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Soil Pollution Detection and Monitoring Technology

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ABSTRACT

The economic losses and health hazards caused by soil pollution cannot be overlooked. Unlike air and water pollution, soil pollution is often neglected due to its hidden nature, and people tend to overlook the presence of pollution because they cannot see contaminants with the naked eye. Therefore, to achieve prevention and control of soil pollution, it is necessary to actively utilize soil pollution detection methods and monitoring technologies to enhance the intensity of soil protection, thereby ensuring the safety of the soil environment and human health. The article explores specific detection and monitoring technologies.

KEYWORDS

Soil Pollution; Detect; Monitoring.

1. THE NECESSITY OF SOIL TESTING

Soil plays a crucial role in sustaining human life, as it not only serves as a habitat for plants and animals but also helps in flood storage, and acts as a tourist resource, among other functions. China has a vast territory with a large absolute amount of soil resources, but there are significant regional differences in these resources. As a virtually non-renewable natural resource, soil is facing multiple issues worldwide, such as soil erosion, acidification, salinization, and pollution. These problems pose a severe threat to food production and security, exacerbate the destruction of nature, and can destroy human habitats. In agricultural production, it is essential to inspect and rehabilitate the soil. Doing so can assist people in scientifically managing crops based on actual conditions, conserving agricultural inputs, and enhancing crop yields and quality. Additionally, it aids relevant technical personnel and researchers in understanding soil conditions, allowing for timely measures to be taken if problems arise. A thorough understanding and knowledge of soil are the foundation and key to effectively managing soil resources and guiding agricultural production. Utilizing various soil testing instruments can help assess and analyze soil properties such as bulk density, moisture, nutrients, salinity, pH, and aggregate structure, enabling people to comprehend and grasp its related characteristics.

The prerequisite for the implementation of precision agriculture is a thorough understanding of soil characteristics, especially the nutrient status of the soil, in order to achieve the saying "know yourself and know your enemy," "prescribe the right remedy," and engage in scientific production. The use of soil testing instruments allows people to more quickly and easily obtain relevant data, providing farmers with soil testing formulas and fertilization recommendations in a timely manner. This helps to reduce their blind inputs, achieve cost savings, protect the environment, and promote sustainable agricultural development that is green and efficient [1].

2. METHODS FOR DETECTING SOIL CONTAMINATION

2.1. Chromatography Method

Chromatography's main advantage lies in its ability to perform efficient compound separation and quantitative analysis. In chromatographic methods, samples are separated as they pass through a chromatographic column, with the packing material of the column and parameters such as column length and diameter being significant factors affecting the separation efficiency. Additionally, the choice of detector is crucial, with common detectors including fluorescence detectors, ultraviolet detectors, and mass spectrometry detectors, among others. Gas chromatography (GC) is typically used for the analysis of volatile organic compounds, such as benzene, toluene, xylene, etc. It works on the principle of exploiting the characteristic of compounds being separated and decomposed at high temperatures to separate volatile organic compounds, which are then detected and quantified by a detector. High-performance liquid chromatography (HPLC) is mainly used for the analysis of polar organic compounds, such as pesticides, glyphosate, etc. It operates on the principle of utilizing the different solubilities and affinities of compounds in various solvents, allowing separation through a liquid chromatography column followed by detection and quantification with a detector. In soil quality monitoring, chromatographic methods are one of the commonly used analytical techniques, known for their accurate and reliable results, as well as their high sensitivity and resolution.

2.2. Mass Spectrometry Method

Mass spectrometry is an analytical method based on the principle of mass analysis. Its fundamental principle involves converting the analyte into ions and then using the mass-to-charge ratio (m/z) of the ions for mass analysis and identification. In mass spectrometry, mass spectrometers and tandem mass spectrometers are commonly used for analysis. A mass spectrometer ionizes the compounds in the sample and detects them based on their m/z values. Tandem mass spectrometers can further analyze and identify the separated ions. Time-of-flight mass spectrometry, on the other hand, utilizes the differences in flight times of ions in an electric field to achieve mass analysis. Mass spectrometry has a wide range of applications in soil quality monitoring. For instance, it can be used to detect organic matter, heavy metals, pesticides, and other contaminants in soil. Due to its high sensitivity and resolution, mass spectrometry can quantify and identify complex chemical substances in soil [2].

2.3. Spectroscopy Method

Spectroscopy can be applied to various chemical and environmental fields, including the monitoring of soil environmental quality. A variety of organic and inorganic compounds exist in soil, and their presence and concentration can be quickly and accurately detected through spectroscopic methods. Additionally, spectroscopy has the advantages of simple operation, no need for sample pretreatment, and convenient data processing. Spectroscopy can measure the elemental content in soil, the structure and types of compounds, as well as the distribution and sources of pollutants. Ultraviolet-visible absorption spectroscopy is mainly used for detecting inorganic substances in soil, such as the content of heavy metal ions, while fluorescence spectroscopy is suitable for detecting organic substances in soil, such as the content of polycyclic aromatic hydrocarbons. In practical applications, spectroscopy often requires the use of standards for calibration and quantitative analysis. However, obtaining appropriate standards can be challenging, especially for specific compounds or emerging pollutants, which may not be readily available. Moreover, the preparation and stability of standards are also crucial for the accuracy and reproducibility of spectroscopic methods. Spectroscopy is suitable for the detection of a wide range of substances, particularly organic and inorganic compounds.

3. THE DEVELOPMENT TREND OF SOIL ENVIRONMENTAL MONITORING TECHNOLOGY

3.1. Apply Wireless Sensor Networks

The application of wireless sensor networks has brought revolutionary innovation to the field of soil environment monitoring. Traditional soil monitoring methods usually only collect a limited number of parameters, such as soil temperature or moisture. In contrast, wireless sensor networks can simultaneously monitor multiple parameters, such as soil temperature, humidity, pH value, electrical conductivity, etc. By deploying multiple sensor nodes in the soil, diversified and comprehensive monitoring of the soil environment can be achieved. This multi-parameter monitoring capability helps to more accurately understand the condition of the soil and promptly identify potential issues. Additionally, wireless sensor networks have achieved the ability to collect real-time data. Sensor nodes can continuously monitor soil environmental parameters and transmit real-time data to the data center or monitoring platform via wireless communication. This allows monitoring personnel to obtain soil environmental data in real-time, and to timely monitor the changes and trends in the soil. At the same time, the self-organization and self-adaptation capabilities of sensor nodes enable real-time network monitoring and management, enhancing the reliability and stability of the monitoring system [3].

3.2. Convergence of Remote Sensing Technology

Remote sensing technology is primarily applied in soil environment monitoring by acquiring remote sensing data of the soil surface through satellites or aerial platforms, and utilizing this data to extract soil characteristics. High-resolution remote sensing images can provide detailed soil information, such as soil texture, organic matter content, moisture, and other key parameters. By applying image processing and soil feature extraction algorithms to remote sensing images, it is possible to obtain the spatial distribution and trends of soil environments over large areas. This non-contact remote sensing monitoring method greatly improves the efficiency and coverage of soil monitoring, enabling rapid acquisition of soil environment information for assessment and management of soil resources.

3.3. Development of Artificial Intelligence Technology

The application of artificial intelligence in soil pollution monitoring and management is continuously deepening. The use of artificial intelligence in this field aligns with the national environmental protection needs and represents a new direction for governance under new circumstances.

The role of intelligent equipment in soil pollution monitoring and management is becoming increasingly prominent. Hefei Smart Agriculture Valley Co., Ltd. of the Chinese Academy of Sciences has successfully designed a high-throughput intelligent soil composition testing robot. This robot can replace a significant portion of manual labor that is conducted in harsh environments and is time-consuming and labor-intensive, thereby increasing efficiency and accuracy. Soil monitoring sensors can also be integrated into agricultural irrigation, transportation, and other systems to achieve multi-purpose use of a single machine. By combining the Internet of Things with intelligent equipment, more devices can be interconnected and even make autonomous decisions based on the data transmitted between them. Therefore, artificial intelligence equipment will continue to enhance the level and effectiveness of governance.

Artificial intelligence in soil pollution monitoring and management is increasingly trending towards integration. Traditional sensors usually only monitor data in one aspect, but as research progresses, more integrated systems have been developed. These systems utilize sensor information from multiple dimensions, enabling artificial intelligence to be more precise and efficient. For example, the sensor team at China Agricultural University has developed the country's 3rd generation "end-to-cloud integrated multi-depth soil moisture monitoring system," which can simultaneously measure parameters such as moisture and temperature at four soil profiles at the same point, as well as air temperature, humidity, and atmospheric pressure. Fei Yanxiao and others have proposed the integration of 5G+AI technology into smart environmental protection to comprehensively enhance the level of intelligent environmental monitoring and management [4].

4. CONCLUSION

As people's awareness of environmental protection continues to increase, so does their concern about land pollution. Environmental protection agencies also need to actively play their role, strictly follow the requirements of China's environmental protection laws, and use advanced technology to detect and monitor land pollution. While grasping the current state of the soil environment, they should work on improving soil pollution issues and achieve a harmonious coexistence between humans and nature.

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