微生物学通报
Microbiology
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MAY 20, 2008, 35(5): 809~814

专论与综述

Application of Microorganisms in the Degradation of Polluted Chemicals in Aquatic Environments

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Abstract: Every year, waters on earth receive large quantities of wastewater from industry, agriculture, fish and poultry raising, and municipal sewage treatment plants. Consequently, the aquatic environment on the earth is under a serious challenge from a very large quantity of pollutants such as antibiotics, insecticides, herbicides, hydrocarbons, etc., contained in the domestic wastewater, industrial and agricultural waste water and illegal effluents. In particular, with the development of intensive aquiculture and poultry, the effluent pollution has recently become more and more serious with more attentions. Furthermore more and more chemical pollutants discharged into aquatic environment have been detected with the advancement of analytical techniques. These chemicals can cause toxic effects on water habitats after discharged into aquatic environment. However, microorganisms have many key functions in pollution control. In this review, applications of microorganism in the degradation of chemicals in aquatic environments are reviewed. It was concluded that most applications of microorganisms degrading chemicals focused on aquaculture waters, whereas other aquatic systems (such as river, lake, sea, coastal waters) have been scarcely studied.

Keywords: Biodegradation, Aquatic environment, Pollutants

微生物在水环境污染物降解中的应用

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摘　要: 每年有大量来自工业、农业、养殖业和城市污水处理厂的废水被排入到水环境中, 因此, 地球上的水环境面临大量来自生活废水、工农业废水、非法排放的废水及其它废水的污染物质(如抗生素、杀虫剂、除草剂、烃等)的严重挑战, 特别是近年来随着集约化养殖的发展, 废水污染问题日益突出, 并且随着分析手段的进步, 能够检测到被排入水环境中的化学污染物质也越来越多, 这些化学污染物对水环境中的生物产生有害影响。但是, 微生物在污染控制上具有许多重要的作用。因此, 本文对微生物在水环境污染物降解中的应用进行了评论。结果表明微生物主要是应用在水产养殖水中, 而在其它的水体系(如河、湖、海)的应用较少。

关键词: 生物降解, 水环境, 污染物

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Received : December 6, 2007;　**Accepted:** March 5, 2008

1 Introduction

Waters such as rivers, lakes and seas, containing many unknown substances, are always sources for drinking water as well as agricultural purposes. However, water is susceptible to be polluted, partly because of intentional releases of chemicals into rivers, lakes and the sea through effluents and wastewater from industry, agriculture, aquaculture, livestock feeding and households without proper treatment, and partly because of accidental discharges via spills, run-off, atmospheric deposition, etc[1]. It was reported that more than 100000 metric tones of chemicals were discharged into waters each year by industrial use in the United States[2].

Recently, the pressure has been further mounted with rapid economic development and growing populations and greater use of water by people, leading to more than 50% of the estuarine of some rivers polluted by effluents in some densely-populated countries. It is known that many natural and synthetic chemicals (such as petroleum hydrocarbons, antibiotics, pesticides and steroid hormones) may give rise to direct toxic effects (e.g. reducing predation rates[3]) on aquatic habitats when discharged into the aquatic environment. Some sensitive species may be impaired or killed by some toxic chemicals, which may result in a trophic cascade or tolerant species. Though many chemicals and their intermediary degradation products are released into water environment, most may be degraded by microorganisms.

In this paper, it mainly discussed chemical pollutants in aquatic environment, microorganisms in water pollution control and application of microorganisms in degrading chemicals in aquatic environment.

2 Chemical pollutants in aquatic environment

With the advance of analytical techniques, more and more chemical pollutants discharged into aquatic environment have been detected (Table 1). To date, antibiotics, steroid hormones, insecticides, herbicides, hydrocarbons and surfactants are found in aquatic environment. However, the exact components detected in aquatic environment, can't be concluded as they depend on many factors, e.g., the properties of chemical applied, ranges, usage and doses, analytical techniques, etc. Regardless, antibiotics, hydrocarbons, insecticides and steroid hormones are significant contaminants in most of aquatic systems.

Table 1 Chemical pollutants in aquatic environment

Class	Source	Reference
Antibiotics:		
Lincomycin	Surface water	[4]
Clarithromycin	Surface water	[4]
Sulphadiazine	Surface water	[4]
Sulphamethazine	Ground water	[4]
Trimethoprim	Surface water	[4]
Tetracycline	Ground water	[4]
Steroid hormones:		
Estrogen	Rriver, S.T.W.effluent	[1]
Androgen	S.T.W.effluent	[1]
Insecticides:		
Endosulfan, carbaryl	Freshwater and marine	[3]
Endosulfan, chlorpyrifos		
Lindane, fenthion		
Cypermethrin, deltamethrin		
Fenvalerate		
Herbicides:		
Atrazine, simetryn, linuron	Freshwater and marine	[3]
Terbutryn and atrazine		
Hydrocarbons:		
Benzene, trichloroethylene	Freshwater and marine	[3]
# 2 fuel oil, diesel fuel and crude oil		
Surfactants:		
Alcohol ethoxylate	Freshwater benthos	[3]
Alkyl sulfate		
Alkyl ethoxysulfate		

Antibiotics are semi-synthetic and synthetic compounds with antimicrobial activity as medicines and animal growth promoters[4]. These substances not only are water-soluble, but also have high affinities for soil and sediment, and therefore residual water concentrations are relatively low. However, over 15 different types of antibiotics are recently found in streams in the US and Germany[5], more than 30 antibiotic substances (including lincomycin, tetracycline, sulphamethazine, oxytetracycline) have also been found in sewage influent and effluent samples, in surface and ground waters and drinking water[4]. Except for positive function of antibiotics (anti-microbial activity as medicines and animal growth promoters), antibiotics cause indirect effects (such as resistant bacteria stains transmitted via food-chain to consumers, allergic reactions, serious photoallergic reactions, chronic photosensitive dermatitis)[4] on organisms in the environment. However antibiotics, with little attention as pollutants in the aquatic environment, are widespread applied in large quantities as medicines and animal growth promoters. It is estimated that quantity of antibiotics consumption worldwide is between 100000 and 200000 tones[4], whereas over 700000 kg/pr in Australia[5]. Thus the antibiotics have become a potential environment risk deserving more attentions.

Aromatic hydrocarbons, more than 300, have been found in the Chesapeake Bay[6]. Pesticides (organophosphorus pollutants) including hlorpyrifos, malathion, diazinon, profenofospirimiphos-methyl and chlorpyfifos-methyl were detected in aquatic environment of the drainage canal by GLC and GC-MS[6]. Hydrocarbons and pesticides can result in direct effects (impairing foundation species, trophic cascade, tolerant species) when released into aquatic environment[3]. In particular, pesticides are highly toxic to arthropod habitants and would inhibit AChE in fish and influence enzyme resynthesis[6]. In addition, both residual water concentrations are lower, e.g., the highest concentration pesticides in water are a-BHC (55.4 ng/L), g-BHC(118.4 ng/L), malathion(80.5 ng/L), pv-DDT(25.2 ng)[6]. These chemicals can be effectively used by microbe as growth nutriments under optimum conditions.

Steroid hormones, including estrogens, androgens, progesterones and phytoestrogens, have recently increased in the environment (such as municipal wastewater discharge, municipal biosolids, pharmaceutical production, and agriculture-related activities)[1]. It is well-known that most of steroid hormones are capable of endocrine disruption (introduced by Theo Colborn and her colleagues[1]), e.g., estrogens can cause ‘feminization’, whereas androgen cause masculinization[1]. Up to date, most focus has been on estrogens and estrogenic effects (e.g. feminization). The natural steroid estrogens 17 β-estradiol and estrone, synthetic steroid estrogen ethinyl estradiol (active ingredient of the contraceptive pill) are found in effluents at lower concentrations, very likely to cause together ‘feminization’ of fish when discharged into aquatic environment[1]. Estrogens may be degraded by microorganisms for the results on less than 15 min of half-life of estrogens in a biological reactor treating urine.

3 Microorganisms in degrading chemicals in aquatic environment

Microorganisms are applied to degrade chemicals in aquatic environment for following reasons: they are microbial component of aquatic ecosystems and have self-purification nature water ability by increased growth and metabolism. They can utilize organic substances (such as kerogen and longchain alkanes, refractory compounds[2]) for producing energy by cellular respiration and for synthesizing proteins and other components in manufacturing new cells. Thus some xenobiotic compounds such as insecticides (e.g. malathion), herbicides (e.g. 3, 4, 5-trichlorophenoxya-cetic acid), steroid hormones (e.g. estrogens) and hydrocarbons, can be degraded by microorganisms.

In addition, microbial membranes are lipophilic and negatively charged (Fig.1). They can absorb aliphatic and aromatic of organic compounds by hydro-

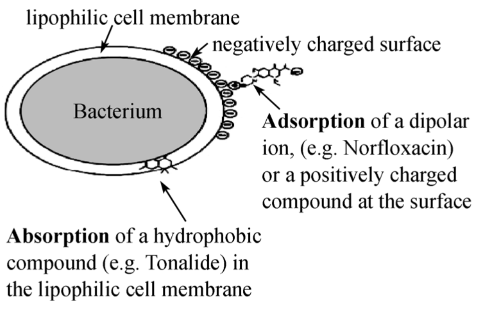

Fig. 1 Absoption and adsorption of micropollutants to particulate matter[7]

phobic interactions and adsorb the positively charged groups of chemicals by electrostatic interactions[7].

In general, microorganisms with capability of degrading chemicals in aquatic environment are Photosynthetic bacteria (PSB), *Nitrobacteria*, *Bacillus* sp., *Bdellovibrio bacteriovorus*, Fungi, *Actinomyces*, etc. However, the former four bacteria are mostly studied, the latter are scarcely touched.

Photosynthetic bacteria is a group of full autotrophic or photoheterotrophic bacteria which not only assimilate carbon dioxide by light energy, but also decompose and use many organic substances (e.g., organic acids, alcohols, carbohydrates and aromatic hydrocarbons) and transforms some toxic substances (such as sulfurated hydrogen, ammonia nitrogen, nitric nitrogen, etc.). It is used as probiotics in aquatic environment, mainly applied to improving water quality (such as decrease the contents of ammonia nitrogen and sulfurated hydrogen, reduce COD, increase dissolved oxygen) in aquiculture by photosynthesis without producing oxygen in aquiculture.

Nitrobacteria are autotrophic organisms that cannot utilize present organic matters, whereas degrade ammonia nitrogen in water body. They are also effective microorganisms applied to purifying water quality in aquiculture.

Bacillus sp. is a gram- positive bacterium with secreting highly active proteinase, which strongly decompose protein, complicated polysaccharides and water-soluble organic acids. It is also applied to purifying water quality because of capability of decreasing the contents of nitrate and nitrite in aquatic environment, e.g, DING Liang[8,9] found the *Bacillus* sp. could decrease obviously nitrite.

Bdellovibrio bacteriovorus is small, highly motile, Gram-negative bacterium with the ability to invade other gram-negative bacteria[10], including several human pathogens (such as *Pseudomonas* and *Salmonella*). It is applied to improving water quality in aquiculture because of ability of deceasing pathogenic bacteria populations and communities, and therefore indirectly improves water quality.

4 Application of microorganism in degrading chemicals in aquatic environment

4.1 Application studies

Based on the above analysis, it is likely to apply microorganism in degrading chemicals in aquatic environment in practice. Recently, some studies of application of microorganisms degrading chemicals in aquatic environment have been reported. YI Yu-hua et al[11] reported that medium dissolved oxygen content was increased by 7.1%, medium ammonia nitrogen concentration was decreased by 28.6%, by PSB applied to prawn culture pond. Ding Wei-jun et al[12] reported that medium dissolved oxygen content was increased by 1.2 mg/L, medium ammonia nitrogen concentration was decreased by 0.4 mg/L, by 1.5 g/m^2 PSB applied to prawn culture pond. Li Shuang-jiang et al[13] reported dissolved oxygen was increased by 15%, COD was decreased by 46.1%, ammonia nitrogen was decreased by 81.2%, by PSB. YE Yi-zuo et al[8,14] reported the removal rate of COD was more than 90% by PSB and actinomyces applied to turtle culture ponds without sands in greenhouse. Gong Xing-wen[15] did similar experiments and reported the dissolved oxygen was increased, COD and ammonia nitrogen were decreased, by PSB and Actinomyces. LI Zuo-jia et al[11] reported that the water quality obviously improved, the dissolved oxygen increased, the concentrations of ammonia nitrogen and nitrite decreased by compound microorganisms including most *Bacillus* sp. applied to tilapia culture pond. It was reported that American scholars used mixed microbial agents including *Bacillus subtilis*, *Pseudonmonas*, *Myxobacteria*, etc, to decompose the waste in water. ZHANG Liang et al[16] reported that medium COD, ammonia nitrogen and sulfide value were decreased by *Bdellovibrio bacteriovorus* applied to *Ctenopharyngodon idellus* culture pond.

4.2 Biotechnologies

The application of microorganism in degrading chemical pollutants is actually a bioremediation course of microorganism absorbing, degrading and transforming pollutants. Treatment effect depends on not only microbe populations, but also communities. So there are some emerging biotechnologies, such as biological turnplate[17], bio-contacter[17], biological filter[17], activated sludge[17] and microbial ecological agent[18]. The former three techniques are adopted in foreign countries at high cost, however the fourth technique which needs high management skills is not widely adopted though having higher purification rate. Microbial ecological agent[11] is also called microecological modulator, living bacteria agent, efficient microbe agent, probiotic. Mainly microbial components of this agent may be PSB, *Nitrobacteria*, *Bacillus* sp., *Bdellovibrio bacteriovorus*, *Bifidobacterium, Actinomyces*, *Lactobacillus*, yeast and fungi. This is a good application prospect way due to lower cost and simpler operation.

Now most studies focus on Efficient microbe and developing microbial ecological agents, and therefore there are some emerging probiotic commodities, such as the biological agents of EBE series, EM agent, Bacterium killer 27, and so on. The tutor of the author is studying application of the Efficient microbe, e.g., Cai Jun-peng[19] found *Bdellovibrio bacteriovorus* had a potential application on lysing vibrios from seafoods.

5 Conclusions

It is clear that most applications of microorganisms in degrading chemicals focused on aquiculture water treatment, whereas other aquatic systems (such as river, lake, sea, coastal waters) have been little studied. Furthermore, there has been no detail studies related to microorganisms degrading antibiotics, steroid hormones, insecticides and herbicides. The study of antibiotics is especially important lying on the facts of overuse and misuse in concentrated animal feeding operations and high toxicity to inhabitants. Much work is needed on the chemicals bio-treatment, selective microorganisms, microbial ecological agents and mechanism. Similarly, additional research is needed on ecosystem indicators that predict effects of chemical pollutants on a variety of aquatic habitats.

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