
<td>Beta-proteobacteria</td>
<td>Nitrosomonas</td>
<td>Soil, Sewage, Freshwater, Marine</td>
</tr>
<tr>
<td>Oxidize ammonia</td>
<td>Thaumarchaeα-group I.1b</td>
<td>Nitrososphaera</td>
<td>Soil and other environments</td>
</tr>
<tr>
<td>Oxidize ammonia</td>
<td>Thaumarchaeα-group III</td>
<td>Nitrosocaldus</td>
<td>Hot water extremophile</td>
</tr>
<tr>
<td>Oxidize ammonia</td>
<td>Thaumarchaeα-group I.1a</td>
<td>Nitrospumilus</td>
<td>Marine and other environments</td>
</tr>
<tr>
<td>Oxidize ammonia</td>
<td>Thaumarchaeα−SAGMGC-1</td>
<td>Nitrosotalea</td>
<td>Omnipresent cluster</td>
</tr>
<tr>
<td>Oxidize nitrite</td>
<td>Gamma-proteobacteria</td>
<td>Nitrococcus</td>
<td>Marine</td>
</tr>
<tr>
<td>Oxidize nitrite</td>
<td>Alpha-proteobacteria</td>
<td>Nitrobacter</td>
<td>Soil, Freshwater, Marine</td>
</tr>
<tr>
<td>Oxidize nitrite (some can carry out complete nitrification Comammox)</td>
<td>Nitrospira group</td>
<td>Nitrospira</td>
<td>Soil, Marine</td>
</tr>
<tr>
<td>Oxidize nitrite</td>
<td>Nitrospinae</td>
<td>Nitrospina</td>
<td>Marine</td>
</tr>
</tbody>
</table>
influence launched hydrogen (H+), which happens in the sediments acidification when most organic nitrogen and ammoniac manures are transformed to nitrate (Sahrawat, 2008). The acidification was major of interaction with the pH of ecosystems. The sediment pH is presently frequented global due to carbon dioxide dissolution (Caldeira, 2005). This frequentation will straight influence the ammonia obtainable for ammonia oxidizers that will in sequence lessen the amount of nitrate obtained and accordingly decreased primary production. This influence is considered one of the effects the acidification may have on ammonia oxidizing. Little investigations have been implemented on the influence pH has on aquatics ecosystems (Gao et al., 2012; Kitidis et al., 2011; Laverock et al., 2014; Zheng et al., 2014).

**Temperature**

Temperature has an immediate influence on microorganism activity, pH, and the moisture of the habitats, anyone can indirectly influence the community structure and abundance of ammonia oxidizing. However, the environmental temperature influences the growth and activity of ammonia oxidizing (Guo et al., 2010). At subtropical latitudes, daily and seasonal temperature variations influence ecosystems. The temperature was major of the important influence on ammonia oxidizers. ammonia oxidizing have been obtained from various environments with a large scale of temperatures seasonal (4°C - 97°C) (Beman and Francis, 2006; Nakagawa et al., 2007; Reigstad et al., 2008; Urakawa et al., 2008). The influences temperature on the diversity and communities composition of AOA and AOB groups were the influential correlation (Zeng et al., 2014).

**Oxygen availability**

The concentration of oxygen is another significant characteristic as it is an additional condition for ammonia oxidizers to oxidize ammonia. Accordingly, it is crucial to realize the depth oxygen can permeate in sediments before sampling. Oxygen permeation in subsurface sediments commonly ranges among 1 mm – 8 mm deep (Kemp et al., 1990; Louati et al., 2013). Oxygen permeation of sediment is easily correlated to the ability of the soils to absorbed oxygen. hence, when oxygen is quickest absorbed, it will not change porous depth in the sediments. The primary key of oxygen utilization is organic decomposition (Wang et al., 2015). Therefore, oxygen concentrations are shown to permeate just a few cm depths; nitrification has been preserved up to 10 cm depth, into the anoxic waters (Gilbert et al., 1998; Laverock et al., 2014). Secondly, the AOA was cultivated efficaciously by co-culturing with sulfur-oxidizing bacteria (SOB). Thiosulfate (S$_2$O$_3^{-2}$) was used as an electron contributor in the SOB; this may be because SOB produces indicator necessary for AOA to grow (Park et al., 2010). SOB activity affected by a large decrease in dissolved oxygen from 250 μM to 30 μM. However, AOA carried out nitrification at this low oxygen concentration at the greatest growth rate of 0.6 per day. Previous reports state that AOA was able to compete with AOB because of position variation about both oxygen and ammonia. AOA can carry out nitrification to reducing ammonium degrees than AOB and at reducing oxygen concentrations. The reducing oxygen concentrations clarify why minimum oxygen layer comprise relatively great numbers of AOA (Erguder et al., 2009).

**Salinity**

Salinity is an apparent environmental characteristic that classifies terrestrial and marine ecosystems. The salinity influences ammonia oxidizers in two systems; firstly, it promotes ammonia obliging or release to sediments, otherwise known as benthic fluxes or ammonia (Weston et al., 2010). High salinity liberates the ammonium bound to soils, while low salinity improves the adsorption of ammonium to soils (Rysgaard et al., 1999), this supports in providing diverging concentrations of ammonia-to-ammonia oxidizers (Dollar et al., 1991). Secondly, salinity can increase environmental pressure to cells such as cell toxicity and osmotic pressure. AOA and AOB phylotypes have various ways of dealing with these pressures affecting to some phylotypes occurring better adapted than others at confronting the pressure of salinity (Roessler and Muller, 2001). Because of this, salinity influences changes in AOA and AOB communities (Zheng et al., 2014).

**Carbon**

Ammonia oxidation microorganisms are usually identified with the autotrophic bacteria, that inorganic carbon as a carbon source and oxidize ammonia as the power source, while various investigations showed that AOA lives heterotrophically hence, could use organic carbon (Guo et al., 2013). Novel sequence analyses of ammonia oxidizing the culturing and genomes of ammonia oxidizing have confirmed mixotrophy by Ca. Nitrososphaera gargensis (Hatzenpichler et al., 2008; Konneke et al., 2014), Cenarchaeum symbiosum (Hallam et al., 2006), Ca. Nitrosotalea devanatera (Lehtovirta-Morley et al., 2011), Nitrosopumilus maritimus (Walker et al., 2010), Ca. Nitrosoarchaeum limnia (Blainey et al., 2011), and Nitrososphaera viennensis could utilize carbon dioxide as the only carbon energy (Tournai et al., 2011). The reductive and oxidative Krebs cycle was determined in the Cenarchaeum symbiosum (Hallam et al., 2006). The consumption of organic carbon was proposed relationships on the genomes sequence of Ca. Nitrosoarchaeum limnia (Blainey et al., 2011). The improvement increase of Nitrososphaera viennensis cultures by little drops of 0.1mM pyruvate (Tournai et al., 2011), also, mixotrophic assistance increase by ammonia oxidizing. The influences of organic and inorganic carbon on ammonia oxidizing and power
source of AOA are subject to future discussion, which deserves deeper studies.

Sulfide

Ammonia oxidizing microorganisms were showed in sulfide-containing water columns and stream sediments (Caffrey et al., 2007; Coolen et al., 2007). The ammonia oxidation microorganisms were discovered in the Black Sea in anoxic areas where the highest sulfide concentration was to the measured 5mM (Lam et al., 2007). It was reported that a negative relationship between sulfide concentration and the abundance of amoA gene (Caffrey et al., 2007). To date, few know are possible on the inhibitory influences of sulfide on the growth of ammonia oxidizing archaean and bacteria, in exacting inhibition entrance concentration, which obliged further studies.

Heavy metals

Heavy metals, including copper, nickel, chromium, cadmium, lead, and zinc could cause inhibition ammonia oxidizing group (Radniecki et al., 2009). It was characterized that AOA was more responsive to Zn ratio than AOB (Ruyters et al., 2010). Moreover, such as in Australian farmland soils, the abundance of gene transcripts and AOA amoA gene copies were decreased clearly after an interference Zn dose (1850 mg Zn kg⁻¹) (Mertens et al., 2009). Furthermore, it is investigated the AOA showed insensitive to Cu pollution than AOB (Li et al., 2009; Wang et al., 2018). It has been found that ammonia oxidizing might be the significant function of the nitrogen cycle in low-pH, low-nutrient, and sulfide-containing environments.

Other Environmental Factors

Among the characteristics of the impacts on ammonia oxidizing listed above the many other indicators were shown to have some influence on the ammonia oxidizing community. These involve soil moisture (Bates et al., 2011; Stres et al., 2008), concentrations of cyanide (CN⁻) (Do et al., 2008), altitude (Zhang et al., 2009), soil types (Takada Hoshino et al., 2011), and phosphate (Herfort et al., 2007). Nevertheless, these parameters either do not have an important influence on ammonia oxidation microorganisms or have not been determined by factors on the ammonia oxidation, although the mechanisms concerned are not fully understood.

HUMAN IMPACT

Human impacts are the period of anthropogenic (Brondizio et al., 2016) just microorganisms, and human influences control the quantity of biologically available nitrogen in the atmosphere as stated by (Galloway and Cowling, 2002). Regrettably, human impacts have significantly affected by the nitrogen cycle transformations; this may influence the rates and sites of denitrification, nitrogen fixation, and nitrification through the effects of increased nitrogen on microorganism transformations in the nitrogen cycle (Vitousek et al., 1997). Anthropogenic is influencing the nitrogen cycle by producing CO₂ in the atmosphere through the combustion of fossil energy and agriculture. The immoderate cremation of fossil energy sources and the grown requirements for nitrogen in farming and manufacture had a different influence on the worldwide nitrogen cycle and the reason some ecosystem problems, for example, the greenhouse and eutrophication in reaction to N₂O emissions. The last objective of getting an idea the N cycle is to counteract that ecological challenges. that lead to climate change and will affect the nitrogen cycle immediately because of its tight links with the carbon cycle.

DYNAMIC OF AMMONIA OXIDATION MICROORGANISMS IN ECOSYSTEMS

The dynamics and structure of ammonia oxidation group in environmental ecosystems have presented a comparatively complicated issues given that they computations for natural resources and characteristics environmental. Up to now, it is incomprehensible which the physiochemical conditions and environmental factors affect AOA overestimated than AOB (Jia and Conrad, 2009). Many investigations have recommended that AOA is dominated than β-AB in ecosystems (Adair and Schwartz, 2008; Bernhard et al., 2010; Kalanetra et al., 2009; Leininger et al., 2006; Santoro et al., 2010). The AOA gene copies were shown several requests for quantity moreover than the beta-proteobacterial amoA gene in the North Atlantic (Wuchter et al., 2006). However, the investigation showed functional relationships among the amoA genes and abundances described by the qPCR targeting 16S rRNA and using CARD-FISH by direct enumeration. Furthermore, it has been confirmed that the number of AOA is higher abundant than AOB in China (Liu et al., 2018), the Gulf of California (Beman et al., 2008), and the Japan Sea (Nakagawa et al., 2007).

The opposite of investigations the AOA is dominated than β-AB in ecosystems, some investigations have determined the AOB be higher overestimated than the AOA (Dang et al., 2010b; Jin et al., 2010; Mosier and Francis, 2008). The qPCR is showed the AOA gene copies were lower than β-AB in the San Francisco Bay, while the AOA was determined various concentrations than β-AB in the bay (Mosier and Francis, 2008).
CORRELATING NITRIFICATION ACTIVITY TO FUNCTION

The identifying the phylotypes and group of nitrifies promoting to the measure/observed nitify functioning is challenging. Few studies detected AOA and AOB found abundances in situ as the AO could be a small percentage of the total community. Furthermore, it is complicated to extract the whole mRNA entirely from environmental samples. RNA and DNA amplified can as such be biased due to characteristics PCR biases (Smith and Osborn, 2009). Despite these difficulties, it is especially useful to quantify transcripts as it brings us a step closer to identifying the active microorganisms than gene quantification alone. Moreover, the carried out the model on how targeting amplified can be available in correlating nitrification activity to function (Zhang et al., 2015). They determine that AOB were unaffected by salinity changes, however, they included lower transcriptional activity as salinity raised, and AOA had maximum transcriptional activity at average salinity. Up to now, the publication has provided complementary confirmation on how AOA and AOB respond to salinity, making it more crucial to encouragement field studies with laboratory-based experiments.

FURTHER APPLICATIONS

The possibility and functional application of ammonia oxidizing during sewage treatment are the comparatively limited right now. Separately, it is essential to describe the competition among AOB and AOA. Furthermore the association among the AOA and anaerobic ammonia oxidation is an anaerobic bacteriological process in which ammonia, combined with nitrites, are transferred to (N₂) dinitrogen gas corresponding to reaction (Kuenen, 2008). Both anaerobic ammonia oxidation bacteria and AOA increase gradually, and their concentration necessities richly experience; accordingly, development of an effective and rapid technique of increasing AOA and anaerobic ammonia oxidation is essential to the widespread application of these novel researchers in ecological conservation. It is also required to improve a unique technology to can use novel functions of ammonia oxidation microorganisms, for example, treating sewage with hyperthermal or manufacturing sewage discharge retardants of AOB rather than AOA. Such as that utterly autotrophic nitrogen removal over nitrite (CANON) procedures the couples AOB and anaerobic ammonia oxidation, nitrogen might be remoted under entirely autotrophic status (Sliekers et al., 2003). It is similarly suggested that a unique process in which a compound of ammonia oxidation and anaerobic ammonia oxidation is applied may be advanced.

CONCLUSION

The ammonia oxidizing microorganisms, which are diversified and abundant groups, have adapted to live in a high diversity of harsh environments. The environmental characteristics such as ammonia, salinity, pH, and temperature all represent a role in determining ammonia oxidizer activity. Studies of the ecological factors affected and the anthropogenic in the community of AOA and AOB across a variety of environments habitats have shown wide physiological diversity under comparing environmental and climatic states. However, to improved understand Nitrogen dynamics, the study on the temporal and spatial variations of AOB and AOA functioning. Integrated studies of AOA and AOB groups using addition methodologies are expected to facilitate determination of nitrification functions of archaeal and bacterial ammonia oxidizers in different ecological situations. Concerned about reducing greenhouse gas emissions and the lost nutrients from agricultural, it is necessary to obtain a better understanding of the bacterial communities concerned and their specific contributions to nitrification and nitrogen cycling worldwide. The further applications of these unique studies in ammonia oxidizing are examined. The unique technological applied for the nutrients removed must not only ensure the wastewater quality and consume less energy. As well as limited the engendering of more N₂O, this will be important to improve our possibility to develop improved strategies for nitrogen cycle management and to better the nitrogen use efficiency, while concurrently to minimize negative ecological impacts.

ACKNOWLEDGEMENT

This work is financially supported by the National Natural Science Foundation of China (Grant Nos. 31070089, 31170078, and J1103514), the National High Technology Research and Development Program of China (grant Nos. 2013AA065805 and 2014AA093510), the National Natural Science Foundation of Hubei Province (grant No. 2015CFA085), and the Fundamental Research Funds for HUST (grant Nos. 2014NY007, 2017KFXJJJ212, 2017KFXKJC010, 2017KFTSZZ001).

CONFLICT OF INTEREST

The authors declare that no competing interests exist.

REFERENCES

Adair, K.L., Schwartz, E., 2008. Evidence that ammonia-oxidizing archaea are more abundant than ammonia-


