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The Ecological and Anthropogenic Factors Influencing the Nitrification: A review

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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.

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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).

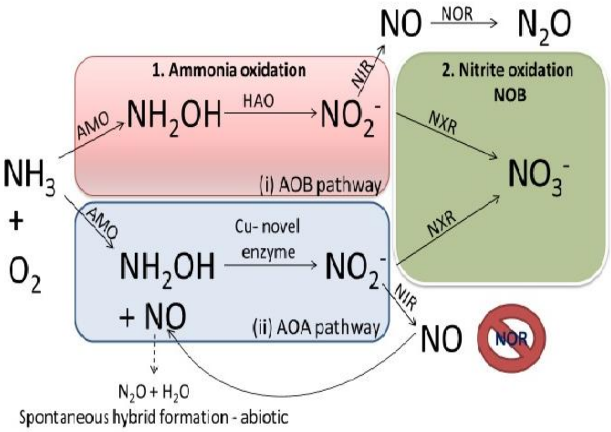

Fig. 1. Schematic design of the nitrification steps through (i) AOA and (ii) AOB along with nitrous oxide formation. Nitrification composed of 1: ammonia oxidation and 2: nitrite oxidation. Dashed arrows indicate gaseous distribution from sediments into the atmosphere. Capital letters above bolts refer to enzymes. **AMO –** ammonia monooxygenase; **HAO-** hydroxylamine oxidoreductase; **Cu- novel enzyme –** reduces NO and NH_2OH; **NIR –** nitrite reductase; **NOR –** nitric oxide reductase; **NXR -** nitrite oxidoreductase.

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 H_2O 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 (NO_3^{-1}) using nitrification by a one or two-step process. Nitrate does not adhere to soil or sediment particles as well as ammonia/ammonium (NH_3/NH_4^+), 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, NO_3^{-1} and NO_2 can also be converted to NH_4^+ 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).

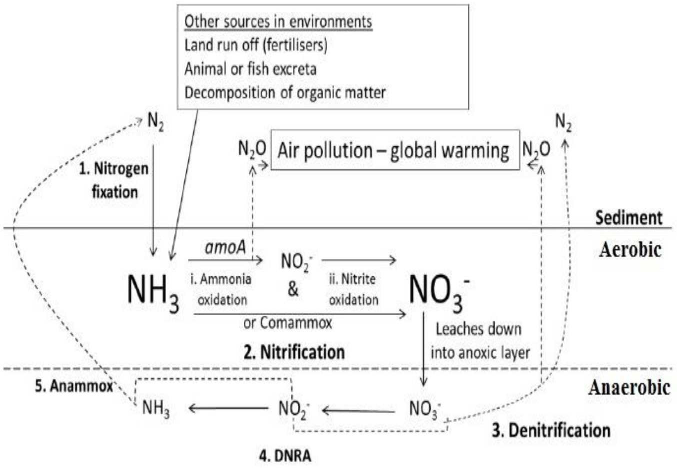

Fig. 2. Schematic representation of the nitrogen cycle in sediments. Various steps in the nitrogen cycle are numbered 1 – 5, dashed line.

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 Pommerening-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 CO_2 (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.

(2) Denitrification relates to the substrate production.
(3) Obtained of nitrous oxide in terrestrial and aquatic ecosystems.
(4) The oxygen consumption in sediments.
(5) The environmental acidification.

Table 1. An example of characterization of nitrifying archaea and bacteria, their phylogeny, and distribution in the environmental.

Characteristic	Phylum	Genera	Habitat
Oxidize ammonia	Gamma-proteobacteria	Nitrosococcus	Freshwater, Marine
Oxidize ammonia	Beta-proteobacteria	Nitrosomonas	Soil, Sewage, Freshwater, Marine
Oxidize ammonia	Thaumarchaea- group I.Ib	Nitrososphaera	Soil and other environments
Oxidize ammonia	Thaumarchaea- group III	Nitrosocaldus	Hot water extremophile
Oxidize ammonia	Thaumarchaea– group I.Ia	Nitrosopumilus Nitrosoarchaeum	Marine and other environments
Oxidize ammonia	Thaumarchaea–SAGMGC-1	Nitrosotalea	Omnipresent cluster
Oxidize nitrite	Gamma-proteobacteria	Nitrococcus	Marine
Oxidize nitrite	Alpha-proteobacteria	Nitrobacter	Soil, Freshwater, Marine
Oxidize nitrite (some can carry out complete nitrification Comammox)	Nitrospira group	Nitrospira	Soil, Marine
Oxidize nitrite	Nitrospinae	Nitrospina	Marine

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 with nitrification function (Lu *et al.,* 2012). Additionally, the *Thaumarchaea spp* are ammonia oxidizers, and they have a urease subunit alpha (ureC) gene affording them the ability to hydrolyze urea. Accordingly, it is crucial to evaluate the urea concentration in the environment habitats (Alonso-Saez *et al.,* 2012).

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 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 ($S_2O_3^{-2}$) 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 devanaterra* (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 (Tourna *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 (Tourna *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 archaeal 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 CO_2 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 N_2O 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-AOB 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-AOB 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-AOB in the San Francisco Bay, while the AOA was determined various concentrations than β-AOB 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 nitrify 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 (N_2) dinitrogen gas corresponding to reaction (Kuenen, 2008). Both anaerobic ammonia oxidation bacteria and AOA increase gradually, and their concentration necessitates 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 N_2O, 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.

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CONFLICT OF INTEREST

The authors declare that no competing interests exist.

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