

Research on the Application of Ecological Environment Monitoring Network Construction in Environmental Monitoring

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Abstract: To enhance the efficiency of environmental monitoring, this paper researches the application of ecological environment monitoring network construction in environmental monitoring. It clarifies the core components, construction objectives, and principles of the monitoring network, comparing its differences with traditional monitoring methods. The application scenarios of the network in the fields of atmosphere, water, soil, solid waste, and ecosystems are analyzed. The technological support system comprising the perception layer and transmission layer is discussed, and directions for network layout optimization, technological upgrades, and data sharing are proposed. This research provides a reference for the efficient application of monitoring networks, helps overcome the limitations of traditional monitoring, and supports environmental management and ecological protection.

Keywords: Ecological Environment Monitoring Network; Environmental Monitoring; Technological Support System; Application Scenarios; Network Optimization

Introduction

The quality of the ecological environment is crucial for human survival and development, and environmental monitoring is key to understanding the state of the ecological environment and formulating protection policies. Traditional monitoring methods suffer from limitations such as limited coverage, data gaps, and delayed response. The ecological environment monitoring network, through multi-node layout and advanced technology, achieves comprehensive, accurate, real-time, and continuous monitoring, enabling the timely detection of environmental changes and rapid response to

environmental issues. Researching its application in environmental monitoring is of great significance for improving monitoring capabilities and ensuring ecological security.

1. Basic Theory of Ecological Environment Monitoring Network Construction

1.1 Core Components of the Monitoring Network

The layout of monitoring nodes must adhere to the principles of spatial coverage and representativeness. Spatial coverage requires node distribution to cover different landforms and functional zones within the monitoring area, avoiding blind spots and capturing



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the environmental status of the entire region. Representativeness necessitates prioritizing the establishment of nodes in environmentally sensitive areas and pollutant-prone zones, enabling monitoring data to reflect the overall characteristics of the region and providing support for subsequent analysis. The data transmission and storage architecture includes real-time transmission and distributed storage^[1]. Real-time transmission relies on stable communication technologies to quickly transmit environmental data collected by monitoring nodes to the processing center, reflecting environmental dynamics. Distributed storage disperses data across multiple node storage devices, preventing data loss due to single-point device failures, enhancing data retrieval efficiency, and meeting the needs of multiple scenarios. The data processing and analysis module possesses multiple core functions. It can clean transmitted data by removing abnormal and redundant information to ensure accuracy; integrate multi-dimensional data to establish correlations between different environmental elements; and also perform data trend analysis and simulation through algorithms, mining potential environmental issues and providing support for environmental management decisions.

1.2 Construction Objectives and Principles of the Monitoring Network

Comprehensiveness and accuracy are the core construction objectives. Comprehensiveness requires the network to monitor various environmental elements such as atmosphere, water, soil, and ecology, forming a complete monitoring system. Accuracy necessitates improving data precision by optimizing equipment performance and data processing methods, ensuring monitoring results truly reflect the environmental status. Stability and scalability are principles that must be adhered to during construction. Stability is achieved by selecting high-quality equipment and optimizing the network architecture, ensuring long-term stable operation and reducing downtime due to failures. Scalability requires the network design to reserve space for upgrades, allowing for the addition of nodes and parameter expansion based on needs, adapting to long-term development. The principles of synergy and sharing help enhance application value. Synergy requires efficient coordination among various nodes and modules to form a collective force.

Sharing necessitates the establishment of data sharing mechanisms to allow data circulation across different departments and scenarios, fully realizing its value.

1.3 Differences Between the Monitoring Network and Traditional Monitoring

The contrast in monitoring scope and frequency is significant. Traditional monitoring mostly involves static, localized monitoring with limited coverage, whereas the monitoring network achieves large-scale, comprehensive regional monitoring relying on multiple nodes. In terms of frequency, traditional monitoring often involves periodic sampling with long data update intervals, while the monitoring network enables real-time, continuous monitoring, increasing the update frequency and capturing environmental changes more promptly. The differences in data integrity and timeliness are notable. Limited by scope and frequency, traditional monitoring is prone to data gaps, making it difficult to fully represent environmental changes; the monitoring network acquires comprehensive, continuous data, significantly enhancing integrity. Regarding timeliness, traditional monitoring data requires time-consuming processes like sampling and laboratory analysis, whereas monitoring network data is transmitted and processed in real-time, providing rapid feedback on environmental conditions. There is a distinction in the efficiency of responding to environmental issues. Due to delays in data acquisition and processing, traditional monitoring responds slowly after identifying problems. The monitoring network can detect anomalies in real-time, quickly triggering alerts and shortening response times, thereby gaining the initiative for implementing control measures.

2. Application Scenarios of Eco-Environmental Monitoring Networks in Multiple Fields

2.1 Applications in Atmospheric Environment Monitoring

In atmospheric monitoring, eco-environmental monitoring networks enable real-time multi-parameter acquisition, simultaneously collecting data on particulate matter, gaseous pollutants, and meteorological factors. Particulate matter monitoring covers multiple particle sizes such as $PM_{2.5}$ and PM_{10} ; gaseous pollutant monitoring includes common components such as sulfur dioxide and nitrogen oxides; meteorological indicators include temperature,

humidity, wind speed, and others. The data acquisition interval can be shortened to less than one hour, ensuring the rapid detection of air quality changes. The network supports pollution source tracing and dispersion trend analysis by integrating data from multiple monitoring nodes and combining it with airflow dynamics to pinpoint pollution sources and forecast dispersion pathways and affected areas, providing precise guidance for pollution control. In addition, the network provides critical data support for regional joint prevention and control. Real-time data sharing across administrative boundaries enables collaborative decision-making and enhances the overall effectiveness of atmospheric pollution management. In particular, during heavy pollution events, rapid integration of multi-regional monitoring data offers timely references for adjusting emergency control measures.

2.2 Applications in Water Environment Monitoring

Monitoring of both surface water and groundwater is achieved through an integrated and comprehensive monitoring network. Nodes are installed at critical locations of rivers, lakes, and groundwater wells to construct a coordinated land–water monitoring system that captures the environmental status of different water bodies and avoids missing key information. Surface water nodes are concentrated around tributary confluences and discharge outlets, while groundwater nodes are distributed based on hydrogeological conditions to ensure scientific monitoring. Dynamic monitoring of water quality indicators includes pH value, dissolved oxygen, and pollutant concentrations. Real-time pH monitoring helps determine acid–base balance, dissolved oxygen reflects the self-purification capacity of water bodies, and pollutant concentration fluctuations help identify water quality anomalies. Monitoring frequencies vary by water body type—for example, hourly for drinking water sources and daily for general rivers—balancing accuracy and efficiency. Water ecosystem health assessment is conducted through the integration and analysis of monitoring data, identifying correlations between water quality and aquatic organisms to evaluate ecosystem stability and key influencing factors. Ecological index models translate multidimensional data into intuitive rating levels, enabling management authorities to have a clear understanding of ecological conditions.

2.3 Applications in Soil and Solid Waste Monitoring

Monitoring soil physicochemical properties and pollutant levels is a core function of the network. Continuous monitoring of soil pH, organic matter, and harmful substances reveals long-term patterns of soil environmental quality. Monitoring depth extends from the soil surface to approximately one meter below ground, providing a comprehensive picture of different soil layers and avoiding biases caused by surface-only monitoring^[2]. Environmental risk monitoring in solid waste storage areas aims to prevent contamination from spreading. Monitoring nodes are placed around storage sites and downstream areas to detect potential soil or groundwater contamination caused by leachate. Node spacing is adjusted according to facility size—approximately 50 meters for large storage sites and 100 meters for small ones—to ensure timely risk detection. Dynamic tracking of soil remediation effectiveness also relies on the monitoring network. Nodes are installed within and around remediation areas to continuously track pollutant concentration changes during the remediation process, evaluate the effectiveness of the treatment measures, and provide data support for optimizing remediation plans. The monitoring cycle covers pre-remediation, mid-remediation, and post-remediation stages, forming a complete record that offers valuable reference for similar future projects.

2.4 Applications in Ecosystem Monitoring

Monitoring of vegetation coverage and biodiversity reflects the foundational status of ecosystems. By combining remote sensing with ground-based monitoring nodes, changes in vegetation area, growth conditions, species abundance, and distribution can be captured effectively. Remote sensing provides rapid, large-scale monitoring, while ground nodes perform localized verification, and the combination improves data reliability. Monitoring of ecosystem structure and function requires integrating various datasets to analyze the interrelationships among vegetation, soil, water, and other ecosystem components. This integration facilitates the assessment of structural stability and the evaluation of functional processes such as material cycling and energy flow. Data fusion techniques help eliminate discrepancies among data sources and establish a unified analytical dataset, ensuring the accuracy of evaluation outcomes. Identification

and early warning of ecological stress factors rely on the network's real-time monitoring capabilities. By detecting the impacts of climate change and human activities on ecosystems, the system identifies potential threats and issues timely warnings, providing critical lead time for ecological protection. Early-warning thresholds are defined according to ecosystem types—for example, fire risk thresholds for forests and water-level variation thresholds for wetlands—to ensure targeted, scenario-specific alerts.

3. Technical Support System for Eco-Environmental Monitoring Network Construction

3.1 Perception Layer Technologies

Sensor technologies are characterized by high precision and low power consumption. High-precision sensors can capture subtle variations in environmental parameters, meeting monitoring requirements in complex environments. Low-power designs extend device operating life and reduce the frequency of field battery replacement, ensuring monitoring continuity. These sensors can also adapt to harsh conditions such as high temperature and humidity, providing a reliable foundation for data accuracy. Remote sensing technologies include satellite remote sensing and unmanned aerial vehicle (UAV) remote sensing. Satellite remote sensing enables large-scale, long-term monitoring, offering comprehensive coverage of regional ecological conditions. UAV remote sensing is suitable for small-scale, high-resolution monitoring and allows data acquisition in complex terrain. The combination of the two enhances the multidimensionality of monitoring data. In situ monitoring technologies provide automatic sampling and online analysis capabilities. Automatic sampling devices collect samples at preset intervals, avoiding delays associated with manual sampling. Online analysis modules process data promptly and output real-time results, shortening the data acquisition cycle, reducing human interference, and improving both objectivity and timeliness of environmental data.

3.2 Transmission Layer Technologies

Wireless transmission technologies mainly include the Internet of Things (IoT) and 5G communication. IoT supports large-scale connections among monitoring devices, enabling multi-node data transmission

suitable for distributed monitoring networks. With high transmission speed and low latency, 5G ensures rapid transfer of massive data volumes, meeting real-time monitoring requirements. Both technologies can be selected flexibly according to application scenarios to ensure efficient data transmission. Wired transmission technologies primarily rely on optical fibers and dedicated communication lines. Optical fiber transmission features strong anti-interference capability and large bandwidth, making it ideal for long-distance and high-capacity data transfer. Dedicated lines provide stable communication channels, minimizing data loss or latency, and are commonly used to connect core monitoring areas with data centers to ensure the stable delivery of key datasets. Ensuring data transmission security is a critical component of the transmission layer. Encryption technologies are employed to prevent data theft or tampering, while data validation mechanisms verify the integrity of received data and promptly correct transmission errors. These measures collectively guarantee secure and accurate data transmission within the monitoring network.

4. Optimization Directions for Eco-Environmental Monitoring Network Construction

4.1 Network Layout Optimization

The node densification strategy in environmentally sensitive areas should focus on key regions. In water source areas, nature reserves, ecologically fragile zones, and other sensitive locations, increasing the density of monitoring nodes enhances the ability to capture environmental changes, preventing monitoring blind spots caused by sparse deployment. This ensures that the ecological status of sensitive areas is accurately understood, providing data support for targeted conservation measures. A dynamic adjustment mechanism for redundant nodes can improve resource utilization^[3]. By analyzing real-time data transmission quality and coverage for each node, nodes that consistently provide overlapping or duplicate data can be relocated or decommissioned, reallocating equipment to under-monitored areas. This achieves a dynamic balance in network layout, ensuring monitoring effectiveness while reducing resource waste.

4.2 Technological Upgrades and Innovation

Integration of advanced sensors can expand monitoring

dimensions. New-generation sensors capable of multi-parameter simultaneous monitoring and stronger anti-interference performance can replace traditional single-function sensors, enhancing the ability to monitor complex environmental parameters, reducing equipment failure rates, and extending service life. This lays a solid hardware foundation for improving data quality. The deep integration of artificial intelligence (AI) in data processing can significantly enhance analytical efficiency. AI algorithms enable rapid filtering, classification, and correlation analysis of massive monitoring datasets, replacing traditional manual analysis, minimizing human error, and uncovering hidden patterns of environmental change, thereby supporting early problem detection. Edge computing and cloud collaboration can alleviate data transmission pressure. By deploying edge computing devices near monitoring nodes, raw data can be preliminarily processed and filtered locally, with only critical data transmitted to cloud platforms. This reduces data volume, decreases network bandwidth usage, accelerates data processing, and ensures timely feedback of monitoring results.

4.3 Data Sharing and Collaborative Application

Constructing cross-department data sharing platforms requires breaking down data silos. By establishing unified data standards and sharing protocols, monitoring data from environmental protection, water resources, forestry, and other departments can be integrated into a shared platform, allowing convenient access, avoiding duplicate data collection, and improving data utilization. This provides essential support for multi-department collaborative governance. A government–enterprise collaborative monitoring mechanism can integrate social resources. By strengthening cooperation between government agencies and environmental enterprises, enterprise monitoring equipment and data can be incorporated into public monitoring networks.

Clear delineation of responsibilities and data ownership ensures complementary advantages, expands network coverage, and enhances overall monitoring capacity. Public participation-based data integration can enrich data sources. Platforms allowing citizens to submit environmental data collected with simple monitoring devices can complement professional monitoring networks. Submitted data are verified and integrated, filling coverage gaps and establishing a monitoring system that engages the entire society.

Conclusion

Eco-environmental monitoring networks have proven effective in achieving comprehensive and precise monitoring of multiple environmental factors, providing robust data support for environmental management. Nevertheless, challenges remain. Continuous efforts are needed in optimizing network layout, promoting technological innovation, and enhancing data sharing and collaboration. Future development should focus on fully leveraging the monitoring network's capabilities to advance ecological protection and governance, promoting harmonious coexistence between humans and nature.

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