Research on Innovative Design of Urban Domestic Garbage Treatment System Based on Intelligent Logistics

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Abstract: This paper aims to solve the problems of low operation efficiency of the traditional urban garbage sorting and recycling logistics network and worrying about the sanitation environment based on social construction. It will be connected to the front end, and the model innovation will be carried out with the collection and transportation logistics of the key link of garbage classification in the end recycling process. The method adopted is to establish a complete system, using differential centrifugal and pneumatic power transportation methods to act on garbage classification and pipeline transportation, formulate standardized collection and transportation procedures, and implement block-based independent management on a community basis. Based on the above methods, the one-stop service of residents' domestic waste collection, classification, recycling, compression, packaging, and transportation is completed, solving the problem of urban waste and finally forming the result of constructing an intelligent process of garbage collection, transportation and classification. This paper uses the domestic waste rail logistics system innovation to provide smarter processing ideas for future communities and create a better living environment for residents. It has a positive effect on implementing urban organic construction, promoting industrial upgrading and economic development.

Keywords: Urban garbage; Garbage classification; Garbage recycling; Rail logistics
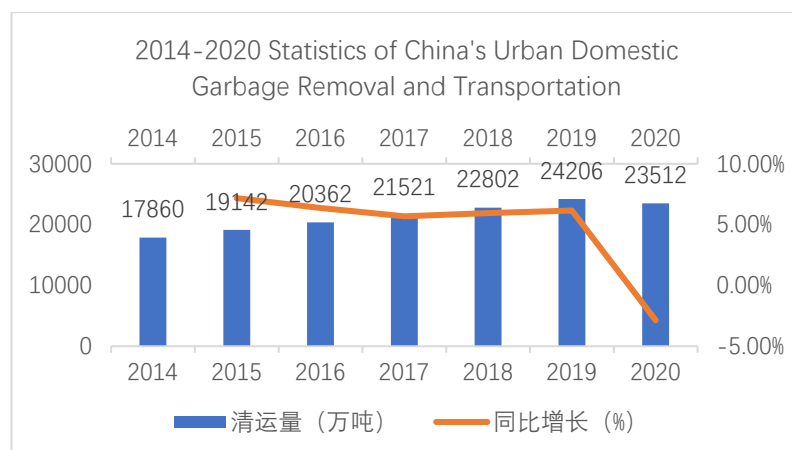
1. Introduction

Figure 1: 2014-2020 Statistics of China's Urban Domestic Garbage Removal and Transportation

There is a large population in China, which is a large country. Economic development, improving living standards, and increasing urbanization have all contributed to the high level of domestic garbage generated. Data from the National Bureau of Statistics "China Statistical Yearbook 2021" shows that China's urban domestic garbage removal and transportation volume has grown rapidly in recent years. In 2019, China's urban domestic garbage removal volume reached 242.06 million tons, an increase of 14.04

million tons compared with 2018, a year-on-year increase of 6.2%. Affected by the new crown pneumonia epidemic in 2020, China's urban domestic garbage removal and transportation volume declined for the first time (see Figure 1).

In recent years, the generation of a large amount of garbage and the proper disposal of domestic garbage have become bottlenecks in developing Chinese environmental protection efforts. It also contributes to environmental pollution and difficulties in reusing resources. Recently, China has accelerated its efforts to classify garbage. Based on the construction plan of garbage treatment investment, according to the "Thirteenth Five-Year Plan" for the construction of facilities for the harmless treatment of domestic garbage in cities and towns, the total investment for the construction of facilities for the harmless treatment of domestic garbage during the "Thirteenth Five-Year Plan" period was 251.84 billion yuan. The domestic garbage treatment and classification industry has experienced good growth since the end of 2021. Over the past few years, domestic garbage classification and treatment companies have increased significantly (see Figure 2), and the growth rate has been relatively fast.
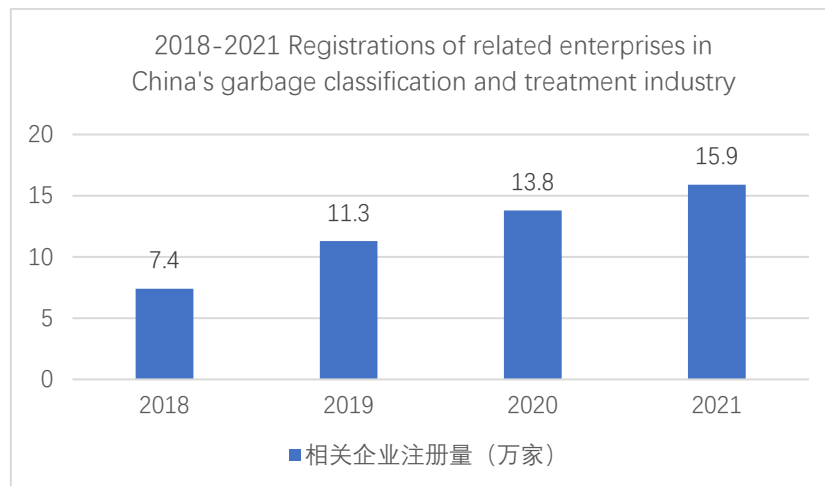

Figure 2: 2018-2021 Registrations of related enterprises in China's garbage classification and treatment industry

In addition, the timely garbage disposal will also be an important trend in the future. Statistics indicate that China's cumulative stockpile of urban domestic garbage has exceeded 8 billion tons, covering an area of approximately 3.5 billion square meters. In China, two-thirds of large and medium-sized cities are surrounded by garbage, and the ecological environment is rapidly deteriorating, seriously affecting residents' health and living conditions. The accumulation of garbage has caused significant environmental problems on the one hand. However, it has also resulted in serious energy losses.

2. Garbage Disposal Status

Due to the relatively short development time of China's domestic garbage treatment and disposal system and the characteristic national conditions of a large population, at this stage, China's domestic garbage treatment facilities still have the following outstanding problems:

(1) The phenomenon of mixed collection and transportation is common. Many urban classification collections and transportation facilities are difficult to meet the requirements of domestic garbage removal and classification. The collection and transportation system does not match the needs of residents for classified delivery, and it is still unable to achieve effective classified collection and transportation.

(2) The innocuous treatment capacity is insufficient. China's urban domestic garbage incineration rate is less than 50%, and its fly ash disposal capacity is severely inadequate. The remaining storage capacity of urban domestic garbage landfills is unclear. Most of the existing domestic waste landfills have reached their service life and are facing closure. There is also a landfill demand for ash disposal after garbage incineration.

(3) Hygiene is dire. It is piled up in the open air, and most transfer stations have imperfect facilities, overflowing sewage, dirty and messy, and serious noise problems. Improper disposal of garbage will increase the pollution level. For example, the leachate in the garbage will ferment and produce many

harmful substances over time, eventually spreading through the air and polluting the regional groundwater sources [1].

In summary, combined with the social background, market needs, and the current key points of garbage disposal, the construction of the supporting system for domestic garbage classification should be updated, along with the improvement of the treatment facilities at various ports connected with garbage treatment. A recycling system that coordinates with the utilization of renewable resources is established to ensure the connection between garbage collection and transportation, recycling, utilization, and treatment facilities.

3. Urban Garbage Recycling Rail Logistics System

3.1 System Components

The urban waste recycling rail logistics system consists of smart delivery ports, pneumatic transport rails, differential centrifugal classification devices, basic automated monitoring, and mobile garbage compressors.

The intelligent delivery port is in the shape of a sealed barrel and is distributed at multiple points in the community. The induction-type delivery port is used for household waste delivery, and the intelligent detection system performs pneumatic evacuation when the waste in the bucket reaches a certain level. The built-in solar violet light is regularly sterilized, cleaned, and maintained by the staff when necessary.

A community's routes are optimized, and underground pneumatic transportation tracks are laid. The pipes are made of materials such as PVC or stainless steel and connect the intelligent delivery port and the community centralized processing station. The pipeline pneumatic system is driven by compressed air or suction air, the transmission speed can reach 5m/s, and it can be installed in series and parallel to ensure fast, pollution-free, and low-noise garbage collection and transportation [2].

The differential centrifugal sorting device is located in the above-ground community centralized processing station, connected to the underground pneumatic transportation track and the garbage compressor. It is the core processing equipment for garbage classification. After the bag is broken and blown away, the preliminary garbage drying is completed. According to the different garbage components, it is divided into multiple density intervals for multiple centrifugal classifications instead of manual sorting [3]. According to different processing scenarios, the equipment parameters can be adjusted to meet the different needs of multi-coarse and fine sieves.

Garbage collection and transportation schedules are at the core of the automatic monitoring system. The dispatch center should monitor all aspects of garbage collection, transportation, and classification. The automatic monitoring system is located in the centralized processing station of the above-ground community, along with a manual operation station, which can control the above-ground injection port and processing station as well as the underground pneumatic transportation pipeline equipment by using the safety network within the system. Ensure the efficient scheduling and scientific use of machinery and equipment, intelligently ensure the safety of the production process, and ensure non-stop operation of the processing system [4].

Domestic garbage collection and compression is an essential step in garbage transfer. Compressing and reducing the volume of sorted domestic waste can effectively improve the efficiency of waste transfer. The mobile garbage compressor is suitable for small garbage disposal stations. It adopts the horizontal compression process and has a processing capacity of 10-80 tons/day [5]. After the mobile garbage compressor compresses the garbage, the garbage docking truck directly pulls the entire equipment away for processing and then pulls the empty equipment back for seamless docking, airtight temporary storage, seepage discharge, and power push.

3.2 Core Technology

The system mainly uses differential centrifugal separation and pneumatic power transportation to act on garbage classification and pipeline transportation.

In centrifugation, differential centrifugation is a subdivision method. The principle is to separate organelles of different sizes by gradually increasing the centrifugal speed. Using the difference in the sedimentation coefficients of different particles in the centrifugal force field, under the same centrifugal condition, by continuously increasing the relative centrifugal force, particles of different sizes and shapes

in a non-uniform mixture are precipitated step by step. The initial centrifugation speed is low, and the larger particles are allowed to settle at the bottom of the tube, and the small particles are still suspended in the supernatant. Collect the precipitate, use a higher centrifugal speed to centrifuge the suspension, settle the smaller particles, and separate particles of different sizes. This design research transfers this principle's idea to garbage classification and explores innovative breakthroughs in undifferentiated delivery and unified classification. The composition of domestic garbage is relatively complex, mainly including kitchen garbage, garbage paper, garbage plastic, garbage fabric, garbage metal, garbage glass, ceramic debris, brick muck, feces, garbage furniture, garbage electrical appliances, garden garbage, etc. In China, in a broad sense, domestic garbage is divided into three categories: organic matter (plants, animals), inorganic matter (lime, brick, etc.), and recyclables (typically paper, plastic, glass, metal).

Table 1: Partial garbage density table

Garbage type	Density(kg/m^3)
Dust dirt	0.6×10^3 kg/m^3
Tile	$1.8\text{-}1.9 \times 10^3$ kg /m^3
Paper	$0.7\text{-}1.2 \times 10^3$ kg /m^3
Iron	$7.3\text{-}7.85 \times 10^3$ kg /m^3
Glass	$1.19\text{-}2.2 \times 10^3$ kg / m^3
Plastic	$0.83 \sim 1.4 \times 10^{-3}$ kg /m^3

Taking Table 1 as an example, after the initial crushing treatment, all the garbage mixtures were placed in the same container and turned into crushed bodies of similar size. Due to the different densities of different types of garbage, adjusting the centrifugal speed can accurately classify them. The initial centrifugation speed of the machine is low, and the iron with the largest mass is first precipitated, which can be separated after falling to the bottom. After gradually increasing the centrifugal speed, glass, bricks, plastics, paper, and soil with smaller mass can be precipitated and separated in sequence. By refining the centrifugal speed difference, the separation is made purer. By changing the centrifugal speed, more types of garbage can be separated to meet the needs of different types of garbage classification [6].

The pneumatic logistics system is powered by the extraction and pressure delivery of air by the air compressor, and the transport bottle is used as the carrier to transport the items in the closed network pipe. Real-time control is carried out through an automatic control system composed of computers. And the behavior trajectory is monitored in real-time by the computer. Its composition includes air compressors, converters, pneumatic pipes (steel or PVC), ordinary workstations, super workstations, and control centers. The system can be designed according to different sites and terrains, and items can be transported safely and efficiently between any two stations. And is not affected by ambient temperature.

3.3 System Applications

The pneumatic garbage logistics system is the first to be widely used to recycle medical garbage and quilts (as shown in Figure 3), and the related technologies are becoming mature [7]. Through questionnaires to collect community residents' willingness and SWOT analysis of long-term development, this study decided to build a domestic garbage recycling rail logistics system with the community as a unit.

Figure 3: Orbital logistics technology for medical garbage and quilt recycling

Develop a standardized collection and transportation process and implement independent management of the block. The community needs to plan and equip the hardware facilities of the domestic garbage recycling rail logistics system in the early stage of construction. After the garbage in the intelligent injection port is full, the power system is activated by induction [8]. The domestic garbage is automatically collected and transported to the community centralized treatment station through the independent pipeline preset in the community underground, using gas as the transport carrier. Differential centrifugal sorting is carried out in the station frequently, sorting and sucking garbage of different densities into the mobile garbage compressor [9]. Multiple boxes are matched with one car, which can be recycled. According to its classification, the collected garbage will be transported out of the community for harmless treatment or transported to a garbage treatment plant for processing and secondary use.

The overall process realizes the automatic logistics and transportation of the domestic garbage of the community residents, which has a short collection time and high efficiency. It also avoids the stench, odor, sewage, and mosquito and rodent damage caused by the traditional garbage collection process。 Therefore, to a certain extent, it liberates manpower and improves the living environment of the residents' community [10].

4. System Design Solutions

The garbage recycling rail logistics system is a new intensive urban community infrastructure. The whole machine operation process is realized through automation and an information system. The design core lies in the pre-laid pipeline routing of infrastructure, using pneumatic negative pressure technology to pump and concentrate the domestic garbage. Finally, it is processed and recycled by density differential centrifugal classification (see Figure 4).
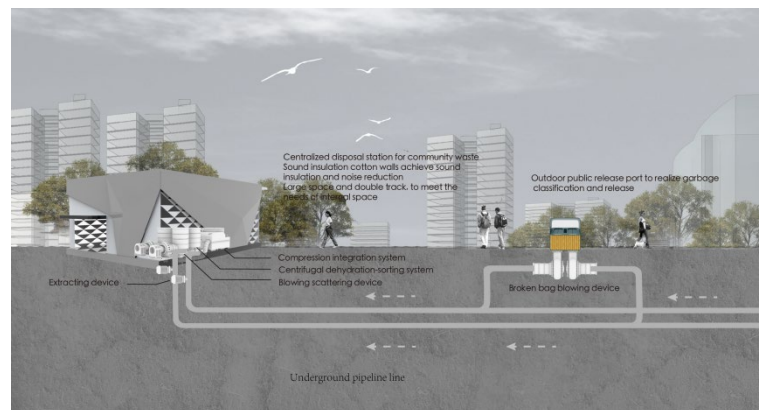

Figure 4: System schematic

Design of facilities and equipment for garbage recovery rail logistics operation system (see Figure 5):

(1)The front-end sites are distributed downstairs of the unit according to the density of residents, and the alternative design replaces the original garbage can. Injection ports should be equipped with intelligent induction suction and cleaning functions. Garbage disposal control systems regulate storage capacity, manage security, monitor usage status in real time, and alert faults. The same injection port is suitable for various types of domestic garbage [11].

(2) The middle end lies in pipeline construction, the service life of the transmission pipeline should be ≥30 years, and the pressure inside the pipeline should be ≥4000Kpa.Corrosion-resistant materials should be used, and the airtight performance of the pipeline should be ensured. The outer wall of the pipeline should be wrapped with sound-absorbing material, and an air isolation valve should be installed above the pipeline. When the height of the transmission pipeline is ≥20m, there should be a camber buffer inside. The end of the vertical pipe should be equipped with a storage section with a volume ≥ 0.5m³.The fan system should use variable frequency fans and install filters, mufflers, and noise reduction covers at both ends. The power of a single fan should be ≥90Kw, the suction pressure should be ≥20Kpa, and the flow rate should be ≥15000m³/h. Backup fans should be provided. The fan control system should monitor and automatically adjust the internal pressure of the duct.

(3)The terminal is the domestic garbage collection station, which should be located in the outdoor corner of the community. The equipment room should take sound absorption and sound insulation

measures [12]. The construction area and height of the collection station should match the centrifugal sorting equipment and the amount of domestic garbage collected, and the surrounding roads should meet the driving requirements of sanitation transport vehicles. The collection station can have sewage pipes, domestic garbage, and dirty clothing collection boxes. The pipeline is connected to the community sewage pipeline to discharge the centrifugal sewage. The volume of the domestic garbage collection box should be ≥12m3, and it should be equipped with a domestic garbage compressor with a compression ratio of ≥3:1. The collection control system monitors the capacity of the collection box. When the collection box is full, it should send out a reminder signal and automatically switch to other under-full collection boxes.
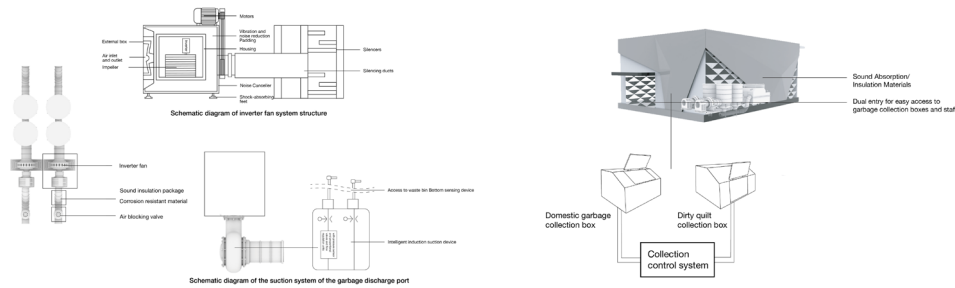

Figure 5: System Components

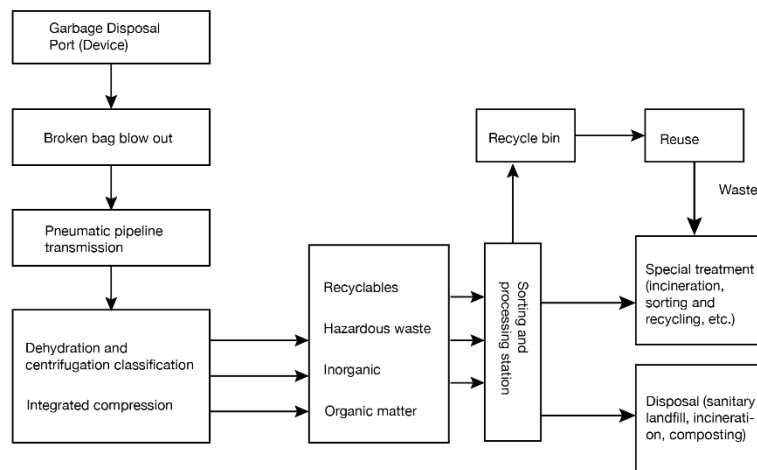The operating mechanism of the system is shown in the figure (see Figure 6).

Figure 6: System Flowchart

In this paper, when designing the rail logistics system for domestic garbage in urban communities, it is also necessary to fully consider the particularity of the construction environment. The intelligent delivery port and community centralized processing station are reasonably arranged in the community, and the system operation is noise-reduced under the application of innovative technology so as not to disturb the residents' rest [13]. At the same time, pay attention to the track laying route planning, prevent the ground from collapsing, ensure the rationality and scientificity of the system, control the construction cost, strengthen the overall design quality, and provide residents with a safe and comfortable living space.

5. Conclusion

As a result, the system integrates collection, transportation, classification, recycling, packaging, and processing, which completely interprets the green and smart household garbage treatment method in the future community, realizes fast and pressure-free waste treatment, and changes the way garbage is previously handled. The impression of dirty and messy accumulation of collection and transportation has improved the efficiency of community services and the quality of life of urban residents. From the

perspective of engineering technology, the system solves the problem of garbage classification from the back end. The bold innovation of pneumatic rail transportation and density gradient centrifugal classification provides new ideas for future construction, conforms to safe and efficient intelligent services, and expands the sustainable operation content of future waste treatment.

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