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Progress on the Main Sources of Microplastics in the Environment and their Detection Methods

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Abstract: With the rapid development of modern economy, microplastics have become one of the important new pollutants. Microplastics are a new pollutant with a particle size of no more than 5 mm that can accumulate in the environment and organisms. In order to better evaluate microplastics pollution in the environment, the presence of microplastics in aquatic environment, air and food was reviewed in detail, and the main detection methods (microscopic analysis, scanning electron microscopy and spectral analysis, infrared and Raman spectroscopy, thermal analysis and mass spectrometry), advantages and disadvantages of microplastics were described. In summary, the detection of microplastics in aquatic environment is mainly by Raman spectroscopy, the detection of microplastics in air is mainly by eye inspection, and the detection of microplastics in food is mainly by scanning electron microscopy. Finally, this paper also looks forward to the challenges faced by microplastics detection and future research directions, to provide reference for scientific and reasonable research on microplastics in the future.

Keywords: Microplastics; Source; Detection Method; Advantages and Disadvantages

1. Introduction

With the development of the global economy, the level of science and technology continues to improve, and the degree of environmental pollution also deepens. In recent years, more and more scholars have noticed that the harm brought by microplastics is particularly significant [1]. Microplastics refers to plastic particles and fragments with particle size of not more than 5 mm, including particles, microfibers, particles, foam or film, etc [2]. Its main components are polyethylene, polypropylene, polystyrene and other polymers. Microplastics already range very widely, such as oceans, rivers, lakes, silt, and have even been detected in Arctic ice cores, human food, and drinking water. Due to its small particle size, good stability, strong adsorption and difficult biodegradation, it poses significant threats to both the ecological environment and human health. For example, microplastics are easy to accumulate in the tissues and body parts of the human body through feeding and other ways, thus causing clinical complications such as the immune system [3].

Microplastics were discovered for the first time in the 1970s. In 2004, the British scholar Thompson formally put forward the concept of “microplastics” [4]. After many countries in the world have carried out the related research of microplastics, and China in 2022 officially released the new pollutant management action plan, the scheme requirements in microplastic pollution control work, to provide reliable analysis technology to detect, identify and quantify the microplastic environment, so the existing microplastics detection method review is very important [5].

Due to the limitations of sampling, pre-treatment and analysis techniques, the size of microplastics detected in existing studies is generally large. The quantitative analysis technique is not mature enough, and the comparability of literature data is poor. Complex components and surface attachments make the analysis and detection of microplastics more challenging. For example, in the current microplastics detection method system, microscope analysis method has become an important method because of its simple, rapid and low-cost characteristics, combined with infrared spectroscopy and Raman spectroscopy means, microplastics samples can be nondestructive analysis. However, with the deepening of research, this method can not be used to study nanoscale microplastics, which requires relevant researchers to carry out in-depth research from the aspects of instruments and methods to solve the above problems. Therefore, this paper systematically reviewed the main sources and detection methods of microplastics, compared the advantages and disadvantages of each method, and prospected the challenges faced by microplastics detection and future research directions.

2. The Main Source of the Microplastics

2.1 Microplastics in the Aquatic Environment

The total area of the ocean on the earth is about 71% of the earth's surface area, and a large number of microplastics directly enter the aquatic environment through rivers, sedimentation, runoff, leaching and other channels. Studies have shown that about 51 trillion plastic microparticles exist in the ocean, which is bound to seriously harm the growth and population development of Marine life [6]. At the same time, with the development of human fishing activities, these organisms rich in microplastics will eventually enter the human body, posing a great threat to human health, such as causing mechanical injuries such as internal scratches in the body, hindering diet, slow growth and even death. At the same time, because of their large specific surface area, microplastics can adsorb many toxins in the ocean, these toxins will have toxic effects on the biological body, thus affecting the growth and development of organisms or reproductive system, more serious may cause endocrine disorders and even cancer [7].

2.2 Microplastics in the Air

A growing number of studies have shown that microplastics also exist in the air due to the factory production of plastic products, atmospheric deposition, human activities and other reasons. For example, tire and road wear in moving vehicles can cause microplastics to discharge into the air, in a dry environment, small fibers can easily fall off from clothes and other fiber products, resulting in microplastic pollution in the air; and many large landfills have many plastic products, which can also degrade into microplastics after ultraviolet radiation and physical wear [8,9]. Microplastics in the air are very light in weight and are easily transmitted through the wind. These microplastics are very easily absorbed by humans or other animals into the body, thus causing respiratory diseases.

2.3 Microplastics in the Food

At present, the research on the impact of the content of microplastics in seafood, salt and packaging materials on the human body is not very deep [10]. We do not know how the content and distribution of these microplastics in the population, and the harm caused by their influence is not clear. At the same time, the soil also contains a lot of microplastics, and the amount of microplastics absorbed in the crops is unknown, and the inner microplastics eventually processed into food and into the human body are less clear. At the same time, many of the packaging in modern society are plastic products, in the production process due to friction, tear and other mechanical effects and ultraviolet irradiation produced microplastics into the food [11,12]. Studies have found that micrometer and nanometer-sized plastic particles were extracted from tea bags.

3. Detection Method for Microplastics

3.1 Microscopy Analysis

Microscopy, analysis is the most simple and traditional method, is the sample to be measured under the microscope, statistics the information in the sample [13]. This method has the advantages of low cost, simple operation and no danger, and is one of the commonly used methods. However, this method may misjudge the sample information, such as other substances may be wrongly identified as microplastics, some substances are difficult to identify as microplastics, and it is difficult to judge the tiny microplastics through microscopic observation.

3.2 SEM and Spectral Analysis

Scanning electron microscopy can greatly improve the resolution, which helps us distinguish microplastics from other fine particle samples [14]. At the same time, X-ray spectral analysis can conduct further elemental composition analysis of uncertain substances, which helps us to accurately distinguish microplastics from other substances. Although this method greatly improves the accuracy, it also has some disadvantages. For example, because the electronic image is gray scale image, it cannot accurately express the original color of the sample and show the color of the sample; it is difficult to distinguish the microplastic with seriously changed shape; the complicated operation and long time; and may cause irreversible damage to the sample.

3.3 Infrared and Raman Spectroscopic Analysis

Infrared spectrum is the use of infrared light through the sample, the group of the sample molecules absorb infrared light to produce vibration, and then get the infrared absorption spectrum. Raman spectrum is the emission spectrum to the sample, the molecular polarizability changes, thus producing Raman scattering [15]. Spectroscopy is performed by comparing the obtained sample spectra with the known spectra, thereby identifying the sample composition. The advantage is that it can quickly detect microplastics less than 100 μ m. Often used in conjunction with microscopy, rapid, qualitative and quantitative goals. However, this method is prone to interference from the samples, making the results inaccurate, such as the failure to detect the samples containing fluorescent substances. At the same time, this method also requires higher particle size of the sample, and usually detects microplastic samples with lower particle size.

3.4 Thermal Analysis and Mass Spectrometry Analysis

Thermal analysis is a method to identifying the degradation product of the polymer. The sample is first thermal degraded, and the product is detected and analyzed by a mass spectrometer [16]. This method is mainly used for polymers containing crystalline components. This method is simple to operate and fast, but it requires the pretreatment of the samples. However, the thermal weight analysis method does not pretreatment the sample, which refers to the method of thermal analysis of the sample under certain conditions. This technique is mainly used for the analysis of solid-state complex samples. Thermal weight-mass spectrometry is also a method for quantitative analysis of microplastics without sample pretreatment. This method is mainly used for samples with high quality, which can provide good qualitative score, but the analysis ability of the results is relatively high, which requires certain experience and ability. Thermal rolGC MS is a means of analyzing polymer thermal lytic gas, which is mainly used to identify and quantify the polymer types of microplastic particles and related organic plastic additives. But this method is also highly destructive, without obtaining information on the number, size, and shape of microplastic particles.

3.5 Method Selection for Different Scenarios

When the physical form analysis of the sample is high, it can be selected, which has the characteristics of high spatial resolution. When the number of samples is large and the size is large, the Fourier transform infrared spectroscopy can be selected, which has the advantages of sample visualization, automatically collecting data and generating images, not destroying the sample, and saving time and effort. When the sample size is small and does not contain fluorescence, the Raman spectroscopy method can be selected, which can meet the requirements of complex sample detection without destroying the sample. When a small batch of samples needs fine analysis, the thermal deattached gas chromatography-mass spectrum can be selected, which has the advantages of quantitative analysis of various components and simple operation. Microplastic detection method is many, but a single method tend to appear wrong judgment, makes the detection accuracy is greatly reduced, this paper introduces the main microplastic detection method, at the same time gives some scenario can choose method, in the process of identification and application of different methods of analyzing samples, so as to get more accurate results.

4. Development Prospect of Microplastics Detection

Because the traditional FTIR and Raman analysis are limited by light diffraction, the spatial resolution of microplastics detection is difficult to reach the nanometer level. The future needs to rely on the development of emerging technologies to continuously improve the detection accuracy, such as

AFM-IR, nano FTIR, SERS, TERS, SHRS, O-PTIR and other new technologies [17-19]. The development of these technologies has made the detection accuracy of microplastics reach the nanometer level, which is of great significance for the understanding of the formation of microplastics.

The various processes of microplastics analysis (Figure 1) are time-consuming, which makes it difficult to conduct microplastics detection on a large scale. In the future, it is necessary to improve the methods of detection and continuous rapid analysis of large quantities of samples, such as hyperspectral imaging technology combined with image processing and stoichiometric methods; Combining near-infrared spectroscopy with stoichiometry, these techniques allow for rapid and efficient microplastics detection in an efficient manner with minimal manual intervention. [20,21]

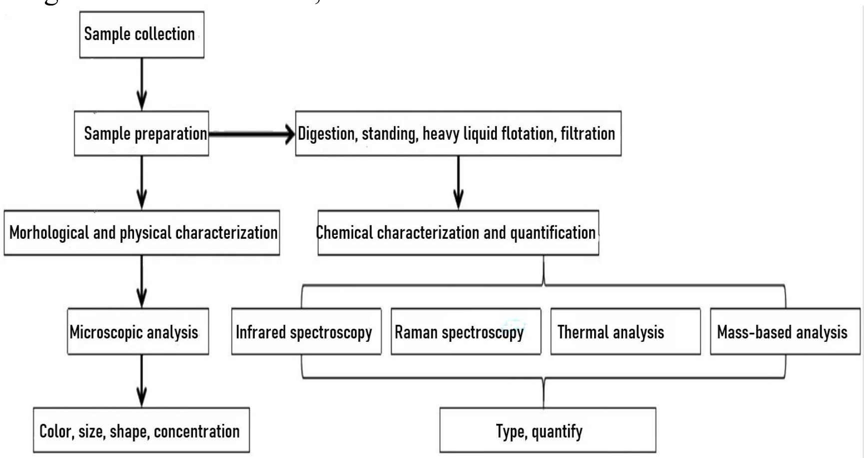

Figure 1. Analytical Process for Microplastics

With the development of detection methods, the detection results are more accurate, the current sources of microplastics also include nano-microplastics, human tissue microplastics, etc., the detection methods for different objects are not the same, the future should continue to improve the microplastics detection method system, develop personalized detection methods for different objects, which is one of the main prospects for the development of microplastics [22-23].

5. Conclusions

In general, the detection of aquatic environment microplastics mainly uses Raman spectroscopy, which has a wide range of applications, stronger sensing ability, lower response signal to non-polar functional groups, and not easy to be disturbed by water, which is more suitable for the detection of microplastics in water. However, Raman spectrum is susceptible to the interference of fluorescent substances, such as pigments. Usually, Raman spectrum and Fourier transform infrared spectrum are measured at the same time. The obtained information can be complementary to make the final result more accurate. The detection of microplastics in the air is mainly conducted by visual inspection method, and its operation is simple and economical. However, when it is easy to identify the microplastics with small particle size, it is easy to mistake and misjudgment, which requires certain experience and ability, or to cooperate with other methods. The detection of microplastics in food is mainly by scanning electron microscope method, which can clearly observe the shape of the sample, but can not determine the composition of microplastics, so it can be used with gas chromatography-mass spectrometry. At the same time, it should be done from the scientific problem to be solved, according to the purpose of research, reasonable selection of analysis technology, special attention to the actual determination results of some analysis techniques in different microplastics samples need to be further explored and verified.

In the future, the collection method of microplastics should be standardized. The collection of microplastics have different sources and different methods. For example, the method of collecting microplastics in landfills cannot be applied to the scene of collecting soil microplastics. Different acquisition methods should be formulated according to different scenarios. Only by establishing a scientific collection method, the comparison of different experimental results in the later stage is more reasonable and reference. At the same time, microplastics are easy to adsorb various microorganisms, organic pollutants and heavy metal elements, so special attention should be paid to the relationship between microplastics and these adsorbed substances, which will help us to analyze the morphological changes and toxic effects of microplastics. In addition, the current microplastic detection of human tissue mainly uses conventional methods, which can not accurately understand the ways and ways of microplastic invading human body. In the future, the microplastic detection methods of human tissue microplastics should be further improved.

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