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专论与综述

好氧氨氧化菌的种群生态学研究进展

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摘要 好氧氨氧化菌是一类能够在好氧条件下将NH_4^+转化为NO_2^-的化能无机自养型细菌，其活动将直接或间接影响土壤养分循环、水体富营养化、温室气体（N_2O）和生态系统的功能。现代分子生物学技术的发展促进了人们对好氧氨氧化菌种群生态学的研究。介绍了近年来基于16S rRNA和氨单加氧酶*amoA*基因序列分析的好氧氨氧化菌的系统发育研究，比较了两种基因序列分析在好氧氨氧化菌遗传多样性研究中存在的差异；概述了环境条件诸如铵浓度、酸度、氧的可利用性、温度、盐度等对好氧氨氧化菌种类、数量及其种群生态分布的影响；阐述了好氧氨氧化菌对铵、氧饥饿的响应特征及其在酸性环境中的生存机制；并对今后好氧氨氧化菌的应用生态学研究及其主要方向进行了展望。

关键词 好氧氨氧化菌；系统发育；生态分布；环境条件

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Research progress on the microbial ecology of aerobic ammonia-oxidizing bacteria

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Abstract Ammonia oxidation by autotrophic ammonia-oxidizing bacteria (AOB) is a key process in agricultural soils, wastewater treatment and natural ecosystems and plays an important role in the global nitrogen cycle. With the advent of cultivation-independent molecular biotechnologies, significant research progress has been made in understanding the ecology, phylogeny and distribution of AOB. These bacteria are widely distributed in nature and are found in soils, sand dunes, biofilms, fluidized bed reactors, lakes, wastewater, and seawater. The 16S rRNA gene is the chief phylogenetic marker that has been used for elucidating AOB evolution. Recent studies have demonstrated that there is a high consistency between phylogenetic trees based on the 16S rRNA gene and those based on ammonia monooxygenase gene (*amoA*) sequences. The amoA gene codes for a functional protein that is involved directly in ammonia oxidation and, therefore, a considerably higher number of differences in amoA gene sequences derived from different AOB are expected. Thus, using amoA as a marker is expected to increase the resolving power in the study of AOB diversity in the environment as compared to 16S rRNA-based markers. Recent studies have also revealed that the distribution of AOB is affected by different environmental conditions. Ammonium availability, acidity, dissolved oxygen, temperature, and salinity have all been shown to selectively affect, to some extent, the number of AOB species and the abundance of AOB in various environments. The ability of certain AOB to grow at continuously low ammonium and oxygen concentrations and to become active again after longer periods of starvation allows these bacteria to better exploit irregular pulses of ammonium and oxygen in the environment and thus persist for longer periods of time. Ureolysis provides a mechanism for nitrification by AOB in acid soils. When urea enters the cells by diffusion, intracellular urea hydrolysis and ammonia oxidation occur independently of extracellular pH in the range 4 to 7.5, thus allowing them to overcome a major constraint to their activity at low pH. Here we describe our perspectives for the future research of AOB in applied ecology and environmental protection.

Key words aerobic ammonia-oxidizing bacteria _ phylogeny _ ecological distribution _ environmental condition

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