Research Status of Generation and Management of Garden Waste in China: A case of Shanghai

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Abstract. In the present study, by complying with the panel data of China’s urban garden waste emissions from 2011 to 2019, a dynamic characteristic analysis and a temporal and spatial analysis are conducted on the existing status of garden waste emissions of our nation. In addition, an in-depth study is carried out on the spatial distribution characteristics of garden waste emissions. Moreover, the current situation of garden waste management in Shanghai is analysed, the lack of garden waste management in typical cities of China is explored, and a theoretical basis is laid for the government to formulate and roll out effective sustainable management of garden waste.

1. Introduction

Garden waste refers to the litter and other plant residues generated by the natural fall of garden plants or artificial pruning. Over the past few years, as the construction of “garden cities” and “park cities” is continuously advancing, China has boosted its investment in urban landscaping. As of the end of 2019, China had successfully constructed the urban green space covering 2,269,400 hm², China’s green space rate and green coverage rate of urban built-up areas took up 37.63% and 41.51%, respectively, and the urban per capita park green space covered 14.36 m², as suggested by the “Statistical Yearbook of Urban Construction 2019”. The generation of urban garden waste is inconsistent with domestic waste [1]. Specific to cities, population acts as the major factor of the amount of domestic waste. The amount of urban garden waste is primarily determined by the area of urban green land and woodland, and different regions are significantly impacted by factors (e.g., seasons and climate). As urban gardening and greening are leaping forward, considerable urban green spaces have been constructed, and the urban greening coverage has displayed a year-on-year increase. As of September 2019, about 1 million tons of green waste was generated, which was the annual total amount of green waste in green space and street trees in Shanghai. Considerable garden waste has imposed a huge burden on the work of urban gardening departments and sanitation departments. Accordingly, the reuse of garden waste turns out to be a hotspot of local governments and numerous researchers.

Foreign relevant research on garden waste had an earlier start, and the related experience, technology, policies, laws and regulations, especially in the United States, the European Union and Japan, are more mature than those in China. In 1994, the U.S. Environmental Protection Agency (EPA) promulgated the composting rules for garden waste and domestic waste, as well as the treatment methods and corresponding regulations of garden waste [2]. The United Kingdom formulated a 10-year plan to “ban peat from commercial applications”, which placed stress on replacing peat with
decomposed organics and other substitutes for garden waste [3]. In 2000, Japan implemented the “Procurement Law for Promoting Recycling Products” and covered all ecological products treated as resources for garden waste into the government procurement list [4]. The resource exploitation of garden waste in China remains exploratory, and the complete industrial chain has not yet been forged. The primary obstacle to the resource exploitation of garden waste is considered the lack of law. Garden waste collection and treatment pertain to different departments. As a result, China’s garden waste output has not yet formed a “ledger” statistical system. Furthermore, systematic and complete garden waste discharge data has been rare at the national or local city level.

2. Emission dynamic characteristics analysis

2.1. Economy and production

As indicated from Fig. 1, over the past few years, the amount of garden waste produced in China has been positively correlated with per capita GDP. In the past decade from 2011 to 2019, the amount of garden waste in China surged from 22.453 million tons in 2011 to 33.134 million tons in 2019. The growth rate took up 47.57%; the per capita GDP of the city was up-regulated from 138,100 yuan to 227,800 yuan, marking the growth rate of 64.95%.

![Figure 1. China’s urban per capita GDP and the change trend of urban garden waste generation (2011-2019).](image)

2.2. Temporal and spatial distribution characteristics

As indicated from Fig. 2, the output of Chinese garden waste in recent years has been primarily in the eastern, southern and northern regions, which shows a correlation with the degree of economic development between regions. Economically developed regions have invested more in landscaping. The overall amount of garden green space has surged, thereby boosting the output of garden waste to rise progressively [5]. The output of garden waste in China tends to be largely more in the east and less in the west. Moreover, the growth trend in Sichuan Province is significantly higher than that in other regions, probably associated with the expansion in the area of urban greening land.
Figure 2. Distribution of garden waste generation in the provinces (2011-2019).

In addition, Fig. 3 illustrates the temporal and spatial distribution of Chinese garden waste per capita. As clearly indicated from 2011 to the present, China’s per capita garden waste production has changed noticeably, as largely reflected in the north and southeast of China. This result may be associated with the advancement of ecological civilization construction and the construction of green spaces in the region over the past few years. As indicated from relevant data, the output of garden waste in Jilin, Hebei, Hubei, Anhui and Guangxi in 2019 has undergone major changes from 2011, which is largely because the green space rate of these provinces has been elevated from 26.41%,
30.28%, 32.62%, 32.17% and 27.06% in 2011 to 34.56%, 38.58%, 34.69%, 39.10% and 35.38% in 2019, respectively.

Figure 3. Distribution of per capita garden waste generation in the provinces (2011-2019).

3. Characteristics of garden waste management in Shanghai

3.1. Related to production
As of 2019, Shanghai has a total of nearly 138,000 hectares of green space, thereby generating approximately 6 tons of green waste per hectare per year, as well as a total of about 1.2 million street trees that produce about 0.12 tons of green waste per year. Given the mentioned calculation, the total
annual greening waste generated by Shanghai's green space and street trees reaches nearly 1 million tons. On the whole, greening waste consists of litter, pruned materials and dead trees.

3.2. Disposal scale and capacity
Shanghai has set 29 green waste disposal sites in 11 districts, covering a total land area over 23,000 square meters and exhibiting an annual disposal capacity over 67,000 tons. To be specific, Jing’an District has formed a relatively perfect collection, disposal and application system of regional greening waste, which has utilized regional greening waste resources in an intensive and standardized manner.

3.3. Management present situation
Shanghai started greening waste disposal earlier and has gained certain experience in treatment technology. The Jing’an and Minhang districts generally exhibit better green waste disposal effects in Shanghai, whereas some problems remain (e.g., lack of preliminary land planning). Besides, due to seasonal fluctuations, a mismatch between supply and demand is caused, and the peak production period in spring and summer is not the peak demand period. For instance, Jing’an District has been disposing and managing greening wastes since 2007. Xinqiao Nursery acted as a demonstration site to produce flower boxes that mainly apply soil media. Recently, as impacted by insufficient sites in the district and business losses, only one disposal site in Jing’an District is currently left on the green space of Xikang Road. The parks and green areas and forest belts in Minhang District are maintained and managed by state-owned enterprises, whereas the garden waste in streets and towns does not receive any standardized management. Since the resource-based products have not been marketed, the “Minhang Landscaping Waste Resource Treatment Station” has not been capable of expanding its operations thus far.

3.4. Disposal mode
The application fields of waste disposal and resource products of Shanghai landscaping consist of four aspects below:

3.4.1. Production of garden coverings.
Landscaping wastes are exploited for surface mulching, which is commonly adopted to optimize the soil environment and boost plant growth. The mulch is capable of preventing the exposed loess, dust and sand, inhibiting the growth of weeds, reducing the evaporation loss of water from the soil, maintaining a more balanced soil and temperature, as well as reducing soil erosion.

3.4.2. Cultivation substrate and fertilizer.
After the landscaping waste is pulverized for the second time, it is composted by regulating the process conditions. When the compost is decomposed, it can be treated to generate cultivation substrates or series products of organic fertilizer, thereby showing good social and ecological benefits and acting as a practical model. After the series of products are applied in production, they are capable of promoting the reproduction of soil microorganisms, improving the soil structure, enhancing the soil’s fertility retention capacity (adjust C/N), and elevating the fertilizer rate.

3.4.3. Preparation of biomass fuel.
By employing branches, leaves, sawdust, bark and other landscaping wastes as raw materials, the waste is processed into rod-shaped solid particle fuels. It refers to a modern clean fuel and an emerging special fuel to generate biomass power. It is characterized by high volatile content, easy precipitation, good carbon activity, low ash content, as well as fast ignition. It can be directly employed in urban traditional coal-fired boiler equipment to replace traditional coal. Moreover, it has been primarily used in heating, heating, hotels, restaurants, bathing and other industries in cities. The output of fuel rods takes up one-third of the total amount of landscaping waste treatment. However, its
market price positioning is correlated with seasons and coal prices. The better the coal prices, the better the price of fuel rods will be.

3.4.4. Production of sponge concrete materials.
The sponge-body “dual waste” permeable concrete refers to the main product of landscaping waste resource utilization at the tamarisk waste utilization point in the outer ring of Putuo. The concrete is composed of several materials (e.g., cement, yellow sand, recycled aggregates, and crushed garden waste); the landscaping waste largely involves wood waste (e.g., waste branches, roots and wood chips); the wood content in the concrete takes up nearly 2%. The material exhibits high water permeability, water absorption, air permeability, water purification performance, as well as high heat dissipation. One cubic meter can hold 150 kilograms of water. It has been successfully employed to construct green roads, ecological revetments, and garden roads (e.g., Lanzhou Road in Yangpu District, Xinbei Road in Shanghai-Hangzhou Highway in Fengxian District, Sanquan Park in Jing’an District, Hongliu Road Greenway in Putuo District, and Yangjiaqiao Green Space in Putuo District).

3.5. The present problem
(1) Shanghai’s top-level planning for the treatment and management system of landscaping waste is limited, and its collection, transportation and disposal require the comprehensive coordination with domestic waste. The land supply of landscaping waste resource disposal sites cannot be effectively ensured. The green waste collection, transportation and treatment system remains incomplete, and the market channels for resource-based products are relatively blocked.

(2) The insufficiency and lack of incentive mechanism for waste recycling in landscaping is one of the vital reasons for the low utilization rate and small industrial scale of waste recycling in landscaping. As impacted by the lacked incentive mechanism support, a big gap remains between China’s garden waste recycling industry and entering the industrial chain and commercial chain. In the absence of incentive policies, as supervised by environmental protection monitoring departments, numerous relevant departments are facing difficulties in greening waste treatment. Moreover, they reduce their enthusiasm for greening waste treatment and impede the improvement of treatment efficiency. An encouragement mechanism that keeps pace with the times, adapts measures to local conditions, and is systematic and scientific is critical to landscaping waste treatment and disposal.

(3) The main problems affecting the disposal capacity of garden waste include the single treatment mode, the difficult site selection of treatment points, as well as the lack of crushing level. Large-caliber crusher is lacked in the existing disposal points of landscaping waste in the respective district of Shanghai, showing the relationship to the area and scale of the disposal sites. Numerous disposal points will transport large-caliber waste to other places for stacking or treatment, thereby noticeably elevating the treatment cost. Only 60%-70% of the landscaping waste generated by the public green space (mainly road green space) in Shanghai can now be treated well. Specific to park green space, since a single community or unit has the small output of landscaping waste and is unable to carry out their own disposal, landscaping waste is treated as domestic garbage or directly stacked in the corner of the community or even discarded in the road, forest belt, and some are mixed in domestic garbage or transported to other places. Thus far, the recycling treatment of landscaping waste generated by parks, courtyards and residential greenbelts has not been launched.

(4) During composting and fermentation, landscape waste is easy to produce considerable leachate, in which the content of COD and BOD is high, and a certain amount of chlorinated aromatic compounds is also contained. The soil quality and groundwater environment of the site are easy to pollute after rainwater scouring or natural settlement.

4. Conclusions and Suggestions
4.1. Synergistic disposal system
In terms of the co-processing technology of landscaping waste and domestic waste, the existing
research and application largely fall into two aspects, i.e., mixed pyrolysis and mixed fermentation. However, at this stage, there have been rare application cases of combined composting and combined pyrolysis of food waste and garden plant waste. Thus, when the relevant government departments make top-level planning to treat and dispose landscaping waste, they should consider effectively linking it with the domestic waste disposal system. By performing scientific research, the two mixed treatment technologies are efficiently integrated, advanced and efficient treatment equipment is developed, and the product quality and production capacity after the two mixed treatments are maximized.

4.2. Preparation of plans and land issues
Large parks and green Spaces can be configured with small landscaping waste disposal points. Planning departments should implement land use indicators for significant disposal points, consider the city’s planning and layout, collect landscaping waste in surrounding areas, implement full coverage, and systematically address the source problem of landscaping waste disposal.

4.3. Transportation system and processing efficiency
Fully exploit the existing collection and transportation system of the sanitation system and incorporate the landscaping wastes of public green spaces, units and residential areas into the resource utilization system. By complying with the principle of classified collection, the landscaping wastes are uniformly transported to the disposal site for unified treatment. From the very beginning, we advocate strict classification collection, classification, collection and transportation when we prune and collect garden waste, so as to maximize the use of resources and reduce the consumption of resources when we deal with garden waste.

4.4. Recycling efficiency and recycling market
To improve landscaping waste management system and commercial chain bridging, relevant government departments should provide policy, land and capital support, and the full support of the respect (e.g., tax and talent) for landscaping waste recycling system in city top layout planning and development, as well as for regeneration industry and business development. Furthermore, the departments should prove that the gestation and development of the industry has a good external factors and policy guidance.

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References
[1] Wang C, Shen G Q, Pu J, Xing T, Che L, Li Z Y 2020. Coupling anaerobic digestion and carbonization of food waste and its application prospect in landscaping, L A 14-18.
[2] Liang J, Lu Z W, Fang L 2009, Status of composting treatment of garden waste abroad and application in China, Chinese L A 1-6.
[3] Liu H Z, Chen D M 2015. On the legal regulation of recycling utilization of urban landscaping waste, Chinese L A 104-108.
[4] Chun J W, Liu H Y, Liang S W 2009. Output, collection and disposal of landscape and greening waste in Shenzhen city, Environ San Engine 47-49.
[5] Xu B, Zhao Y, Ju M T, Chu C L, Zang Z Y 2019. Regional differences of municipal solid waste generation in China based on the STIRPAT model, China Environ Sci 4901-4909.