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Development and Application of Constructed Wetland

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Abstract

Constructed wetland is a new sewage treatment technology developed in recent years. several types of constructed wetlands: surface flow constructed wetland, horizontal flow constructed wetland, vertical flow constructed wetland and tidal subsurface flow constructed wetland were mainly introduces. Its composition, purification mechanism and current research status are briefly described.

Keywords

Constructed wetland; Sewage treatment; Purification mechanism.

1. Introduction

Constructed wetland system is a kind of special ecosystem, its unique soil, vegetation and biological characteristics are different from terrestrial ecosystem and aquatic ecosystem [1]. In the Wetlands Convention, constructed wetlands are defined as natural or man-made, permanent or temporary bogs, peat or water areas, and shallow water areas not exceeding 6.0 m in depth at low tide. Constructed wetland ecological sewage treatment technology is an ecological restoration method to manage and maintain the natural wetland system under human control and to treat all kinds of pollutants. The technology has the advantages of simple process, low construction and operation cost, strong impact resistance load and good sewage treatment effect. In the following, the research and development of constructed wetland technology, its application prospect and purification mechanism are briefly introduced.

2. Basic Information of Constructed Wetlands

2.1. Classification and Characteristics of Constructed Wetlands

At present, there are different classification standards for constructed wetlands [2, 3]. According to the flow form, constructed wetland can be divided into surface flow type, subsurface flow type, vertical flow type and tidal flow type. According to different hydraulic conditions, constructed wetlands can be divided into surface wetlands and percolation wetlands [4]. According to the difference of plant growth characteristics, constructed wetland system can be divided into floating plant wetland system, emergent plant wetland system and submerged plant wetland system.

(1) Surface flow constructed wetland

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Surface flow constructed wetland is the closest to the natural wetland system in terms of its internal structure, ecological stratification and appearance, but its water inlet and outlet is designed, supervised, operated and maintained by human science, so that its decontamination capacity has been significantly improved, and it is applied to the treatment of pollution and wastewater in production and life. Surface flow wetland adopts surface water distribution, and the inlet water forms a sewage layer of about 10 cm ~ 30 cm thick on the upper surface of the wetland substrate. The sewage is evenly distributed and infiltrated on the surface of the substrate, and flows out of the system after confluence in the water catchment area to complete the sewage purification process. Surface flow constructed wetlands are mostly similar to pools, and the amount of substrate is less, so the initial investment cost of wetland operation is relatively low. However, because the sewage is directly exposed to the air, the purification effect and sanitary condition of the system for all kinds of pollutants in the sewage are easily affected by seasonal changes. In winter, the exposed water in the upper layer of the wetland bed is easy to freeze, which seriously affects the sewage treatment capacity. In addition, poor sanitary conditions in summer can easily breed mosquitoes and flies [5].

(2) Horizontal subsurface flow constructed wetland

The constructed wetlands in which sewage flows horizontally between substrates are called horizontal subsurface flow constructed wetlands. This kind of wetland system can make full use of substrate interception and precipitation, adsorption exchange and plant root absorption, and also increase the interaction time between microorganisms and pollutants in water. In practical application, compared with surface flow constructed wetland, horizontal subsurface flow constructed wetland has relatively large inflow load and pollution load, especially strong removal ability for organic pollutants, suspended matter and heavy metal pollutants [6]. As the sewage flows inside the wetland bed, the sanitary condition is good and less affected by the season. In addition, due to the movement of sewage inside the module, if the flow pattern is kept stable, it can still maintain a better performance of decontamination in the winter with lower temperature. However, compared with surface flow constructed wetland, its maintenance and management are relatively complex. In addition, the removal effect of nitrogen and phosphorus is not high, and the substrate is easily blocked, which also hinders its further promotion and application.

(3) Vertical flow constructed wetland

The constructed wetland in which the sewage mainly moves vertically in the matrix bed body is called vertical flow constructed wetland. First, water is distributed uniformly over the surface of the matrix and then flows vertically inside the matrix to the bottom catchment to exit the system. Because water flow is saturated or half full inside the matrix, in addition to atmospheric oxygen enrichment, oxygen in the air can also be transferred through the pores between the matrix, which is conducive to the removal of NH3-N in sewage. However, the practice shows that the vertical flow constructed wetland is not good at treating organic matter and SS, and the dynamic control system is relatively complex.

(4) Tidal subsurface flow constructed wetlands

The basic principle of tidal subsurface flow constructed wetland is alternately filled and emptying with sewage in the matrix bed, accompanied by the filling and emptying of air [7]. The latest research found that when sewage is discharged from the system, organic pollutants are left in the matrix. At this time, oxygen consumption is the highest, so the fresh air brought in during the drainage process of the system can be used as a supplementary oxygen source to remove organic pollutants. Under the alternating action of water and air, the degradation effect of organic matter in wetland is obviously enhanced. However, due to the vigorous growth of microorganisms in the substrate, the clogging of the substrate has become a limiting factor for its popularization and application.

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2.2. Composition of Constructed Wetland System

Constructed wetland system is mainly composed of substrate, wetland plants and microorganisms.

(1) substrate

Matrix is the carrier for the growth and attachment of wetland plants and microorganisms in the constructed wetland system. At the same time, due to its own physical and chemical properties, it also plays a certain role in the removal of pollutants in wastewater by chemical adsorption and interception and precipitation. During the design process, the final substrate configuration of the constructed wetland system is directly related to the purification capacity of the wetland system, especially in winter when the wetland plants wilt. The removal of various pollutants in wastewater mainly depends on the growth and metabolism of microorganisms on the substrate surface and the physicochemical adsorption properties of wetland substrate. In addition, the cost of the substrate directly affects the initial investment of constructed wetland construction, and its maximum adsorption saturation capacity affects the replacement cycle of the substrate and the effective service life of the wetland system. Gravel, sand and gravel, or direct use of soil, etc. are usually selected as substrates of traditional constructed wetlands. Nowadays, with the further exploration of the deconstructing mechanism of constructed wetland, the selection of substrates tends to be diversified, mainly based on the principles of high porosity, large specific surface area, good flow conditions and uniform grading.

(2) Wetland plants

During the construction process of constructed wetland, it is necessary to fully understand the climate conditions of the project site, and rationally select wetland plants with strong root growth, strong tolerance, good landscape effect and adaptability to the environment and climate of the project site as the main screening objects. The removal of pollutants in water by wetland plants is mainly reflected in the direct absorption of pollutants by plants and the promotion of microbial purification by supplying oxygen to microorganisms in roots through photosynthesis.

(3) Microbial

Microorganisms play an important role in the degradation of various pollutants in constructed wetland system. Aerobic degradation, nitrification, denitrification and phosphorus polymerization transformation are all completed with the participation of microorganisms. Different types of microorganisms have different ability to remove different pollutants in sewage, and their distribution is mainly related to sewage flow mode and plant root depth. The species and quantity of microorganisms are two key factors affecting the purification efficiency of wetland system.

3. Research Status of Constructed Wetland Technology

In recent years, constructed wetland wastewater treatment technology has been promoted and applied rapidly in Europe and the United States. There are nearly 20,000 constructed wetland sewage treatment systems in use in North America and more than 10,000 in Europe, and there are more and more pilot constructions of constructed wetland in Australia, Latin America, Asia and other countries. China only started to study the technology of constructed wetland wastewater treatment during the Seventh Five-Year Plan period, and has made significant progress in the research, development and application of wetland substrate, wetland plants and wetland microorganisms.

(1) Wetland substrate. The researches on constructed wetland substrates mainly focus on the development and application of new substrates, the combined removal effect of conventional

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wetland substrates, and the determination of the laying methods of substrates with different properties. The development of new substrates mainly uses unconventional materials to process new wetland substrates and the secondary development of traditional constructed wetland substrates.

(2) Constructed wetland plants. At present, the research on constructed wetland plants at home and abroad mostly focuses on the selection and cultivation of plants. A large number of studies have shown that the principle of plant selection is to use aquatic plants adapted to the environment of the project site as the screening pool, and the purification effect of wetland plants on pollutants in sewage is closely related to the change of season and influent water quality. Therefore, screening wetland plants with strong pollution tolerance, developed root system and long growth cycle is also an important part of wetland plant research.

(3) Wetland microorganisms. Microorganisms in constructed wetland mainly grow on the substrate surface, and some of them grow in suspension mode, which is the core part of the whole system and an important condition to realize the wetland system's long-term and efficient treatment of pollutants in water. The study shows that the removal of pollutants and total nitrogen in wastewater is mainly dependent on the degradation of microorganisms, and the degradation performance of microorganisms and their number also show a very obvious correlation.

4. Problems and Development Prospects of Constructed Wetland Research

(1) Existing studies mainly use new materials instead of traditional substrates to achieve efficient removal of nitrogen and phosphorus, but these materials are not yet commercialized, and are often difficult to obtain in practical application. The survey results show that more than 90% of constructed wetlands still use locally accessible materials such as gravel, gravel and brick as the wetland substrate, which makes the theoretical research seriously separated from the practical application of constructed wetland technology.

(2) The removal effect of nitrogen and phosphorus was improved by matrix performance optimization alone, and the nitrogen and phosphorus were transferred from aqueous phase to the matrix material through adsorption or ion exchange. However, the adsorption capacity of these materials for nitrogen and phosphorus is often limited, and the adsorption or exchange saturation will appear after 3~5 years of use.

(3) Constructed wetland technology has the characteristics of easy maintenance and management. However, maintaining a well-functioning operating condition requires the necessary maintenance and overhaul. However, once the existing constructed wetlands are built, there is not much to maintain and manage except to control the water intake conditions of the system, which is the main reason for the failure of the operation of most constructed wetlands.

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