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Research on the application of microbiological treatment technology in environmental engineering

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Abstract. With the rapid development of China's economy, the problem of environmental pollution has become increasingly serious. In order to effectively treat all kinds of environmental pollution, pollution treatment technology needs to be constantly updated and improved. Microbial treatment technology, with its high efficiency and environmentally friendly features, shows a broad application prospect in pollution treatment. In this paper, the application of microbial treatment technology in the treatment of three typical environmental pollutants is systematically reviewed through extensive literature research. The basic principles of microbial treatment technology are described, and the successful applications of microbial technology in the treatment of wastewater, solid waste and soil heavy metal pollution are discussed in detail in combination with typical cases of environmental pollution treatment. Compared with the traditional physical and chemical methods, microbial technology is easy to operate, with significant treatment effect, lower comprehensive cost, and less likely to produce secondary pollution. In order to give full play to the unique advantages of microbial technology, this paper focuses on the possible limitations of microbial technology in practical application and discusses its future development direction.

Keywords: environmental engineering, microbiological techniques, wastewater treatment, soil heavy metal pollution, atmospheric pollution

1. Introduction

Since the reform and opening up, China's social and economic development, the people's living standards have been greatly improved, but the environmental pollution problem is also gradually exposed to the public view, the increasingly serious pollution trend makes environmental protection work urgent. Compared with physical treatment technology and chemical treatment technology, microbial treatment technology is less likely to produce secondary pollution, and has more prospects in the application of environmental remediation. Therefore, microbial treatment technology is prioritised to be applied in the treatment of wastewater, solid waste and other pollutants, making full use of its environmentally friendly features, which can achieve the green and efficient removal of pollutants while promoting the harmonious development of man and nature.

Microbial treatment technology is based on the gradual development of biology to form a new treatment technology, the technology can be produced through the use of various types of microorganisms in the metabolic process of the reaction, or the use of microorganisms to synthesise the corresponding substances, and then achieve a comprehensive detection, evaluation and prevention of environmental pollution. This technology is usually widely used in environmental engineering, which is characterised by low cost and low pollution in the process of application, and can achieve better pollutant management results.

At present, microbial treatment technology has become a hot spot in environmental engineering research. Give full play to the environmental characteristics of this technology, widely used in solid waste treatment, water treatment and other fields, not only can efficiently purify the pollution, but also generate beneficial microbial products, to promote the development of people and nature. In the future, with the microbiology, synthetic biology and other technological advances, the screening and design of functional microorganisms will be more accurate and efficient application. We have reason to be hopeful that microbial treatment technology will play a key role in helping the cause of environmental engineering, and building a better home where human beings and nature coexist harmoniously.

2. Application of microorganisms in the treatment of water pollution

2.1. Overview of water pollution

Water pollution is usually caused by pollutants generated by human production activities, mainly divided into three categories: industrial water pollution, agricultural water pollution and domestic water pollution. Industrial wastewater usually refers to the industrial production process of wastewater and waste liquids, the overall characteristics of a wide range and complex composition. Industrial wastewater usually contains different pollutants according to different industrial production processes, such as heavy metal smelting and industrial electroplating wastewater usually contains heavy metals such as mercury, lead and cadmium, petroleum refining industrial wastewater contains phenol and petroleum pollutants, pesticide manufacturing industrial wastewater contains a variety of pesticides. Distinct from industrial wastewater, agricultural wastewater is the wastewater discharged from agricultural cultivation, livestock and poultry breeding, and processing of agricultural products. Mainly contains farmland drainage, feedlot drainage, agricultural product processing wastewater, these agricultural wastewater generally has a large amount of water, the impact of a wide range of characteristics. Domestic wastewater is the wastewater discharged by residents in their daily lives, mainly from residential buildings and public buildings, such as homes, institutions, schools, hospitals, shops, public places and industrial enterprises, such as toilets. The pollutants contained in domestic wastewater mainly contain protein, carbohydrates, fat, urea, ammonia nitrogen, etc., in addition to a large number of pathogenic microorganisms (e.g., parasitic eggs and intestinal infectious diseases such as toxins). As the organic matter present in domestic wastewater is extremely unstable, it is easy to decay and produce a bad odour, which makes bacteria and pathogens multiply in large quantities using the organic matter in domestic wastewater as nutrients, which can easily lead to the spread of infectious diseases [1]. The direct discharge of these wastewater without reasonable disposal will cause serious harm to human health and the ecological environment, therefore, wastewater must be effectively treated before discharge.

2.2. Mechanisms of microbial action for water pollution remediation

Microbial adsorption and microbial degradation techniques can usually be used to remediate polluted water bodies. Microbial adsorption technology mainly relies on the adsorption of microorganisms to achieve water purification, such as filamentous fungi can be produced through the cell wall functional groups (such as -SH, -COOH) and heavy metals to produce bonding, in order to achieve the play of its high efficiency of adsorption capacity [2]. Microbial degradation technology is the use of specific microorganisms to decompose complex organic matter in water and convert it into bioavailable small molecule organic matter, water and carbon dioxide and other substances. For example, Pseudomonas aeruginosa (IES-Ps-1) can convert phenol to catechol, and subsequently degrade catechol through the neighbourhood cleavage pathway, which ultimately leads to the degradation of phenol [3].

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2.3. Application of microbial technology in water remediation

Microbial technology is widely used in the treatment of water pollution because of its high efficiency and environmental advantages. For eutrophic water bodies, microorganisms can be introduced to inhibit the outbreak of cyanobacterial bloom, thus realising the management of bloom [4]; and functional flora can also be artificially added to effectively remove ammonia nitrogen, nitrate and phosphate in wastewater [5]. In addition, through the construction of artificial wetland systems, the use of plant-microbial joint action to complete the purification of water bodies has also become one of the research hotspot technologies in recent years [6]. For water bodies containing oil pollutants, the addition of microorganisms (e.g., Bacillus and Flavobacterium) with the ability to decompose oil substances is usually used [7]. By adding these microbial agents through inoculation, the self-purification ability of water bodies can be effectively and efficiently improved [8]. In summary, by combining a variety of microorganisms synergistically, all kinds of water pollution problems can be efficiently managed, so microbial technology has a huge potential for application in water environment remediation.

3. Application of Microorganisms in Air Pollution Control

3.1. Overview of atmospheric pollution

With the rapid development of social and economic development and urbanisation, the problem of air pollution in China is becoming more and more serious. The main air pollutants include sulfur dioxide, nitrogen oxides, volatile organic compounds, ammonia, and dust, etc. Most of these pollutants come from the oxidation of sulfides produced in the process of coal combustion, various types of industrial production emissions, and motor vehicle exhaust. Relevant research results show that the emission of these air pollutants has caused serious harm to the ecological environment and human health. For example, sulphur dioxide is one of the main causes of acid rain, acid rain will corrode the surface of buildings and destroy vegetation; nitrogen oxides can be produced in the sunlight photochemical smog, reducing the visibility of the atmosphere; there are a variety of volatile organic compounds in the human body of toxic substances, can stimulate the eyes, nasal cavity and respiratory tract and other parts of the; particulate matter can be deep into the lungs, increasing the incidence of respiratory diseases. Overall, air pollution has been proven to have a positive correlation with the occurrence of respiratory diseases, cardiovascular diseases [9] and lung cancer. Based on these hazards, effective prevention and control of air pollution has become an important issue in today's environmental science research. Currently, researchers are committed to developing new technologies and methods for managing air pollution, with a view to improving the air quality in China as soon as possible and maintaining public health.

Compared with the traditional physical and chemical methods, microbial treatment technology shows unique application prospects, compared with the traditional physical and chemical methods, microbial technology to treat air pollution has unique advantages. Firstly, microbial technology is less polluting in the process of application and does not produce secondary pollution. Secondly, microbial technology is easy to operate, the investment in equipment is relatively low, and the operating cost is lower than traditional methods. In addition, microorganisms can efficiently degrade various types of air pollutants with high degradation rate. In short, microbial technology to control air pollution is efficient and environmentally friendly, in line with the concept of sustainable development, and has an important position in the prevention and control of air pollution.

3.2. Role of microorganisms in air pollution control

Microbial enzymes can achieve the degradation of specific pollutants in the air. For example, bryophytes and symbiotic bacteria can absorb and accumulate nitrogen oxides [10]; some fungi and actinomycetes can eliminate volatile organic pollutants through degradation [11]. In addition, some artificially designed genetically engineered bacteria (microorganisms or bio-enzymatic agents) have the ability to degrade a variety of pollutants, and through metabolism or co-metabolism, they exert catalytic activity that is difficult to achieve by traditional methods, thus broadening the range of degradable pollutants [12].

3.3. Application of microbial technology in deodorisation

Microbial technology has achieved certain effects in removing malodorous odours and other aspects, and the removal of malodorous substances through microbial degradation and conversion processes has gradually become one of the mainstream deodorisation methods [13]. A common microbial deodorisation method is to uniformly spray microbial strains or microbial synthesised enzymes that degrade organic waste gases around the source of malodour pollution, thereby reducing the content of volatile organic pollutants through microbial metabolism and to [14]. In addition, microbial curing is also one of the commonly used techniques, which involves integrating microorganisms into natural or synthetic carrier materials to make an immobilised microbial bacterial system, in order to improve its mechanical strength, stability and regenerative use of the material in processes such as deodorisation. Commonly used curing methods include aluminate curing and polymer-embedded curing. Microbial bacterial agent after curing can be made into biological ball and biological column and other deodorant devices, placed in the air circulation area can achieve continuous deodorisation. Cured microbial deodorisation technology is easy to operate, adaptable, and is one of the important technical means in the field of air pollution control. In addition, microorganisms can also be coated on the surface of inorganic carrier materials, made of biofilter material, used for air purification and deodorisation. In summary, microbial technology in the treatment of malodour pollution shows a broad application prospect.

4. Application of microorganisms in soil heavy metal management

4.1. Overview of soil heavy metal pollution

Heavy metal pollution mainly refers to the pollution of the environment by some metal elements that are dense and potentially toxic to organisms, such as lead, mercury, cadmium, chromium and copper at certain concentrations. These heavy metals mainly originate from the emission of industrial waste gas, automobile exhaust and the dumping of municipal waste [15]. Heavy metal pollution can cause serious damage to the structure and function of soil ecosystems, jeopardise crop yield and quality, and ultimately cause potential harm to animals, plants and human health through the food chain. For example, lead can affect the intellectual development of children; cadmium affects kidney function; and mercury affects the nervous system [16]. Therefore, there is a need to use effective means to manage heavy metal pollution in the soil environment.

4.2. Mechanism of microbial enrichment and transformation of heavy metals

Microorganisms have certain heavy metal tolerance and enrichment ability. Many bacteria and fungi can accumulate heavy metals on the cell surface or inside the cell through surface adsorption. Some microorganisms can produce substances (e.g. humic substances) that can complex with heavy metals, thus reducing the toxic effects of heavy metal ions in the environment on other organisms [17]. Other microorganisms can also change the valence or morphology of heavy metals through redox reactions, thereby reducing their toxicity or ability to migrate. Common functional microorganisms include iron oxidising bacteria, sulphur oxidising bacteria and denitrifying bacteria [18]. Using the biological functions of these microorganisms, the treatment of heavy metal contaminated soil can be achieved.

4.3. Application of microbial technology in soil remediation

Microbial technology plays an important role in soil heavy metal treatment because of its high efficiency, environmental protection and low cost. Common applications include: 1) developing novel engineering strains to promote the biotransformation of heavy metals in soil; 2) building microbial-plant systems using plant and microbial synergistic remediation mechanisms, and 3) constructing reductive microbial fuel cells to achieve heavy metal passivation using microbial redox capacity.

In recent years, there have been studies on the use of biological compost to remediate low concentrations of heavy metal contaminated soil. Microorganisms can decompose organic matter into humic acid, fulvic acid and other organic acids, dissolve and mineralise heavy metals, and reduce their

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biotoxicity [18]. In addition, the redox process of microorganisms has been used as an effective means of eliminating soil heavy metal pollution, such as iron oxidising bacteria oxidising ferrous ions to produce ferric hydroxide, which can adsorb and immobilise heavy metals in the soil [18]; and denitrifying bacteria can adulterate and precipitate heavy metals through the nitrate reduction process [18]. In addition, specific heavy metal-binding proteins can be created using genetic engineering techniques and subsequently implanted into functional microorganisms, ultimately achieving effective management of heavy metal-contaminated soils [19].

5. Problems facing the development of microbiological technology

5.1. The growth conditions of microorganisms are relatively harsh, making it difficult for them to perform stably in large-scale applications.

Many functional microorganisms require high temperatures, pH values and nutritional conditions, etc., while the actual conditions of contaminated sites are complex and variable, making it difficult to meet their rapid growth requirements, thus affecting the degradation effect. In addition, environmental stresses may cause genetic mutations in microorganisms, resulting in reduced degradation of pollutants. In order to achieve large-scale application, it is necessary to study the adaptive mechanism of microorganisms and optimise the environmental conditions required by microorganisms by means of reasonable configuration of nutrient substrates and maintenance of redox potential, so as to ensure the pollutant removal ability [20].

5.2. Microbial degradation process cycle is long, difficult to quickly reduce pollution

Traditional microbial degradation of organic pollutants often takes days or even weeks, while many polluted sites need to be quickly effective. This limits the application of microbiological techniques in emergency management. In view of this, the degradation rate can be improved by screening highly active bacterial strains, adding inducers, and regulating the amount of dissolved oxygen. When the conditions of the contaminated site are more complicated, the combination of physical and chemical technical means to optimise the degradation process can be properly considered.

5.3. Different microorganisms have synergistic or antagonistic effects, and the combination optimisation is difficult.

The degradation ability of a single microorganism is limited, while a variety of microorganisms will affect each other when they coexist. For example, some microorganisms will secrete inhibitory substances, resulting in the development of other functional bacteria is limited. Different microorganisms can also show synergistic effects, thus achieving the common degradation of some stubborn pollutants. Therefore, how to optimise the composition of the bacterial community and construct an efficient and synergistic microbial degradation system is the main hotspot of current research.

6. Outlook

Microbiological treatment technology has a broad application prospect in the field of environmental engineering [21]. The future research direction can be carried out in the following aspects.

6.1. Enhancement of microbial function and environmental adaptability by using synthetic biology and systems biology technology

The rapid development of synthetic biology and systems biology provides new ideas for microbial processing technology. Gene editing technologies such as CRISPR/Cas9 can be used to precisely locate the microbial genome, achieve targeted modification of degradation-related enzyme genes, improve the activity of microbial degradation enzymes, and broaden the types of degradation substrates. In addition, the environmental adaptability and stability of microorganisms can be enhanced through the introduction of adaptation-related genes, thereby improving their ability to survive in complex environments.

Systems biology can study the interaction law between microbial components, optimise the composition of microbial flora using multi-component analysis, play a synergistic role, and improve the degradation efficiency.

6.2. Digging for more environmentally adaptable and efficient functional microbial resources

The functional microorganisms discovered so far are only the tip of the iceberg, and a large number of excellent microbial resources have not been fully explored and utilised. In the future, we can continue to carry out the screening of various environmental samples and the application of functional genomics technology to explore some microorganisms with strong adaptability in special environments, such as extremophiles and salinophiles, etc. These microorganisms usually possess unique metabolic pathways. These microorganisms usually possess unique metabolic pathways and enzyme systems, which can provide a wider range of options for the creation of functional microorganisms. Meanwhile, attention should be paid to protecting the intellectual property rights of microbial resources.

6.3. Strengthen the cooperation between industry, academia and research, and promote the transformation of technological achievements into practical applications

There is still a certain distance between the environmental microbial treatment technology from laboratory to practical application. In the future, it is necessary to strengthen the close cooperation between the industry, academia and research institutes to build an integrated technological innovation platform and share resources and achievements. Researchers can understand the needs of the industry in a timely manner, and develop operable technical solutions; enterprises can provide on-site feedback, which contributes to the continuous optimisation of technical solutions. Talent training can also be carried out jointly to achieve knowledge transfer. This will help the results of microbial treatment technology to serve the environmental management practice faster and benefit the society.

In conclusion, microbial treatment technology has a broad outlook, but it still needs continuous efforts. It is hoped that through the unremitting exploration of scientific and technological workers, we can make more progress, and use functional microorganisms as a weapon to build a beautiful environment in which human beings and nature coexist harmoniously.

7. Conclusion

Environmental engineering plays an extremely important role in the current environmental protection work, and microbial treatment technology has become an important force in the field of environmental engineering. Microbial treatment technology uses the metabolic function of microorganisms to achieve the degradation of various types of pollutants, compared with conventional physical and chemical methods, it avoids the generation of secondary pollution, easy to operate, and low cost of treatment. Therefore, microbial treatment technology has been successfully applied in the remediation of heavy metal pollution in soil and water, biodegradation of oil pollution, purification of industrial waste gas, etc., and has made excellent contributions to environmental pollution control. Some intermediate products produced by microbial treatment can also promote plant growth and have certain fertiliser effects.

Currently, microbial treatment technology has become a hotspot for environmental protection workers, and the scope of research is also expanding, in addition to environmental pollution control, but also applied to microplastics degradation, solid waste treatment and other fields, showing strong potential for application. With the further development of microbiomics, synthetic biology and other technologies, the screening and utilisation of functional microorganisms will be more efficient, and microbial treatment technology will certainly achieve more fruitful research results.

Looking to the future, microbial treatment technology will be optimised and upgraded in the direction of more environmental protection, high efficiency, economy and stability, and effectively coupled with other technological means to provide stronger technical support for the field of environmental engineering. With the help of microbial treatment technology, human society will establish a more harmonious and sustainable mode of living with the natural environment, and achieve a virtuous cycle of economic development and ecological civilisation. Environmental engineers will continue to devote themselves to the innovative research of microbial treatment technology and guard our common home with the power of microorganisms.

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