Source-Separated Collection of Rural Solid Waste in China

Chao Zeng, Hangfen Li, Fafa Xia, Dongjie Niu, and Youcai Zhao

Abstract The rapid urbanization progress and the continuous improvement of rural residents' living standards are contributing to the increase in rural solid waste (RSW) in China. RSW generation rates range from 0.25 to 2.3 kg (capita d)$^{-1}$ in different rural areas, and the real total RSW generation amount was far higher than official data in 2014. RSW is dominated by food residue and coal ash/cinder/dust in rural China, and most of it is discarded randomly without any treatment. In this work, rural household behaviors toward RSW treatment and their perceptions in terms of awareness and attitudes on the source-separated collection of RSW are investigated with a questionnaire survey consisting of 518 valid samples. The results indicated that some rural households had spontaneously separated the recyclable waste and food waste to some extent. The public were aware of the importance of RSW separation through various media, and more than half of households were willing to participate in a separation program. The dominant barriers to participation were the lack of awareness of separation, inconvenience, and an insufficient separation facility (53.7%). 62.5% of rural households had a positive willingness to pay (WTP) for RSW separation and management, and the mean WTP was estimated to be 3.8 USD/year. Age, annual household income, and location significantly influenced the respondents' WTP. More positive policy is necessary to encourage the local government to devote efforts to provide collection service and improve RSW management by combining the governmental financial budget and rural household payments.

Keywords Characteristics, China, Informal sector recycling, Management, Public opinion, Rural solid waste, Source-separated collection

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Contents

1 Introduction

As the largest developing country with the highest population in the world, China has achieved immense achievements in terms of economic growth and urbanization process from the late 1970s to date but meanwhile has paid a heavy price in the environment and ecology. It is well known that China has devoted extensive efforts to environmental protection in recent years. Yet the former research and policies on environmental protection preferentially focused on industry and urban pollution control instead of rural areas. Currently, with the rapid development of the rural economy and social transformation, rural China is also faced with multiple environmental problems, and one of the increasingly serious consequences is rural solid waste (RSW) [1].

As is known to all, little attention has been paid to RSW in most developing countries. As a fast-developing country and the largest municipal solid waste (MSW) generator in the world, China is no exception. In earlier times, a considerable amount of RSW (especially the organic wastes) was recycled as food for livestock or fertilizer for agriculture. However, the ever-accelerating urbanization progress and the continuous improvement in rural residents' living standards contributed to the rapid increase in RSW generation. Nevertheless, the Chinese government faces great difficulties in providing RSW management services in rural China. Generally, for those rural areas in developed regions, RSW was first collected in the village and then transported to transfer stations situated in towns

or the county for downstream treatment and disposal. This mode is restricted by the cost of waste transportation in those remote rural areas. Consequently, RSW management has become a challenge to local governments.

Rural areas account for 90% of mainland China, which consist of towns and villages, the two smallest administrative levels in China under nation, province, prefecture/municipality, and county. There were 642 million people (about 47.43% of the Chinese population) in rural areas in 2012. The current social and economic backgrounds of the typical rural areas in different cities or provinces vary greatly. It is reported that the per capita net annual income varied from 652.6 to 2,578.4 USD in 2012. As mentioned before, MSW management is only practiced in cities, while RSW management is at best only partially established in some developed rural areas.

Worldwide experiences show that the source-separated collection of solid household waste is an effective method for the enhancement of waste reduction and recycling [2, 3]. It has been widely used in developed countries for the purpose of sustainable development. In 2000, a pilot program focusing on the source-separated collection of MSW was launched in eight major cities throughout China, and some successful experiences were accumulated [4]. As a key component of an integrated waste management system, it is necessary for rural households to separate RSW at the source. The source-separated collection of RSW cannot only reduce the transportation costs but also contribute to recycling waste and diverting part of the RSW from the dumping sites. However, it has not been applied broadly in rural China, with merely some pilot projects in single villages reported in casebooks or newspapers. However, it can be predicted that the source-separated collection of RSW in China is promising in the next 5 years [5].

2 RSW Generation and Composition

RSW consists mainly of organic wastes, including food and kitchen waste, and recyclable wastes including papers, plastics, glasses, metals, textiles, and leather. The nonrecyclable wastes include slag and its by-products and other hazardous wastes. Special rural waste streams, such as solid wastes produced in rural industries and agricultural and forestry waste, are beyond its scope.

2.1 RSW Generation

According to the *National Rural Environmental Pollution Prevention Planning Outline (2007–2020)*, the annual total amount of RSW generation is approximately 280 million tons. However, the newest authoritative data declared by the Ministry of Housing and Urban-Rural Development (MOHURD) of the People's Republic of China in *People's Daily*, the government's official newspaper in China, is

approximately 110 million tons, which shows a distinct divergence in annual RSW generation. Some researchers conducted a field survey to explore this issue themselves, whereas most data are based on small-scale surveys or just simple case studies of pilot projects. Some estimated results based on the rather incomplete statistics in different studies vary widely, e.g., with estimated generation of 140 million tons in 2000 [6], 180 million tons in 2005 [7], and 236 million tons in 2010 [1]. This is mostly because some differences may exist with the survey errors and statistical method. Despite some uncertainties in these results, it still reveals an increasing trend in the total amount of RSW generation. Otherwise, the RSW generation rate in nationwide rural areas also varies in different literatures, e.g., with estimated rates of about 1.34 kg (capita d)$^{-1}$ in 2003 [8], 0.9 kg (capita d)$^{-1}$ in 2006 [9], and 0.95 kg (capita d)$^{-1}$ in 2010 [1].

Table 1 presents RSW generation rates across regions of China [10], showing that most data are less than 1 kg (capita d)$^{-1}$. Similar to the estimate of RSW generation, the RSW generation rate also shows an increasing trend. It varies significantly among different rural villages across regions of China (ranging from 0.15 to 2.22 kg (capita d)$^{-1}$) and sometimes even in the same region (e.g., Beijing, Jiangsu, and Zhejiang province, respectively). In general, it implies that the rate in northern China is higher than that of southern China, and the rate in eastern China is higher than that of western China, and this result is consistent with the previous study. Several factors may account for this phenomenon: rural population and its distribution, income level, dietary habits, consumption level, etc., which are similar to the main factors that influence the MSW generation rate in China.

2.2 RSW Composition

Table 2 presents a comparison of the physical composition of RSW in various cities or provinces in China [10]. On the one hand, the proportion of RSW compositions differs dramatically, owing to differences in climate, dietary habits, culture, season, and living standards. Besides, as was reported, RSW composition (No. 6–8) was similar to MSW composition in some relatively developed rural areas of eastern China, inferring that urban lifestyle could influence surrounding rural villages. On the other hand, food residue and miscellaneous inorganic wastes, regarding coal ash, slag, and dust as well as plant ash, are the two major components of RSW. It is noticeable that waste composition in northern China is dominated by high inorganic content, achieving the highest proportion at approximately 70%. These wastes probably originate from household fuel because of heating in the cold season or the preparation and cooking of food. However, there would be a reduction in ash/soil residue content in the future, as coal will be replaced by natural gas or rural biogas [11, 12]. Besides, RSW composition in most villages in eastern China and southern China is dominated by a high proportion of organic content in terms of food residue. It can be considered that food residue will still continue to be the main component in rural China in the future. In addition to organic waste and inorganic

Table 1 Summary of the RSW generation rate in China

No.[a]	Location	Year	Survey method	Generation rate/kg (capita d)$^{-1}$
1	Beijing 1	2006	Household survey	1.5–2.1
2	Beijing 2	2010	Questionnaire	1.46
3	Shenyang, Liaoning province	2005	Household survey	0.66–2.33
4	Jilin province	2010	Questionnaire	1.25
5	Hebei province	2010	Questionnaire	1.13
6	Yixing, Jiangsu province	2002–2005	Household survey	0.15–0.30
7	Nantong, Jiangsu province	2007	Household survey	0.69
8	Fujian province	2006	Questionnaire	0.73
9	Zhejiang province 1	2006	Questionnaire	1
10	Zhejiang province 2	2008	Household survey	0.48
11	Zhejiang province 3	2010	Questionnaire	0.83
12	Chongqing	2008	Household survey	0.21–0.43
13	Anhui province	2010	Questionnaire	0.75
14	Sichuan province	2010	Questionnaire	0.73
15	Yunnan province	2010	Questionnaire	0.58
16	Guangzhou, Guangdong province	2012	Questionnaire	0.82
17	Dongguan, Guangdong province	2012	Questionnaire	0.75
18	Zhongshan, Guangdong province	2012	Questionnaire	0.58

[a]No. 1–5 belong to northern China, No. 6–11 belong to eastern China, No. 12–18 belong to southern China

waste, there is a certain amount of recyclable waste, indicating a trend of urbanization and economic development.

2.3 *Comparison of Characteristics Between RSW and MSW in China*

Figure 1 presents a brief comparison of generation rates between RSW and MSW in China. Surveyed RSW data are selected in Table 1, with the corresponding MSW data of their administrative city or province in 2008 obtained in the literature [13]. It is clear that most MSW generation rates are substantially higher than in their

Table 2 Comparison of typical RSW compositions in different regions across China/wt. %

No.[a]	Location	Year	Food residue	Plant ash	Coal ash, cinder, dust	Paper	Plastic	Glass	Metal	Textiles	Wood	Hazardous waste
1	Beijing 1	2006	26.28	–	58.97	3.94	5.48	0.9	0.16	1.16	3.05	–
2	Beijing 2	2013	36.84	–	35.43	4.2	12.81	2.69	1.33	5.76	0.95	–
3	Shenyang 1, Liaoning province	2005	4.43	25.46	68.57	0.08	0.14	0.97	0.03	0.13	0.19	–
4	Shenyang 2, Liaoning province	2005	81.25	–	–	4.92	8.71	0.27	2.62	1.13	1.1	–
5	Yixing, Jiangsu province	2004	62.7	–	8.9	4.1	21.2	0.8	0.1	2.2	–	–
6	Danyang, Jiangsu province	2006	30.9	–	47.68	2.21	1.52	2.44	0.42	2.59	9.39	–
7	Nantong, Jiangsu province	2007	49.4	–	29.1	3.3	8.6	2.4	2.2	3.8	–	1.3
8	Zhejiang province	2006	69	–	–	9	15	4	1	–	–	–
9	Yunnan province	2012	55.07	–	15.91	8.37	8.28[b]	1.55	0.1	0.37	9.26	–
10	Macheng, Hubei province	2013	12.38	–	53.09	6.73	15.16	3.54	1.56	4.52	2.84	0.38

[a]No. 1–4 belong to northern China, No. 5–8 belong to eastern China, No. 9–10 belong to southern China
[b]8.28 represents rubber here

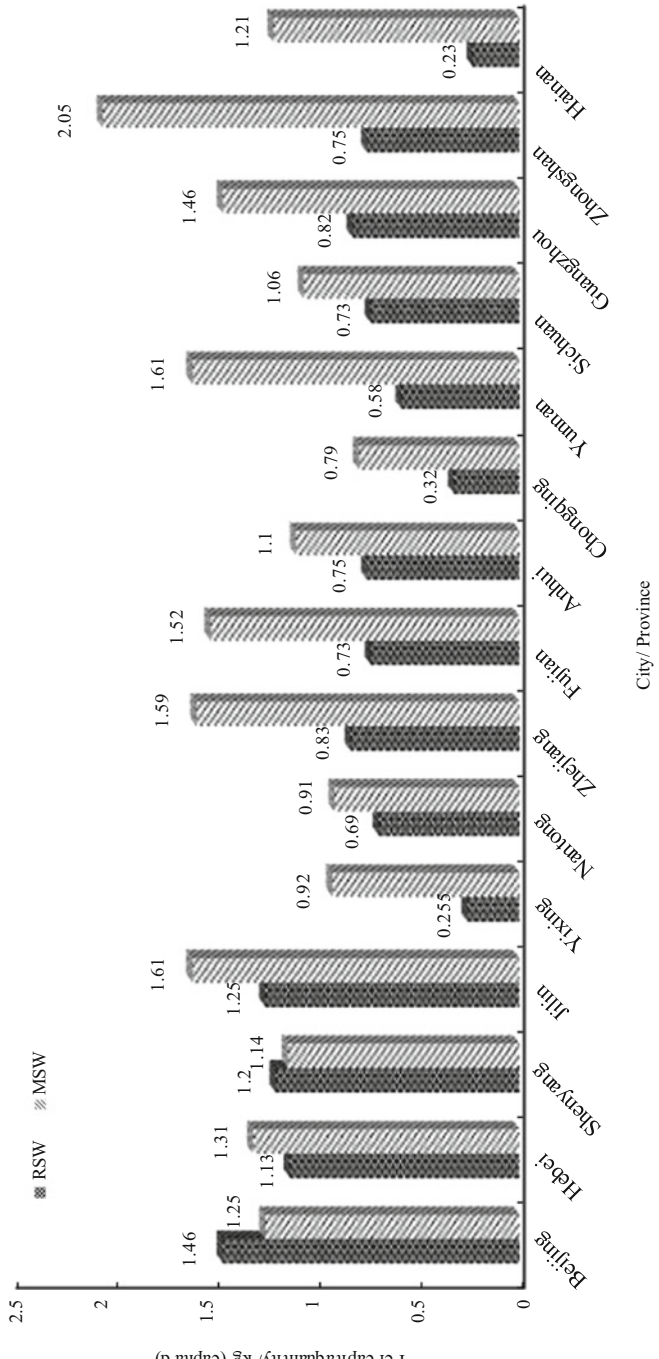

Fig. 1 Comparison of the generation rates between RSW and MSW in China

corresponding rural areas except for the provinces of Beijing, Shenyang, and Hebei. There is a possibility that official MSW data is slightly lower than the reality, while RSW data is probably higher than previously discussed. Although the generation rate of RSW is much lower than that of MSW, rural China faces greater difficulties in RSW management and service support in rural areas than that of MSW in urban areas.

Based on Table 2, it is observed that the compositions of RSW and MSW are extremely homogenous. Generally, waste composition in rural China is dominated by ash and organic waste, as analyzed previously. In contrast, the overwhelming majority of MSW composition is organic waste (more than 50%). Besides, the proportions of recyclable compositions in RSW are far less than that of MSW. Indeed, with the urbanization and rapid economic development of rural China, the proportion of recyclable waste will definitely increase in the future.

Applying the MSW management method would be unconscionable for rural China. Since the generation rates and compositions of RSW are diversified across regions, it would be necessary for local governments in different regions to adjust the RSW management approaches, including the methods of source-separated collection of RSW according to local conditions. Hence, considering the similarities of the RSW generation rate and the composition in rural areas of the same region, such as southern China, northern China, or eastern China, solutions can be focused on separately [10].

3 Current Status of RSW Management

3.1 RSW Collection, Separation, and Recycling

For rural China, one of the most popular means of RSW collection is carried out by the specific collection containers offered by local authorities. A centralized facility at roadside, usually called a refuse chute, which is made of cement or is just a natural pit, has been widely introduced, while in developed rural areas, outdoor trash cans have been widely implemented, which can reduce the risk of waste exposure, mosquito and fly growth, as well as odor occurrence. In addition, in many rural areas, such as small and remote villages, or in hilly or mountainous areas, RSW is not considered in the modern waste management system.

Systematic RSW separation and recycling are not implemented in rural areas, whereas only several pilot programs have been reported. As reported that MSW is collected in a mixed state in China [11], it likewise holds true for RSW that all sorts of RSW is mixed together and thrown into the refuse chute. Nevertheless, there is a voluntary source-separated collection of recyclables that exists for rural residents or scavengers.

Similar to MSW recycling [11, 14], informal sectors including some rural residents or scavengers are also involved in the collection, processing, and trading

of the recyclable waste to buyers, who call door to door or sometimes deliver recyclables to the service sites themselves in order to exchange money. The buyers then store and, in turn, sell the recyclables to an upper level of recycling service sites in the county or somewhere else. Finally, recyclable waste is provided for the demands of industry as raw or processed material. Nevertheless, the amounts of recyclable waste informally picked out of the RSW stream are unknown.

3.2 RSW Treatment and Disposal

China initially established the fundamental mode of household separation, village collection, township transfer, and county treatment in some provincial pilot programs (not very far from the urban region) for RSW management, which has achieved noticeable progress (Fig. 2). In 2010, the first list of 28 counties (districts or cities) was released to the public by MOHURD due to the full coverage of RSW treatment at the county (district and city) level. The distribution of these 28 countries is shown in Fig. 3. These areas were mainly in relatively developed regions, including the Beijing, Jiangsu, Fujian, Anhui, and Guangdong provinces. However, the implementation of this mode in most remote rural areas was restricted by many factors, for example, the high transport cost and the lack of manpower and budget to supervise at the bottom of the local authorities and the local environmental protection bureau.

After being transported to the county or above the county level for downstream treatment and disposal, the applied technologies are mostly the same as that of MSW, including sanitary landfill, incineration, and composting. Table 3 lists the application status of MSW treatment technologies in China in 2012, showing that sanitary landfill is the dominant disposal method.

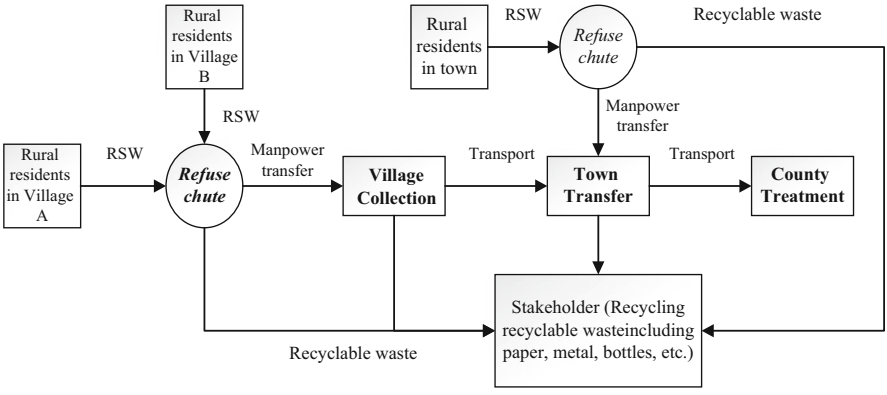

Fig. 2 Framework for the mode of household separation, village collection, township transfer, and county treatment for RSW management

Fig. 3 Locations of 28 counties (districts or cities) for the full coverage of RSW treatment at the county (district and city) level

Table 3 Application situations of MSW treatment techniques in 2012

Technology	Landfill	Incineration	Other
Facility quantities	540	138	23
Proportion (%)	77	19.7	3.3
Harmless disposal capacity (tons/day)	310,927	122,649	12,692
Harmless disposal amount (10^4 tons)	10,512.5	3,584.1	393

In addition to the formal mode for RSW management, however, most RSW is discarded randomly, incinerated temporarily, or dumped on the river banks and the roadsides, often without any initial treatment but generally with agricultural and forestry waste, industrial solid waste, and even with household hazardous waste, which not only takes up land but also causes contamination and secondary pollution. For instance, as a disposal method, hazardous waste paints, cleaners, varnishes, batteries, and pesticides are often mixed with household waste [15]. Although its amount is small, it can cause considerable negative impacts on human health.

3.3 Case Study: The Town of Guoyuan in Changsha County, Hunan Province

Changsha County in Hunan Province is well known in China for the reputation of the Top One County of central China. It was chosen to be 1 of the 18 representative areas during reform and openness by the government. The first environmental protection cooperative was established in the town of Guoyuan in Changsha County in 2008, the highlight of which was that the cooperative purchased RSW from rural households and promoted the rural residents' participation for waste recycling and collection. It established collection spots in every village, and the prices for recyclable waste of plastics, batteries, and glasses were 0.04 USD kg^{-1}, 0.09 USD kg^{-1}, and 0.01 USD kg^{-1}, respectively. Moreover, the local government provided a subsidy of 0.43–0.72 USD to the rural households that participated. In 2012, the total financial investment in Changsha County reached 3.6 million USD, which improved the serious situation of RSW management.

From 2011 on, the cooperative upgraded the mode of household collection to household separation and required rural residents to dispose of food waste by composting themselves in order to conserve financial budgets. Otherwise, after being separated and collected, RSW would be separated again before the town transfer. Finally, an amount of less than 10% RSW was sent to the county for downstream disposal. In particular, it was estimated that the total waste disposal expense decreased from 4.4 million USD to 434.9 thousand USD [16].

3.4 Problems and Challenges in RSW Management

3.4.1 Decentralized Multiple Generation Sources

RSW management is confronted with a dilemma of a large amount of total generation nationwide that is decentralized across regions, which significantly increases the costs of waste collection, transportation, treatment, and disposal. Therefore, informal collection and recycling still play a significant role in rural

areas. RSW treatment is going through a critical phase because suitable technology is unavailable, e.g., some have fatal drawbacks like geographical restrictions, high costs for operation, or a strong preference for one kind of waste, while some can achieve benefits only under a certain processing scale. Based on this, it is possible that RSW pollution is more serious than that of MSW.

3.4.2 Poor Infrastructure Construction

RSW management infrastructures include collection, transport, treatment, and disposal facilities like trash cans, vehicles, transfer stations, etc. Refuse chutes at roadsides for RSW collection are not enough at all. Poor infrastructure significantly contributed to the fact of irresponsible dumping of RSW. As a result, the phenomenon of *Garbage Besieging Villages* is often reported. And worst of all, it is still far from enough to make up for the inadequacies nationwide.

3.4.3 Imperfect Legislation System

The primary formulated legal system for RSW still has many shortcomings, because most of the legislation and administrative regulations were intended to treat the MSW, which essentially did not consider the RSW characteristics in China. Besides, specific national guidelines to enforce published laws are absent in Chinese laws; hence the unclear responsibility mechanism makes it more ineffective in RSW management. Moreover, there are many equivocal words in the related laws and regulations of RSW, such as *should*, *recommend*, *encourage*, and *can*, which mitigate against implementing these laws. Like so much in China, the legislative process of environmental protection is always led by the government, while the part of public participation is often overlooked.

4 Public Opinion Toward the Source-Separated Collection of RSW

China faces a different situation in RSW management than other developed countries. Meanwhile, the way of source-separated collection of solid waste in rural areas is different from urban areas in China. Generally, an individual is either active or reluctant to participate, mainly due to personal environmental beliefs. Therefore, rural residents' public opinion toward the source-separated collection of RSW was

examined for a better implementation of the program in the future, based on a well-designed questionnaire and face-to-face interviews [5].

4.1 Empirical Design of the Questionnaire

The questionnaire was based on focus group discussions among the professors, doctoral candidates, and postgraduate students of Tongji University, who devote themselves to research on solid waste management, and specifically, most of them were born in rural China, so they are familiar with rural residents. After a series of group discussions, the questionnaire was drafted, then evaluated, and modified by two experts who devote themselves to rural issue studies and surveys. A pretest on 12 rural residents was conducted in order to uncover possible misinterpretations of the questions and to determine the bids in the final questionnaire.

The questionnaire consisted of four parts.

- The first part included questions related to the behaviors and perceptions of rural households toward RSW treatment and disposal and whether they were satisfied with local RSW management.
- The second part included a series of questions about the attitudes, awareness, and knowledge toward the source-separated collection of RSW. The respondents were interviewed about the importance of RSW separation, the sources of information about RSW separation, and their willingness to participate. Rural households who gave positive feedback were further requested to choose an acceptable waste separation category, while those who were not willing to participate, or willing to participate but could not participate in waste separation continuously, were requested to answer a follow-up question on the reasons for their choice.
- The third part included questions about respondents' willingness to pay (WTP) for RSW separation and management. In order to avoid the impatience of rural residents during the interview, this study used a payment card format rather than the dichotomous choice format. For respondents' better understanding, a specified scenario was given as follows: In order to create a better rural environment, the implementation of RSW source separation and environmental management will need a cost. Although the government may finance this program, it may not be enough. In case the village committee or community requests your family to pay for the program every month, are you willing to pay for it? Respondents, who answered yes, were then confronted with five bids (0.14, 0.29, 0.43, 0.58, and 0.72 USD) and requested to choose their maximum WTP for the program, while those who were not willing to pay were required to describe the reasons for the choice.
- The fourth part collected respondents' socioeconomic information, including gender, age, education, annual household income, local resident population, and dwelling place, which was used to determine the personal attributes.

An empirical model – a logistic model – was applied to examine the factors that affect the WTP of the rural households toward the RSW separation and management. The model is shown as follows:

$$\text{Log}\, P_i/(1-P_i) = Z_i = \beta_0 + \beta_i X_i + e$$

where $P_i = 1$ if the respondent is willing to pay for the RSW separation and management; otherwise, $P_i = 0$; β_0 = constant term; β_i = the coefficient of independent variables; X_i = a vector of explanatory independent variables; and e = a random error term. The independent variables of this model are gender, age, education, annual household income, local resident population, and location and perception of RSW treatment, and the model can be expressed as below:

$$\begin{aligned}\text{WTP} = {} & \beta_0 + \beta_1 \text{Gender} + \beta_2 \text{Age} + \beta_3 \text{Education} + \beta_4 \text{Income} + \beta_5 \text{Population} \\ & + \beta_6 \text{Location} + \beta_7 \text{Perception} + e\end{aligned}$$

Assuming that negative values do not exist for RSW separation and management, the mean WTP is calculated by using the formula of

$$\text{WTP} = \left(\sum (P_i \times N_i)\right)/N$$

where P_i = rural household's average acceptance of bid (USD/month); N_i = No. of rural households that accepted the average bid; and N = No. of rural households that gave a positive WTP.

4.2 Survey and Sampling Method

With special considerations on geographical distributions, socioeconomic characteristics, and budget constraints, the survey was carried out in 2 months (from January to February 2015) in three regions of mainland China, including the eastern region (Shandong, Jiangsu, Zhejiang, Fujian, and Guangdong Province), central region (Shanxi, Anhui, Henan, Hubei, and Hunan Province), and western region (Guizhou Province and Chongqing City). Locations of surveyed rural areas are presented in Fig. 4. In each province, at least one town consisting of several villages was chosen randomly to survey. To ensure that the results are representative of the entire region, the interviewees were randomly selected among the villages. Specifically, all respondents were from the village. Meanwhile, the interviewee was aware of the overall situation of his/her household.

Special attention was paid on two points. Firstly, face-to-face interviews were conducted in the research. Secondly, instead of an individual basis, rural households were chosen as the unit of sample and analysis. During the survey, the interviewer was guided by a village cadre (i.e., village party secretary, village head) who understood the dialect and was acquainted with local residents. Thirteen

Fig. 4 Locations of surveyed rural areas

postgraduate students and doctoral candidates who major in environmental engineering at Tongji University participated in the interviews. A total of 541 questionnaires were received, and 518 valid questionnaires (95.75%) were obtained after removing the questionnaire in which the respondents misunderstood the questions (including incomplete or inconsistent questionnaires). Sample distributions are as follows: 188 questionnaires were collected from 8 towns with 16 villages in the eastern region, 252 questionnaires from 7 towns with 14 villages in the central region, and 78 questionnaires from 2 towns with 4 villages in the western region.

To supplement the information obtained from the survey, some informal discussions were held with local cadres (i.e., village party secretary, village head), rural residents, informal sectors, and waste transfer workers in various villages to obtain a better knowledge of real situations and collect as many public perceptions as possible.

4.3 Socioeconomic Characteristics of Respondents

Socioeconomic characteristics of the respondents are presented in Table 4. The respondents were 56.8% male and 43.2% female. 66.5% of respondents were

Table 4 Socioeconomic characteristics of the respondents

Item	Response	No. of respondents	Percentage (%)
Gender	Male	294	56.8
	Female	224	43.2
Age group (year)	18–25	133	25.7
	26–35	114	22.0
	36–45	108	20.8
	46–60	123	23.7
	>60	40	7.7
Education	Primary school or lower	55	10.6
	Junior high school	211	40.7
	Senior high school or secondary technical school	116	22.4
	Junior college	56	10.8
	Undergraduate or above	80	15.4
Annual household income	0 USD up to 1,450 USD	54	10.4
	1,450 USD up to 2,899 USD	107	20.7
	2,899 USD up to 4,348 USD	116	22.4
	4,348 USD up to 5,798 USD	57	11.0
	>5,798 USD	184	35.5
Local resident population	1	7	1.4
	2	75	14.5
	3	147	28.4
	4	124	23.9
	5	109	21.0
	6	30	5.8
	7	14	2.7
	8	4	0.8
	9	5	1.0
	10	3	0.6

between 26 and 60 years old. Only 15.4% of respondents had any higher education. The average local resident population in one rural household was 3.91, probably revealing a consequence of the One Child Policy. Only 35.5% of the rural households had an annual income higher than 5,798 USD. That might be because some respondents were conservative and unwilling to answer with their real income.

4.4 Behaviors and Perceptions Toward RSW Treatment

Rural household behaviors toward RSW treatment and disposal were investigated, and 65.1% of rural households dumped RSW into the refuse chute or trash bin, but only a few villages in the eastern region had well-controlled collection,

transportation, and treatment of RSW. 14.29% of rural households burned RSW out in the open without any pollution control system. 31.08% of rural households just dumped RSW on the moat banks and the roadsides, even without any initial treatment.

The potential of source separation behavior with RSW in rural households was also investigated and was shown in Table 5. The percentages of mixed dumping for food waste, recyclable waste, and hazardous waste were 67.8%, 21.9%, and 75.1%, respectively, which reveals that most RSW is dumped mixed. Owing to Chinese eating habits, one of the main fractions of RSW is food waste [10]. It was also found that good potential for the in situ utilization of food waste existed, as rural households used food waste for composting or biogas production (4.5%) and animal feed (15.5%). Meanwhile, 75.8% of rural households sorted out their recyclable waste for selling. Similar to MSW recycling in China, rural households are used to trading the recyclable waste to buyers who are called door-to-door traders (50.3%) or sometimes selling waste to the service sites by themselves (25.5%). This evidence proves that some rural households do have the behaviors of source-separated RSW collection, although most of them only separate their recyclable waste.

The respondents were requested to comment on the status of RSW treatment and disposal in their village. Only 23.8% of the respondents were satisfied with the RSW treatment in their villages. The result indicates that is mostly because local governments invest in the construction of refuse chutes or provide trash cans only. These collection and storage facilities strengthened the pollution control of RSW.

Table 5 Initiative behaviors toward different kinds of RSW in rural households

Items	No. of rural households	Percentage (%)
Food waste		
No food waste was produced and dumped	63	12.2
Used for composting or biogas, feedstuff, etc.	23	4.5
Partially used for livestock and poultry feed, the rest dumped	80	15.5
Mixed dumping	350	67.8
Recyclable waste		
Delivered to the recycling collection sites in the village	132	25.5
Waited for informal sectors' door-to-door service	260	50.3
Mixed dumping	113	21.9
Other	12	2.3
Hazardous waste		
Sent to specialized sites for hazardous waste	38	7.3
Discarded randomly, such as in fields, on river banks and roadsides, etc.	75	14.5
Mixed dumping	389	75.1
Other	16	3.1

Meanwhile, the percentages answering "average" and "unconcerned" were 30.0% and 7.7%, respectively. However, more respondents (38.5%) were unsatisfied with RSW management. The reasons could be summarized as follows: no specific worker was responsible for the collection and cleanup of RSW, the storage room (i.e., refuse chute, trash can) was close to their home, and the foul odor from the storage room created dissatisfaction. It indicates that RSW management is neglected or out of order in these areas. The interviewees also regarded RSW as one of the most serious environmental problems, which echoed the findings of previous research [4, 17, 18].

4.5 Awareness of the Environment and Source-Separated RSW Collection

In recent years, the central government has placed growing attention on the pollution in rural China. A series of laws and regulations related to RSW have been issued. Some pilot programs have been launched to find a feasible and suitable treatment process in different rural areas [10]. During the survey, it was found that in some rural areas, also public is aware of the source-separated collection of RSW. However, 10.4% of respondents were not conscious of the importance of the source-separated collection of RSW, while most respondents, accounting for 75.0%, considered that RSW separation could alleviate environmental pollution and negative health impacts. Meanwhile, 45.1% of respondents thought that they could separate recyclable waste for selling, and 44.1% knew that RSW separation could reduce the quantity of disposed RSW and save transportation expense. Although a relatively high awareness is not necessarily consistent with practical actions [19], it will be a basis for implementing the program of RSW separation at the source in rural China in the future. This result indicates that the difference in people's awareness on the importance of waste separation between rural residents and urban residents is not obvious in China, compared with previous studies [18].

The sources of information on source-separated RSW collection are summarized in Table 6. 72.7% of respondents obtained their knowledge from television and 31.6% from the newspaper. It was found that internet and community education are

Table 6 Sources of information about source-separated RSW collection

Response		Newspaper	Television	Radio	Community education	Others	Internet	Other
No.		162	372	67	96	78	120	18
Age groups (year)	18–25	64	112	19	23	30	57	9
	26–35	39	86	14	14	13	31	5
	36–45	29	74	16	22	16	15	0
	46–60	23	75	9	31	15	14	2
	>60	7	25	9	6	4	3	2

also popular, which is probably related to personal habits. For instance, younger respondents widely use the internet, while middle-aged respondents are more easily impressed by the policy and education in the village. However, it was found that the community education of source-separated RSW collection is very shallow and lacks implementation. These results suggest that a sufficient publicity program that includes public education and various media sources should be introduced by the local government to help raise more awareness toward the source-separated collection of RSW.

4.6 Attitudes Toward Source-Separated RSW Collection

As presented in Table 7, the attitudes toward source-separated RSW collection were generally positive. More than half of rural households (61.3%) declared that they were willing to participate in the program. Moreover, 47.9% of rural households agreed to separate RSW into the four categories "food waste, recyclables, dry waste, and hazardous waste." However, 25.0% of the rural households were willing to participate in source-separated RSW collection but probably couldn't commit to the source-separated collection of RSW continuously, and 13.7% clarified that they refused to participate. The detailed obstacles were also investigated and presented in Table 7.

A more detailed survey of barriers of rural households for RSW separation was carried out, and the results are present in Fig. 5. Rural households among the three regions considered the lack of separation awareness (64.9%) to be the major barrier to implement the program of RSW separation at the source. Complications,

Table 7 Comparison of different attitudes toward RSW separation participation

	No. of rural households	Percentage (%)
Positive participation	317	61.3
Rejection of participation	71	13.7
Inconstancy of participation	129	25.0
Positive participation		
Food waste, recyclables, dry waste, hazardous waste	152	47.9
Recyclables, hazardous waste, other waste	83	26.2
Food waste, dry waste, hazardous waste	45	14.2
Recyclables, nonrecyclables	37	11.7
Rejection of participation or inconstancy of participation		
Negative neighbor effect	33	16.5
Complication and inconvenience of separation	111	55.5
Mixed transport and disposal after separating at source	37	18.5
Other	19	9.5

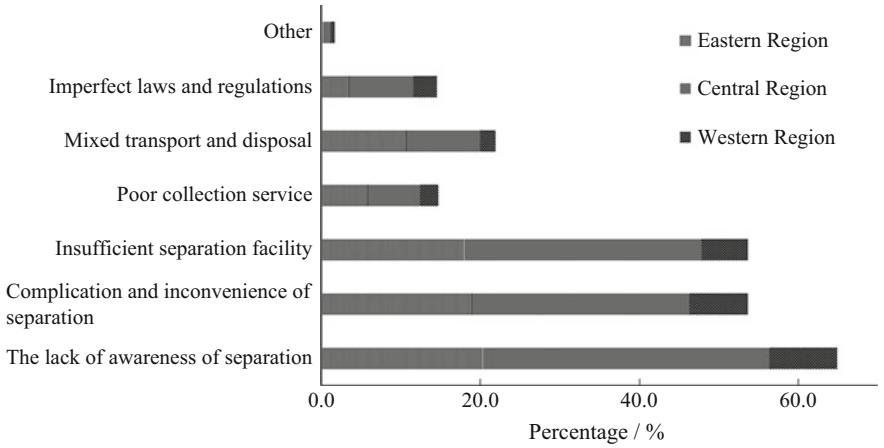

Fig. 5 Rural household barriers to RSW separation

inconvenience of separation, and insufficient separation facilities accounted for the same percentage of 53.7%, both of which were the second major barrier and might have a great influence on people's participation. Therefore, it is essential to provide sufficient separation facilities (i.e., garbage cans, storage room) for RSW separation and improve rural households' awareness, which is vital to public participation.

4.7 Estimation Results of WTP Toward RSW Separation and Management

The rural households who were willing to pay for RSW separation collection and management are regarded as having a positive WTP, and their opinions on the cost and payment method were also investigated. Otherwise, if they were unwilling to pay, they were asked a follow-up question concerning the reasons. The rural households who answered "have no extra money," "do not believe that RSW source separation and management would bring desired changes," or "refuse to pay, but otherwise would participate in RSW separation collection" are regarded as having a valid zero WTP. The rural households who answered "it is government's responsibility to improve RSW source separation and treatment" or "those households who throw away RSW should be responsible to pay," as well as "other," are treated as having rejected the contingent market. The WTP values of the rural households in these categories are summarized in Table 8. In total, 324 rural households (62.5%) reported a positive WTP, while 140 rural households (27.0%) reported a valid zero WTP, and only 54 rural households (10.4%) reported a rejection of the contingent market.

Table 8 Comparison of positive WTP, valid zero WTP, and rejection of contingent market

Comparison of positive WTP, valid zero WTP, and rejection of contingent market	No. of rural households	Percentage (%)
Positive WTP	324	62.5
Valid zero WTP	140	27.0
Have no extra money	38	7.3
Do not believe that RSW source separation and management would bring desired changes	64	12.4
Refuse to pay but otherwise would participate in RSW separation collection	38	7.3
Rejection of the contingent market	54	10.4
It is the government's responsibility to improve RSW source separation and treatment	33	6.4
Those households who throw away RSW should be responsible for paying	16	3.1
Other	5	1.0

Table 9 Results from the binary logistic regression (WTP >0, $n = 324$)

Variables	*B*	S.E.	Wals	df	Sig.	Exp (*B*)
Gender	0.192	0.194	0.987	1	0.320	1.212
Age	0.285	0.099	8.225	1	0.004***	1.330
Education	−0.066	0.108	0.366	1	0.545	0.937
Annual household income	−0.168	0.075	5.020	1	0.025***	0.845
Local resident population	0.097	0.066	2.168	1	0.141	1.102
Location	−0.722	0.159	20.641	1	0.000***	0.486
Perceptions of RSW treatment	0.050	0.106	0.225	1	0.635	1.052
Constant	−0.045	0.861	0.003	1	0.958	0.956
−2LL	636.403					
Cox and Snell R square	0.088					

***Significant at $p \leq 0.05$

Factors that affect the rural households' WTP toward the RSW separation and management were explored by using a logistic regression model (as described before). The respondents who were willing to pay for RSW separation and management and selected their WTP were given the value of "1," while those who were unwilling to pay were given the value of "0." Results from the binary logistic regression are presented in Table 9. It was found that respondents' age, annual household income, and location significantly influenced the WTP (at the 5% level). Besides, the correlation between WTP and annual household income as well as location was negative, while the correlation between WTP and age was positive. The results obtained in this research show that a considerable portion of respondents with higher incomes in the eastern region of China had a lower WTP than that of other regions. However, it was regarded that those with a higher household income have the ability to pay [18]. Such a discrepancy could be explained as the

result of the situation that RSW management systems in higher GDP areas are running better, and the rural households there usually have already paid for waste management. Those with lower incomes usually face more serious RSW pollution, and hence they are more likely to pay for RSW separation and management in order to improve the environment. The elder respondents were more likely to pay, and this was because older people are often involved in RSW treatment and disposal and thus are more concerned about environmental quality. The results suggest that it is important to consider regional differences, including location and GDP, when implementing the program of RSW separation at the source. Meanwhile, targeted public education can be adopted to involve young people and those with higher incomes in the program.

The estimated mean WTP toward the RSW separation and management is 0.32 USD/month, meaning a rural household in the entire sample would support approximately 3.8 USD/year. This result is lower than that of previous studies about the estimation of WTP toward RSW management in rural China [17]. Based on this result, one can see that the economic development and levels of RSW management between rich rural areas and poor rural areas are unbalanced. The WTP for source-separated RSW collection is related to the GDP and waste management level. In some rich rural areas, the public is more satisfied with the current RSW management system and environmental quality than in those low-income rural areas. So currently, the urgent effort is to establish an RSW management system in poor rural areas as a priority, rather than the improvement of RSW management in rich rural areas. This assumes there are approximately 10,000 rural households in a representative town. The aggregate value of WTP in rural households would be $(10{,}000 \times 3.8) = 380{,}000$ USD, which shows considerable potential for local governments to provide services for RSW separation and management.

4.8 Policy Suggestions

To reduce the RSW pollution in rural China, the following measurements could be considered.

Firstly, policymakers should take the opportunity to transform rural households' willingness and awareness into action, because rural households urgently expect the government's effort on RSW management, and they have a strong intention to support source-separated RSW collection. Based on the current situation, it is feasible to implement a pilot program of RSW separation at the source in rural China.

Secondly, policymakers should consider the cost and financial support, especially for the facility and collection service of the program of RSW separation at the source. This is also the concern of rural households. It is therefore of utmost importance to add state allocations to rural households to implement the program. Local governments should also examine the number of WTP budgets for RSW separation and management, although an appropriate payment, according to the

survey, would be acceptable to most rural households. Two payment methods, including "pay by amount of RSW" and "equal charge standard for every household," are more popular, accounting for 37.3% and 34.6% of the rural households (among those willing to pay), respectively.

Continuous efforts to raise public concerns about environmental awareness and behaviors through education and publicity, including RSW separation, reduce, reuse, and recycle, should be made as soon as possible. The discrepancies of villages across rural areas are also worth considering. Similar investigations are needed for the future implementation of source-separated RSW collection accordingly, since public perceptions and determinants may be different across regions due to the disparity of socioeconomic backgrounds.

5 Recommendations and Expectations for the Future

In recent years, China has recognized the critical situations of RSW and has devoted considerable efforts to promoting RSW management. As a result of the improvement of related laws and regulations, financial support, and investment infrastructure, RSW management is relatively developed. However, the RSW management system still represents smaller parts of rural areas. RSW characteristics differ considerably across regions of China, since the survey results of RSW generation rates range from 0.25 to 2.1 kg (capita d)$^{-1}$. The fundamentally formal separation of waste in households, village collection, township transfer, and county treatment for RSW management has been partially established in rural areas.

Since most of the RSW is still discarded randomly without any initial treatment, source separation and waste recycling are regarded as effective methods to minimize waste from the source. Based on the investigation of public perceptions on source-separated RSW collection in rural China, it can be concluded that most respondents are aware of the importance of RSW separation and more than half of rural households are willing to participate in the separation program. The WTP for RSW separation and management is significantly influenced by respondents' age, annual household income, and location. Here, the mean WTP is estimated to be 3.8 USD/year. To improve RSW management in rural China, especially in poor rural areas, the establishment of a waste separation system is an urgent duty. The separation method (waste category, sorted waste collection schedule, etc.) needs further research. After collected separately from residents, the inorganic waste and nonrecyclable waste can be separated in the village again. Finally, different wastes can be separately treated and disposed of according to local conditions. On-site treatment of RSW in villages or towns could help to reduce the cost of waste transportation.

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