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# *The Application and Prospect of AI Technology in the Resource Utilization of Solid Waste*

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***Abstract.*** As a country with a huge population base, China is witnessing a continuous increase in the production of domestic waste. Traditional landfill methods have obvious deficiencies in resource recovery and pollution control. To achieve the goals of reducing, harmlessly treating and recycling waste, the introduction of artificial intelligence technology has become an innovative approach to transform solid waste management. This article systematically analyzes the application of AI technology in intelligent waste sorting and the optimization of bioreactors. Research shows that AI sorting systems based on machine vision and deep learning can significantly improve sorting accuracy and recycling efficiency. Embedding AI control systems in bioreactors can achieve real-time optimization of key parameters such as temperature, humidity, and pH value, greatly shortening the waste stabilization period and improving methane recovery efficiency. Despite challenges such as high initial investment and technical adaptability, AI technology still has the potential to drive solid waste treatment towards intelligent and resourceful directions, providing important technical support for China to achieve green and sustainable development.

***Keywords:*** AI Technology, Solid Waste Resource Utilization, Intelligent Sorting, Bioreactor Landfill, Transformation of Waste Treatment

## 1. Introduction

In recent years, with the acceleration of urbanization in China and the continuous improvement of residents' consumption levels, the amount of domestic waste has increased sharply. According to the statistics released by the urban and rural construction department, the annual output of domestic waste in Chinese cities exceeds 200 million tons and maintains an average annual growth rate of 5% to 8% [1]. Facing such a huge amount of waste to be processed, efficient, green and resourceful treatment is a problem to be solved in China's ecological construction and an inevitable requirement for following a sustainable development path.

Internationally, developed countries have shifted from traditional landfill sites to a comprehensive treatment model that mainly relies on incineration for power generation, supplemented by source classification and resource recycling for domestic waste management. However, due to China's large population base and high density, it is impossible to completely abandon the traditional landfill method in the short term. Therefore, it is particularly important to explore a technical path that suits China's national conditions.

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Currently, AI technology is rapidly penetrating various fields, which also provides ideas for the upgrading and transformation of solid waste treatment. Traditional landfill sites often encounter bottlenecks when dealing with complex pollution due to the difficulty in identifying the true key control factors, resulting in a lack of precision in governance measures. In recent years, AI technology has brought about changes in this regard. Pollutant source tracing and prediction based on machine learning have shown great potential. Therefore, the research frontier is gradually shifting towards causal machine learning, integrating statistical learning with causal inference theory, which is expected to provide decision-making basis for precise pollution control in complex scenarios [2]. There are already many mature cases overseas.

WasteExpo is the largest trade show in North America for solid waste, recycling, organics, food waste recycling and sustainability, targeting both the private and public sectors. Marc Acampora, Vice President and Market Director of WasteExpo under the Infrastructure & Construction division of Informa Markets, said, "AI technology is revolutionizing waste management through automated sorting systems that use robots and machine learning to accurately sort waste and improve efficiency."

EverestLabs is a company with an independent industrial 3D vision system. They have established a dedicated dataset containing over 5 billion recyclable objects to train their recognition algorithms. Faced with a large amount of solid waste collected from households and enterprises, AI algorithms need extensive training to identify the different types of garbage we discard. Their data and robot platform RecycleOS can classify objects with an accuracy rate of over 95%. These systems will also improve over time and adapt to more new types of waste, ensuring that the sorting process remains adaptable even when the composition of the garbage changes. For example, the Alameda County Industries (ACI) has reduced its labor costs by 59% within three years with the help of EverestLabs' robots. To date, these robots have sorted approximately 30 million items.

Rebecca Hu, the founder and CEO of Glacier, explained, "Glacier's AI model can detect over 30 types of items, ranging from beverage bottles to toothpaste tubes and more." The AI employs advanced algorithms to distinguish between various materials and objects with similar appearances. Accurate identification of recyclable materials such as fibers, PET, HDPE, and black plastics helps reduce contamination rates and enhance the purity of recyclables. For instance, Glacier's robots can, after training, identify and remove plastic bags that have been accidentally mixed in with paper materials. This results in higher quality and value of the final paper products [3].

AI technology is expected to fundamentally transform the operation mode of landfills. By combining machine vision technology and AI technology after deep learning, precise classification of household waste can be achieved at the source, significantly increasing the recovery rate of recyclables. In the process optimization of bioreactors, the learned AI technology can intelligently and in real time regulate the temperature, pH value, humidity, and leachate collection of the reactor, providing the most suitable degradation environment for the waste and shortening the stabilization time required.

Based on this, this paper, through case studies and industry data comparisons, reviews the application paths of AI technology in solid waste treatment. The research focuses on AI-driven intelligent sorting systems and bioreactor optimization, demonstrating their significant achievements in improving sorting accuracy, accelerating waste stabilization, and enhancing methane recovery efficiency through specific data. It also analyzes the economic and technical challenges faced, aiming to clarify the driving role of AI technology in the transformation of traditional landfills and provide theoretical references and practical paths for promoting the intelligence and resource utilization of solid waste treatment.

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## 2. The inevitability of the transformation of traditional landfills

The traditional sanitary landfill method has long been adopted by most cities in China due to its simple technology and low processing cost. However, the traditional anaerobic landfill mode has significant drawbacks, such as: the generation of methane and other greenhouse gases during processing cannot be controlled; leachate is prone to soil and groundwater pollution, requiring the construction of a dedicated anti-seepage system; recyclable and reusable energy in the garbage is processed together, resulting in resource waste, etc.

Internationally, developed countries have gradually closed traditional landfills and shifted to more efficient and environmentally friendly treatment methods. Although developing countries still rely on landfills, they are actively seeking technological upgrades. The introduction of AI technology not only liberates human resources and reduces operating costs but also serves as a key technical support for achieving intelligent and resourceful waste treatment.

## 3. Application of AI technology in intelligent sorting

Intelligent sorting is a crucial part of waste recycling and a key to improving the recycling rate. Currently, AI sorting systems based on machine vision and deep learning have been widely commercialized in Europe and America. For instance, the sorting system of AMP Robotics in the United States can identify materials such as plastic, metal, and paper through high-resolution sensors, with a sorting accuracy of over 90%, significantly enhancing the purity of recyclables [4]. Intelligent sorting technology not only liberates human labor and reduces costs but also increases the recycling efficiency of waste by 20-30%, laying a solid foundation for subsequent resource utilization (Table 1) [5].

Table 1. Efficiency comparison between AI sorting system and traditional sorting methods

| Sorting method | Sorting accuracy rate | Processing capacity (tons per hour) | Manpower requirement (personnel per shift) | Applicable types of garbage |
|---|---|---|---|---|
| Manual sorting | 60%–70% | 2–5 | 10–15 | Mixed waste, recyclables |
| Mechanical sorting | 70%–80% | 5–10 | 3–5 | Preprocessed garbage |
| AI visual sorting system | 90%–95% | 10–20 | 1–2(Surveillance) | Mixed waste, recyclables |

## 4. The combination of bioreactors and AI technology

A bioreactor landfill is a municipal solid waste landfill (MSWLF) that enhances the microbial process by adding liquid and air to help bacteria break down waste. This bioreactor concept is different from the traditional municipal landfill method. Bioreactor landfills shorten the waste degradation cycle by actively controlling internal environmental parameters. The application of AI technology in this field mainly lies in process optimization. It sets up a sensor network to monitor data such as temperature, humidity, and pH value in real time, and uses AI technology's deep learning algorithms to adjust the leachate recirculation and ventilation systems in real time, creating the best environment for microbial degradation. Studies have shown that the intervention of AI technology can shorten the stabilization period of traditional landfills from 20-30 years to 5-10 years [6]. In addition, cases from the US Environmental Protection Agency (EPA) show that after

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optimization by AI technology, the methane collection efficiency in bioreactors can increase by more than 40%, significantly enhancing the energy recovery capacity and economic benefits of landfills (Table 2) [7].

Table 2. Performance comparison between bioreactor landfills and traditional landfills [8]

| Indicator | Traditional landfill site | Bioreactor landfill (without AI) | AI-type bioreactor |
|---|---|---|---|
| Degradation cycle | 20–30 years | 10–15 years | 5–10 years |
| Methane recovery efficiency | 30%–40% | 50%–60% | 70%–80% |
| Leachate treatment cost | high | medium | low |
| Operational maintenance manpower and complexity | high | medium | Low (automated monitoring) |

## 5. Challenges faced and future prospects

Although AI technology shows great potential in the field of solid waste management, its large-scale and commercial application still faces many severe challenges. For instance, high-precision sorting robot arms and complex sensor networks require a high initial capital investment. The World Bank report indicates that insufficient funds are one of the main obstacles for developing countries to improve solid waste management [7]. The investment for a complete AI sorting system can reach hundreds of thousands to millions of US dollars (see Table 3), which is a heavy burden for many municipal departments or enterprises with limited budgets [9]. In addition, the later maintenance of the system, software upgrades, and technological iterations also require continuous financial support, further intensifying the economic feasibility challenges. At the same time, the accuracy of AI models is highly dependent on the quality and quantity of training data. In China, the composition of domestic waste is complex, with significant regional and seasonal differences, and a high degree of mixing during collection and transportation. This poses a huge challenge to the universality and accuracy of AI models. A model trained for one region may not be directly applicable to another, requiring extensive local data collection and model re-training. However, there is currently a lack of high-quality, standardized databases of waste images and components, and more efforts are needed. The availability and quality of data are key limiting factors for the application of AI in waste management [4, 5]. The environment for solid waste treatment is harsh, with equipment constantly exposed to dust, humidity, corrosive substances, and physical shocks. The lenses of visual sensors in AI sorting systems may become contaminated, and mechanical arms may malfunction after long-term high-load operation. The stability and reliability of the system are directly related to the continuous operation of the entire processing line. How to ensure the long-term stable operation of AI systems and their hardware facilities in such a harsh environment is an urgent problem to be solved.

The promotion of technology cannot do without the guidance and regulation of policies and standards. Currently, the technical standards, acceptance norms, data security and privacy protection guidelines for the application of AI in solid waste resource utilization are still not complete. For instance, there are policy imperfections or even blanks regarding how to determine the quality grades of recycled materials sorted by AI and how to define the regulatory responsibilities. The US Environmental Protection Agency and other institutions have relatively clear technical guidelines for bioreactors [6], but the regulatory framework for integrating AI into them is still in the exploratory stage. The lack of clear policy signals and industry standards will dampen investors' confidence and

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slow down the market penetration speed of the technology. The introduction of new technologies may also bring about social-level challenges. The advancement of automation and intelligence will inevitably replace some traditional manual sorting jobs, which may lead to short-term unemployment for some workers and trigger social resistance. Therefore, it is necessary to have a corresponding labor force retraining program and transition placement policy to smooth out the pain brought by technological change. At the same time, the public has doubts about the transparency and credibility of AI's decision-making in waste treatment, which requires enhancing social acceptance through popular science and communication. In the future, research should focus on developing low-cost, modular AI solutions to lower the entry threshold and promote the establishment of international cooperation and data sharing platforms to address the issue of data scarcity. Technically, efforts should be made to enhance the robustness of the system in harsh environments. Meanwhile, the government should introduce targeted subsidies and tax incentives and accelerate the formulation of relevant technical standards and regulatory frameworks. Finally, it is essential to attach importance to social impact assessment and formulate fair transition strategies to ensure that AI technology can promote the intelligent and resourceful transformation of the solid waste treatment industry while achieving the coordinated development of environmental, economic and social benefits.

Table 3. Investment and return analysis of AI sorting system (taking a medium-sized processing plant as an example)

| Project | Amount (in ten thousand US dollars) | Explanation |
|---|---|---|
| Initial investment | 80–100 | Including the visual system, robotic arm, and software deployment |
| Annual maintenance fee | 5–8 | Software update, sensor replacement |
| Annual labor cost savings | 15–20 | Reduce the number of sorting workers by 10 to 15. |
| Annual increase in recycling value | 20–30 | High-purity recycled materials command higher prices. |
| Investment payback period (estimated) | 3–5 years | Based on actual operation data estimation |

## 6. Conclusion

This study explores the application of AI technology in revolutionizing traditional landfill sites and promoting the continuous update of solid waste resource utilization methods. Firstly, traditional landfill methods have high resource recovery rates but also pose significant pollution risks, have long stabilization periods, and are labor-intensive. In contrast, AI technology, through machine vision and deep learning algorithms, demonstrates significant advantages in intelligent waste sorting, not only greatly enhancing the utilization rate of recyclables but also effectively reducing labor costs. Secondly, the integration of AI with bioreactor landfill technology enables active and intelligent control of the landfill environment. By optimizing parameters such as temperature, humidity, and leachate recirculation in real-time, the stabilization period of waste can be shortened from 20-30 years to 5-10 years, and the recovery efficiency of methane can be significantly improved, greatly enhancing the energy recovery efficiency of landfill sites.

However, the wide application of this technology still faces problems such as high initial construction costs and difficulty in adapting to each city. In the future, it is still necessary to

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continue to explore more universal solutions, such as building an open data platform to train AI models. In conclusion, AI technology is a turning point for the solid waste treatment industry to move towards a new model. The deep integration and application of AI technology will surely lay a better foundation for China's green and sustainable development.

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