Design and Implementation of an Intelligent Monitoring and Early Warning System for Kitchen Garbage Treatment

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Abstract With a population of 1.4 billion in China and a huge daily output of kitchen waste, intelligent treatment of kitchen waste is imperative. This article elaborates on the design and implementation of an intelligent monitoring and early warning system from five aspects: system architecture design, hardware equipment selection and configuration, data collection and processing flow, early warning algorithm and model development, and system integration and testing verification. It also points out the advantages of the intelligent monitoring and early warning system in kitchen waste treatment.

Key words Environmental sanitation; Ecological environment; Garbage disposal; Intelligent systems

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With the acceleration of urbanization and the improvement of people's living standards, the amount of kitchen waste generated has been increasing year by year, bringing enormous pressure to urban waste treatment. According to the statistics of the Office of the Ministry of Housing and Urban Rural Development, the total amount of urban household waste cleared and transported in China in 2021 was 248.7 million t[1], while kitchen waste accounted for more than 50%[2]. Kitchen waste is mainly generated in various cooking places, including waste from the cooking process, spoiled food, expired food, leftover semi-finished and finished products, which are highly prone to decay, breeding mosquitoes and flies, and causing certain environmental health and safety hazards. This also poses challenges to the kitchen waste disposal system. Improper treatment of traditional kitchen waste may lead to problems such as high leachate production, emission of pollutants[3], excessive load, and the growth of harmful bacteria and pathogens, making it difficult to meet the needs of sustainable development in modern cities. Currently, research on the treatment of kitchen waste is focused on the development and improvement of mechanical equipment. A system is still needed to assist in monitoring the treatment process and verifying the results to ensure the normal and effective operation of the entire treatment system. Therefore, the innovation and application of intelligent monitoring and early warning systems for kitchen waste treatment have important practical significance and urgency[4].

The introduction of intelligent monitoring and early warning systems can achieve real-time monitoring and early warning of the kitchen waste treatment process, improving the efficiency and quality of waste treatment. Through intelligent management of the system, abnormal situations during garbage disposal can be detected and handled in a timely manner, avoiding garbage accumulation and environmental pollution. At the same time, intelligent monitoring and early warning systems can also reduce the cost of kitchen waste treatment, improve resource utilization, improve the efficiency and quality of waste treatment, achieve waste reduction and resource utilization, and contribute to the sustainable development of cities. In addition, the application of intelligent monitoring and early warning systems can also promote the improvement of environmental awareness and the implementation of environmental protection actions. Through real-time monitoring and large screen display of the system, people can have a more intuitive understanding of the process and effectiveness of garbage treatment, helping to enhance their environmental awareness and sense of responsibility. At the same time, the intelligent management of the system can also provide more scientific and effective waste treatment solutions for governments and enterprises, promoting the sustainable development of urban waste treatment.

1 Design and implementation of intelligent monitoring and early warning system

1.1 System architecture design The system architecture design is the core component of the intelligent monitoring and early warning system for kitchen waste disposal, which determines the stability and efficiency of the entire system. When constructing this system, a layered architecture design principle was adopted, and the advantages of layered abstraction lie in functional decoupling and layered optimization. The system is divided into data collection layer, data processing layer, and application layer, and is connected to each layer through appropriate network models to carry out work. The wireless ZigBee communication mode is used between the sensor and the gateway, and the gateway is connected to the Internet through wifi. This design allows various parts of the system to work independently of each other, while also facilitating maintenance and upgrades in the later stage.

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In the data collection layer, high-precision sensors and cameras were selected to obtain key data in real-time during the kitchen waste treatment process, such as garbage weight, humidity, temperature, odor gas volume, *etc.* These data are transmitted in real-time to the data processing layer through wireless transmission technology. At the data processing layer, big data analysis and machine learning algorithms are utilized to clean, classify, and predict the collected data. By constructing predictive models, the system can detect potential problems and risks in advance, providing data support for early warning. At the application layer, utilizing the processing results of the data processing layer, on the one hand, they are displayed in the browser through a large data screen, and on the other hand, information and warnings can be prompted and viewed through the APP[5].

1.2 Selection and configuration of hardware devices The selection and configuration of hardware equipment is crucial in the design and implementation of an intelligent monitoring and early warning system for kitchen waste disposal. These devices not only determine the performance of the system, but also directly affect the stability and reliability of the system. Therefore, when selecting hardware devices, it is necessary to fully consider factors such as performance parameters, compatibility, scalability, and cost-effectiveness.

Firstly, for the data collection equipment, high-precision sensors were selected, including temperature and humidity sensors, pressure sensors, electrochemical gas sensors, *etc.*, to ensure accurate capture of key parameter changes during the kitchen waste treatment process. Among them, electrochemical gas sensors are a set of sensors that detect typical types of garbage odor. These sensors can monitor the operational status of garbage disposal equipment in real-time, providing accurate data support for early warning algorithms. The gateway device is selected to connect with the sensor, and is responsible for forwarding the data in the personal domain network to the Internet[6].

Secondly, in terms of data processing, combined with cloud computing, multi-core processors are selected. 8 GB of memory space is equipped for the collection frequency and magnitude of sensors during the processing. Combining cloud computing storage facilities (distributed) to record sensor data, data reliability and access speed could be improved.

In addition, in order to achieve real-time monitoring of the kitchen waste treatment process, high-definition cameras and audio acquisition devices were also selected, so as to observe the situation of the waste treatment site in real time and record sound information, providing a basis for subsequent troubleshooting and analysis. Audio and video are collected to an upper computer for viewing.

In terms of hardware device configuration, the scalability of the system has been fully considered. For example, modular design is adopted, allowing the system to flexibly expand according to actual needs. At the same time, sufficient interfaces and slots are reserved to support wired connections, in order to easily add new hardware devices or upgrade existing devices in the future.

In summary, the selection and configuration of hardware equipment are crucial in the design and implementation of an intelligent monitoring and early warning system for kitchen waste disposal. By carefully selecting and configuring hardware equipment, the performance, stability, and reliability of the system can be ensured, providing strong guarantees for efficient, safe, and environmentally friendly kitchen waste disposal.

1.3 Data collection and processing process In the design and implementation of intelligent monitoring and early warning systems, data collection and processing processes are crucial. This process involves the collection, organization, analysis, and utilization of various data generated during the kitchen waste treatment process. The accuracy and real-time performance of data are directly related to the effectiveness and reliability of early warning systems[7].

Firstly, data collection is the foundation of the entire process. By installing sensors and monitoring equipment, the system can collect key data such as temperature, humidity, pH value, garbage volume, and odor gas content in real-time during the kitchen waste treatment process. These data not only reflect the actual situation of garbage disposal, but also provide raw materials for subsequent data processing. The data collection device connects to the gateway device through wireless, and the gateway device connects to the Internet to transmit data to the cloud computing platform.

Secondly, the data processing flow is the process of cleaning, integrating, and analyzing these raw data.

The system periodically obtains data from various sensors and integrates them into sequences. By processing data within a time range, smooth data curves are fitted to assist in data cleaning, removing outliers and noise, and improving data quality, and analyze whether the data at a certain point in time is within a reasonable range through data snapshots.

The system also records the time series of data anomalies, combined with corresponding sensor detection values. In the data analysis stage, statistical and machine learning methods are used to mine the underlying patterns and trends based on data changes, providing support for early warning algorithms.

In addition, the data collection and processing process still needs to be continuously optimized and improved. With the advancement of technology and the development of waste treatment processes, new data sources and processing methods are constantly emerging. Therefore, intelligent monitoring and early warning systems need to be constantly updated and upgraded to meet new needs and challenges.

1.4 Early warning algorithm and model development The goal of treating kitchen waste is to separate, store, and utilize oil, water, and residue. According to the requirements of the *Soil Conditioner and Use Regulations for Kitchen Waste Raw Materials*

(NY 3925 – 2021), the humidity information of the waste residue should be tested. At the same time, it should check whether the current garbage handling capacity is reasonable through pressure sensors. Electrochemical gas sensors are used to check whether there is excessive odor leakage in the system and whether the detection amount meets the requirements of the *Emission Standard for Odor Pollutants* (GB 14554 – 93). If the sensor detection volume does not meet the standard, a warning message will be sent to the display screen and forwarded to the relevant staff's APP notification.

In the data processing process, the system uses stacking multiple learnable filters to filter data noise, including fast Fourier transform, multiple learnable filters, and inverse fast Fourier transform, which can effectively reduce noise in agricultural data and obtain purer data.

Model development is a core component of the intelligent monitoring and early warning system for kitchen waste disposal. In this stage, an early warning model was constructed by recording historical time series data. This model can analyze various key indicators in the kitchen waste treatment process, such as waste volume, humidity, temperature, gas, *etc.*, and predict the possible situation of waste treatment in the future by analyzing the trend of these data changes. For example, within a certain time frame, the amount of garbage may increase rapidly, and the system needs to remind the staff to do a good job of scheduling. For example, under a certain humidity and amount of waste residue, it could predict changes in the quality of kitchen waste treatment and changes in equipment operation status, and remind staff to do a good job of supervision.

In order to verify the effectiveness of the early warning model, field tests were conducted at kitchen waste disposal centers in multiple cities. The test results show that the model can accurately predict potential problems during the garbage disposal process, such as equipment failures and decreased processing efficiency, providing timely warning information for management personnel. The acquisition of this information enables management personnel to quickly take measures to avoid further expansion of the problem, thereby ensuring the smooth progress of the kitchen waste disposal process.

In addition, the early warning model has been continuously optimized and improved. By introducing more influencing factors such as seasonal changes and holidays, the model's prediction results are more accurate and reliable, in order to improve the robustness and adaptability of the model. These technical solutions have enabled the early warning model to achieve good results in practical applications, providing strong support for the intelligent management of kitchen waste treatment.

1.5 System integration and testing validation In the design and implementation process of intelligent monitoring and early warning systems, system integration and testing verification are crucial. This stage is not only related to the stability and reliability of the system, but also directly affects the performance of the system in practical applications. Therefore, a significant amount of effort and resources have been invested in the development of an intelligent monitoring and early warning system for kitchen waste disposal, including system integration and testing verification.

In the system design phase, a modular and layered design approach was adopted to facilitate the development and debugging of various components. During the integration phase, various functional modules are organically integrated to ensure collaborative work between various parts of the system. At the same time, the system has been debugged and optimized multiple times to ensure its stability and performance in actual operation. These works not only improve the overall performance of the system, but also lay a solid foundation for subsequent testing and verification work.

In the testing and verification phase, various testing methods were adopted in stages, including unit testing during the development phase, black box testing during acceptance, integration testing, *etc.*, to comprehensively verify the various functions of the system. At the same time, various practical scenarios were simulated to test the performance of the system in practical applications. These testing works not only help identify problems and defects in the system, but also provide strong support for subsequent improvement and optimization.

2 Advantages of intelligent monitoring and early warning systems in kitchen waste treatment

2.1 Improving garbage disposal efficiency The intelligent monitoring and early warning system can significantly improve the efficiency of kitchen waste treatment through real-time monitoring and data analysis. Traditional garbage disposal methods often rely on manual monitoring and operation, which is not only inefficient, but also prone to problems such as untimely and improper disposal. The introduction of intelligent monitoring and early warning systems has made the garbage disposal process more automated and intelligent. The system can collect and analyze various data during the garbage processing process in real time, such as garbage volume, processing speed, processing effect, *etc.*, and issue warnings in a timely manner based on preset warning algorithms to remind operators to take corresponding processing measures. In this way, the garbage disposal process is more precise and efficient, greatly improving the processing efficiency.

2.2 Reducing the cost of kitchen waste disposal The intelligent monitoring and early warning system can detect abnormal situations and issue warnings in a timely manner by monitoring various parameters during the kitchen waste treatment process in real time, such as waste volume, humidity, temperature, *etc.*, thereby avoiding resource waste and cost increase caused by equipment failures, operational errors, and other problems. The application of this system not only improves the efficiency of garbage disposal,

but also plays an important role in cost control.

2.3 Optimizing garbage disposal process The intelligent monitoring and early warning system plays a significant role in optimizing the waste disposal process. Through real-time monitoring and data analysis, the system can accurately predict the operating status and load situation of garbage treatment equipment, thereby early warning of possible faults or congestion. This predictive maintenance not only reduces the unexpected downtime of equipment, but also extends its service life, significantly improving the efficiency of garbage disposal.

2.4 Promoting waste reduction and resource utilization The intelligent monitoring and early warning system plays a crucial role in reducing waste and resource utilization of garbage. By monitoring the garbage disposal process in real-time, the system can promptly detect abnormal situations and take corresponding measures to adjust and optimize. This intelligent management method not only improves the efficiency of garbage disposal, but also effectively reduces processing costs. More importantly, the intelligent monitoring and early warning system can detect the peak period of garbage generation in advance through data analysis and prediction, and thus formulate targeted measures to reduce garbage. For example, in the catering industry, intelligent monitoring and early warning systems can monitor the amount of kitchen waste generated in real time and predict future trends in waste generation based on data. In this way, catering enterprises can adjust their food procurement volume based on the predicted results, reduce food waste, and thus achieve waste reduction. At the same time, the system can also provide guidance on garbage classification, helping catering enterprises better carry out garbage classification and resource utilization.

2.5 Enhancing environmental awareness and action The intelligent monitoring and early warning system not only brings technological innovation to kitchen waste treatment, but also plays an important role in enhancing public environmental awareness. Through real-time monitoring and early warning, the system can promptly identify problems during the garbage disposal process, thereby guiding the public to pay more attention to the importance of garbage disposal. For example, when the system detects a decrease in the efficiency of garbage disposal, it will issue a warning, prompting relevant departments and residents to take timely measures to reduce the generation and waste of garbage. This timely feedback and intervention approach enables the public to have a more intuitive understanding of the process and results of garbage disposal, thereby enhancing their environmental awareness and sense of responsibility.

In addition, the intelligent monitoring and early warning system provides the public with more intuitive and specific environmental education materials through data analysis and visual display. The system can collect and analyze a large amount of garbage processing data, including garbage generation, classification, processing efficiency, *etc.*, and display these data in the form of charts, reports, *etc.* These data and reports not only provide decision-making basis for the government and enterprises, but also provide a window for the public to understand environmental knowledge. By reviewing these data and reports, the public can gain a deeper understanding of the process and results of waste disposal, thereby becoming more actively involved in environmental actions.

3 Conclusion

The innovation and application of intelligent monitoring and early warning systems for kitchen waste disposal have broad prospects and enormous potential. It not only improves the efficiency and quality of waste treatment, but also promotes waste reduction and resource utilization, promoting the development of circular economy. At the same time, the application of the system has also enhanced public environmental awareness and action, making positive contributions to building a beautiful China and achieving sustainable development goals.

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