Research Progress of Detection Methods for Microplastics

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Abstract Microplastics are plastic particles or fibers with a diameter of less than 5 mm, and they widely exist in the environment and pose potential risks to the ecosystem and human health. Microplastics detection can provide basic data for formulating effective environmental protection strategies. In this paper, the physical, chemical and biological detection methods of microplastics are reviewed, and the advantages and disadvantages of different methods are analyzed. The problems and challenges encountered in microplastics detection are analyzed, and the future research is discussed.

Key words Microplastics, Detection method, Research progress

1 Introduction

Microplastics refer to plastic particles or fibers with a diameter of less than 5 mm. Their tiny size makes them widely exist in the environment and pose potential risks to ecosystems and human health. These microplastics come from a wide range of sources, including the decomposition of large plastic fragments, the release of fibers when washing clothes, the generation of tire powder in road traffic and microplastic particles in industrial wastewater. Because microplastics particles are small and difficult to decompose, they have been widely distributed in water, soil and atmosphere all over the world[1].

The existence of microplastics has caused concern about the environment and ecosystem. In water, microplastics may cause harm to aquatic organisms because they can be eaten and transmitted through the food chain. In soil, microplastics may have negative effects on plant growth and soil quality. In addition, the existence of microplastics may also lead to the adhesion of chemicals in the environment, which increases the risk of spreading toxic substances. The potential impact on human beings is still under study, but previous studies have shown that microplastics may enter human food through the food chain, causing a series of health problems[2]. Therefore, it is very important to have a deep understanding of the source, distribution and potential impact of microplastics in order to formulate effective monitoring and management strategies and protect the environment and human health[3].

2 Importance of microplastics detection

Microplastics widely exist in water, soil and atmosphere, posing a potential threat to the environment. By detecting the existence and distribution of microplastics, scientists can assess their actual impact on the ecosystem, understand the interaction between microplastics and the ecological environment, and formulate targeted protection strategies[4]. Microplastics have potential effects on aquatic and terrestrial organisms because they can be eaten and transmitted through the food chain. By detecting the accumulation of microplastics in different ecosystems, researchers can assess the threat degree of microplastics to biodiversity and provide scientific basis for taking corresponding protection measures[5]. The existence of microplastics may enter human food through the food chain, posing potential risks to human health. By detecting the existence of microplastics in food and drinking water, scientists can evaluate the degree of human exposure to microplastics, and then study its potential impact on human health, providing basic data for public health[6]. By detecting the type, concentration and distribution of microplastics, scientists can trace their sources, which is helpful to formulating targeted measures to reduce the emission and pollution of microplastics and protect the environment and ecosystem[7].

Therefore, microplastics detection is not only of great significance to scientific research, but also provides basic data for formulating effective environmental protection strategies, which is helpful to maintaining ecological balance and human health.

3 Classification of microplastics detection methods

Microplastics detection methods can be divided into physical, chemical and biological methods.

3.1 Physical methods Physical methods are mainly used to observe the shape, size, color and other characteristics of microplastics, and microscope, spectrometer and other kinds of equipment are used to detect. This includes microscopic examination, infrared spectrum analysis, Raman spectrum and so on. It is direct, rapid and can obtain the morphological information of microplastics. However, it can not provide the chemical composition of microplastics, and has certain limitations for microplastics with similar colors or transparency[8].

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3.1.1 Screening, filtration and centrifugation. Screening is suitable for the separation of large particles; filtration can separate medium-sized microplastics; centrifugation method separates particles under high-speed centrifugation. These methods are fast and suitable for large sample processing, but the separation effect for small particles may be poor, and external pollution may be caused[9-10].

3.1.2 Optical microscope and Raman spectroscopy. Optical microscope can be used to visually observe the shape and size of microplastics, but can not provide chemical information. Raman spectroscopy can be used to identify different types of microplastics by measuring scattering spectra caused by molecular vibration, and does not need special sample treatment, so it is suitable for rapid identification of microplastics[11].

3.1.3 X-ray diffraction and scanning electron microscope. X-ray diffraction can be used to analyze the crystal structure of microplastics particles and provide information about their structure and composition. Scanning electron microscope (SEM) scans samples by electron beam, which provides high-resolution surface topography and structure information, but it requires complicated operation and professional knowledge[12-13].

3.2 Chemical methods Chemical methods are to extract microplastics and analyze them by chemical treatment of samples. Typical methods include sample dissolution, liquid chromatography, gas chromatography, mass spectrometry and so on. The advantage of chemical method is that it provides chemical information of microplastics and has good recognition ability for different types of microplastics. The disadvantage is that complex laboratory equipment and treatment steps may be required, and in some cases, it may lead to microplastics pollution[14].

3.2.1 Mass spectrometry. Mass spectrometry is a highly sensitive chemical analysis technique, and it can be used for qualitative and quantitative analysis of microplastics. The mass spectrometry mainly includes tandem-mass spectrometry (MS/MS) and gas/liquid chromatography-mass spectrometry (GC-MS, LC-MS).

MS/MS can determine the chemical structure and composition of microplastics by analyzing the mass spectrum fragments of microplastics molecules. This method requires high sensitivity and high resolution of microplastics, and has the advantage of providing accurate chemical information[15].

Gas/liquid chromatography-mass spectrometry combines gas or liquid chromatography (LC) with mass spectrometry, and can further carry out chemical analysis on the basis of separation. This method is suitable for various types of microplastics and can realize the analysis of complex mixtures[16].

3.2.2 Chromatography. Chromatography is a commonly used microplastics analysis method by separating the components in the mixture and then detecting them. Chromatography mainly includes gas chromatography (GC) and liquid chromatography (LC).

Gas chromatography is mainly suitable for the analysis of volatile organic compounds, and has a good separation effect for some volatile plastic components. However, GC method has some limitations in the analysis of microplastic particles[17].

Liquid chromatography can be used for the analysis of microplastics in water samples, and its separation effect is good. Combined with different detectors, such as UV-Vis or fluorescence detector, different types of microplastics can be detected[18].

3.2.3 Spectrometry. Spectroscopy uses the absorption, scattering or emission characteristics of light to analyze microplastics, mainly including infrared spectrum and ultraviolet-visible spectrum.

Infrared spectroscopy can determine the molecular structure and composition of microplastics by measuring the characteristic peaks of infrared light absorbed by microplastics. This method has good identification ability for different types of microplastics[19].

Ultraviolet-visible spectrum can be used for qualitative and quantitative analysis by measuring the absorption of ultraviolet or visible light by microplastics. This method is suitable for the detection of dyed or colored microplastics[20].

3.3 Biological methods Biological methods mainly use specific biological reactions to detect the existence of microplastics, such as biosensors, and bioluminescence labels. Biological methods are highly selective and sensitive, and some methods are more sensitive to the detection of microplastics. However, it may be affected by environmental factors and sample complexity, requiring specific organisms or bioreactors, and the results may be affected by biological activity[21].

3.3.1 Microplastics detection using biosensors. Biosensor is a highly selective and sensitive technology that uses biological elements (cells, enzymes, antibodies, *etc.*) to detect specific substances. Biosensors provide a fast, specific and real-time analysis method for microplastics detection.

Cell-based biosensors utilize the biological responses of cells to microplastics, such as cell respiration, growth or fluorescence changes. These cells can be designed to interact with microplastics specifically, so as to realize the detection of microplastics[22].

Enzyme-based biosensors utilize the specific reaction of enzymes to microplastics, and detect the existence of microplastics by measuring the changes of reaction products. This method has high sensitivity and selectivity, and is suitable for different types of microplastics[23].

Antibody-based biosensors use specific antibodies to identify microplastics, and detect them through the signal changes produced by the combination of antibodies and microplastics. This method can be used for highly specific identification of microplastics[24].

3.3.2 Microbiological detection methods. Microbiological detection method can detect and monitor microplastics by analyzing the behavior of microorganisms in the environment where microplastics exist. Some microorganisms show special growth reactions to the existence of microplastics. By monitoring the growth of microorganisms, the existence and concentration of microplastics can be indirectly judged[25]. Microorganisms may produce specific metabolites when decomposing microplastics. By analyzing these products, we can infer the decomposition degree and type of microplastics[26].

4 Challenges and prospects

4.1 Challenges and problems At present, there is a lack of uniform standards and calibration methods in the field of microplastics detection, which makes it difficult to compare the results among different laboratories. Establishing a standardized detection method is an urgent problem to be solved[27].

Samples in natural environment usually contain various organic and inorganic substances, which may interfere with the accurate detection of microplastics. It is a challenge to develop processing and analysis methods for complex samples[28]. There are many kinds of microplastics and they are widely distributed. Different detection methods may show different sensitivity to different types and sizes of microplastics. Therefore, it is a difficult problem to comprehensively consider the detection of various microplastics[29]. The distribution and migration of microplastics in the environment are complex, involving many media such as water, soil and atmosphere. Understanding the behavior of microplastics in different environments is of great significance to its detection[30].

4.2 Prospects and directions Future microplastics detection may adopt multi-level comprehensive methods, including mutual verification among physics, chemistry and biology, in order to improve the accuracy and comprehensiveness of detection[31]. The development of automated and high-throughput detection technology can quickly process a large number of samples and improve detection efficiency. This will help to monitor the distribution of microplastics in different environments more widely[32]. It is necessary to strengthen international cooperation, formulate unified testing standards for microplastics, establish shared databases, and promote the comparison and exchange of research results. This is very important to solving the current standardization problem[33]. Developing new microplastics marking and tracking technology can help us to track the source and destination of microplastics. This will provide important support for formulating more accurate prevention and control strategies[34].

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relatively high, and therefore, speeding up the establishment of a social security system in full coverage of rural economy involving medical care, unemployment and pension is very necessary. By doing so, a vast majority of farmers can be treated in illness and taken care of in old age.

Thirdly, it is necessary to safeguard farmers; further transfer to the secondary and tertiary industries, stable contracting rights, invigorate operation right, and protect the right of return. In this way, we can remove worries of farmers about losing land because of leaving, to avoid or reduce farmers' disputes arising from land interests, so that farmers can enjoy their job and gain earnings regardless of land transfer or contracting. Only after such protection mechanism is established, farmers can reduce their concerns and tend to mortgage their land in need of money.

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