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Residents' Household Solid Waste (HSW) Source Separation Activity: A Case Study of Suzhou, China

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Abstract: Though the Suzhou government has provided household solid waste (HSW) source separation since 2000, the program remains largely ineffective. Between January and March 2014, the authors conducted an intercept survey in five different community groups in Suzhou, and 505 valid surveys were completed. Based on the survey, the authors used an ordered probit regression to study residents' HSW source separation activities for both Suzhou and for the five community groups. Results showed that 43% of the respondents in Suzhou thought they knew how to source separate HSW, and 29% of them have source separated HSW accurately. The results also found that the current HSW source separation pilot program in Suzhou is valid, as HSW source separation facilities and residents' separation behavior both became better and better along with the program implementation. The main determinants of residents' HSW source separation behavior are residents' age, HSW source separation facilities and government preferential policies. The accessibility to waste management service is particularly important. Attitudes and willingness do not have significant impacts on residents' HSW source separation behavior.

1. Introduction

Household solid waste (HSW) management is a great challenge in urban areas around the world. Additionally, source separation is widely accepted as a key method for minimizing waste and enhancing recycling and disposal efficiency [1,2]. Some developed countries, such as Japan, have achieved great success in HSW source separation. For example, in 2008, the number of waste separation categories was over 25 in some municipalities in Japan [3].

China, the world's second largest generator of municipal solid waste (of which HSW is the main part), has not experienced successful HSW source separation in any cities [4]. Though the Ministry of Construction (MC) launched a pilot program in eight major cities (*i.e.*, Beijing, Shanghai, Shenzhen, Guangzhou, Guilin, Hangzhou, Nanjing and Xiamen) in 2000 to explore HSW source separation, all of the pilot cities have experienced very slow progress toward improving their HSW source separation systems [1,4–7]. However, the Chinese government has not given up attempts on HSW source separation. According to the *Construction Plan for Harmless Treatment Facilities in the Twelfth-Five-Year Period* (2012), the Chinese government will invest a total of 21 billion RMB (U.S. $3.4 billion; 1 U.S. dollar = 6.2 RMB) in the HSW source separation field from 2010–2015.

Therefore, doing research on HSW source separation in China is significantly important for giving suggestions for its future improvement. HSW source separation refers to the separation of HSW into several categories at the generation phase before further treatment. The main body of source separation activity is the community resident. Many researchers have studied the determinants of residents' source separation or waste recycling activities all over the world. Matsumoto made a detailed literature survey of previous works, and he summarized that residents' recycling/source separation activities for HSW may be mainly influenced by five kinds of parameters: socio-demographic variables, pro-environmental attitude, opportunity cost, recycling knowledge and social norms [3].

Many previous studies on the socio-demographic variables have found that: women are more involved in recycling than men [8,9]; high-income people engage in recycling more than low-income people [9,10]; well-educated people engage in recycling more than less-educated people [11,12]; and elderly people cooperate better with waste reduction efforts than younger ones [12,13].

Majority studies on pro-environmental attitudes have found little or no correlation between general environmental concern and recycling [9,14]. Studies on opportunity cost have found significant positive correlations between the opportunity cost (*i.e.*, time and energy-cost, adequate interior space, and distance to recycling/separating bins) and people's environment activities [15–18]. Studies on recycling knowledge have found that knowledge can predict the recycling behavior of respondents [19,20]. Studies on the social norms have found that social norms determine recycling behavior [14,21].

However, in China, only a few studies have been conducted to evaluate the waste source separation activity for the eight pilot cities [6,22]. Yang *et al.* [22] have established a mathematical model of source separation activity (MSSA) that correlates residents' source separation ratio with separation facilities, awareness, separation transportation, participation atmosphere, environmental profit, sense of honor and economic profit. They also applied the model for the calculation of the source separation ratio of residential communities, office buildings and primary and middle schools in Beijing. They found that the HSW source separation in residential communities is the hardest part in MSW; its separation ratio is much lower than the other two.

Zhuang *et al.* [6] studied residents' correct HSW separation rate and its impact factors in Hangzhou by using a questionnaire survey. They found that residents' knowledge is very closely related to the HSW correct separation rate. However, the study only examined the relationship between residents' correct HSW separation rate and their knowledge. Other variables are not considered.

The findings and limitations of these previous research studies have set a good basis for this study, especially for the selection of determinants on residents' HSW source separation behavior. This study designed the determinants in three aspects with 17 variables, as defined in Section 2.3. However, all of the above research studied residents' HSW source separation activity in the eight pilot cities in China. Even fewer studies have studied residents' source separation activity in non-pilot cities [23]. Chu, taking Harbin as a case, studied the correlation of residents' HSW recycling behavior with environmental attitudes, convenience, information, knowledge and economic incentives, by reliability analysis and logistic regression analysis; and it was found that neighbors' affection, residents' responsibility, recycling location and information are important factors in recycling behavior [23].

However, some non-pilot cities have also carried out HSW source separation as early as the pilot cities, such as Suzhou. Suzhou is a coastal city in Jiangsu Province in eastern China and also is one of the most important cities in the Yangtze River Delta. Though Suzhou was not a pilot city chosen by the central government in 2000, it located very close to three pilot cities (*i.e.*, Shanghai, Hangzhou and Nanjing). Suzhou started building its HSW source separation system in 2000. During 2000 to 2010, Suzhou invested 12 million RMB (U.S. $1.9 million) in MSW (including HSW) source separation, but with very limited effects [24]. From 2007 to 2012, the amount of MSW collected in the urban area of Suzhou increased 41%, from 2848 tons per day to 4,030 tons per day. Food waste is the main part of HSW, accounting for 60%–69% [24,25]. Since 2012, the Suzhou government has issued a series of new regulations and has increased the intensity of HSW source separation pilot programs. In 2012 and 2013, Suzhou launched pilot programs in 25 and 197 communities respectively. Furthermore, it planned to invest another 46.6 million RMB (U.S. $ 7.52 million) in MSW source separation during 2010 to 2015. The HSW source separation in Suzhou is developing quicker and quicker [25].

In addition, as many Chinese cities have carried out HSW source separation pilot programs for more than 10 years, the HSW source separation system in different communities of the same city is not the same. However, no researchers have considered the difference among community groups, and all have treated the entire city as a whole in their studies.

Thus, this study fills the gap by investigating residents' HSW source separation activities among five different community groups in Suzhou. These five community groups already existed according to the implementation of the HSW source separation program. In this study, the authors not only evaluated residents' HSW source separation activities in a non-pilot city of China, but also compared residents' HSW source separation activities among the five community types. Overall, the main objectives of this study are listed below.

(1) Evaluate the current HSW source separation system and residents' HSW source separation activities in Suzhou.
(2) Compare the five community groups on their HSW source separation system and residents' source separation activities.

(3) Explore the main factors that impact residents' HSW source separation behavior and the reasons for participation or lack thereof.

(4) Analyze accommodations for improving the HSW source separation system with regard to different community and age groups.

2. Methodology

2.1. Experimental Sites

2.1.1. City of Suzhou

Suzhou, located in the center of Yangtze Reviver Delta in eastern China, is one of the best developed cities in China. In 2013, Suzhou's gross domestic product (GDP) ranked sixth in China, and its GDP per capita reached 123,382 RMB (U.S. $19,900), higher than that of both Beijing (94,238 RMB) and Shanghai (90,749 RMB) [26]. The urban area of Suzhou includes seven districts of 2743 square kilometers (km^2) and houses a permanent population of 5.4 million. Furthermore, Suzhou is a famous water country region with over 20,000 rivers and over 300 lakes. The secondary pollution caused by the great amount of HSW has been harmful to the surrounding's sanitation and environment, especially to the water and soil [27].

2.1.2. Survey Application

This survey was conducted in the core area of urban Suzhou, which is the wealthiest region of the city, and the government has put more money and people here for HSW source separation than other parts of the city. As the aim of this study is not only to study residents' activities toward HSW source separation, but also to study how their activities have changed with the implementation of the HSW source separation programs, the researchers launched the survey in five community groups that already existed in Suzhou, as defined bellow.

Community Group 1: communities that have not carried out HSW source separation by the government. Residential communities in Suzhou not included in the other four groups are in this group. Currently, there are 1230 such communities in Suzhou.

Community Group 2: communities that have carried out HSW source separation pilot programs in 2013, but the programs have not been evaluated and granted by the government. Currently, there are 197 such communities in Suzhou.

Community Group 3: communities that were acknowledged as a "source separation pilot community" at the end of 2012 by the government and that have implemented HSW source separation better than Group 1 and Group 2. Currently, Suzhou has 22 such communities.

Community Group 4: communities that have been chosen by the government as a food waste source separation pilot community and that have implemented HSW source separation better than Group 1, Group 2 and Group 3. Currently, Suzhou has one such community, which is Tian Yi Wan Hua Yuan.

Community Group 5: communities that were lauded as an "HSW source separation demonstration community" at the end of 2012 by the government and that have implemented HSW source separation

better than all of the other four groups. There are currently two communities of this group in Suzhou: He Run Jia Yuan and Xu Jiang Lu Gan Xiu Suo.

2.2. Determination of Samples

To obtain reliable and representative data for the research, the approach of multistage sampling was applied in this study. Firstly, five community groups in the core area of Suzhou were determined. Secondly, 15 representative communities were selected for the questionnaire survey, among which, 4, 5, 3, 1 and 2 communities respectively belong to Group 1 to Group 5. The number of the selected communities is mainly based on two considerations: the total number of the five community groups (*i.e.*, Group 1 has much more communities than other groups); and the goal of the study (*i.e.*, one of the main goals is how residents' activities changed along with the implementation of the HSW separation program). Thus, the selecting ratio of respondents in Group 2 to Group 5 in which HSW source separation programs have been carried out is designed to be higher than Group 1. The features of the selected five community groups are depicted in Table 1.

Table 1. Features of the selected communities.

Group	Number of communities	Number of communities selected	Households	Households size (person)	Economic level (RMB/month/ household)	Age (Year)	Education (year)
Group 1	1230	4	2024	3	8000	44	13.5
Group 2	197	5	2866	4	7500	39.5	11
Group 3	22	3	1210	3	6000	43	11
Group 4	1	1	770	3	4000	45	8
Group 5	2	2	1025	4	4814	48	8

Thirdly, the authors calculated the necessary sample size, n, by the equation of $n = Z_{a/2}^2 (n-1) \times S^2 / \Delta^2$. In this equation, S and Δ are the maximum standard deviation and tolerable error of the experimental survey. Given a desired confidence level of 95%, when $n \geq 30$, the $Z_{a/2}^2 (n-1) \approx 2$. Thus, the above equation can be transferred to $n \approx 4S^2 / \Delta^2 = 4 \times (\frac{S/u}{\Delta/u})^2 = 4 \times \frac{V}{\Delta/u}$, where $V = S/u$ is the covariance of sample variables and Δ/u is the tolerable relative error. Given the tolerable relative error of 5%, the necessary sample size n on the variables, gender, education, income, and age, is 166, 227, 485 and 261, respectively. Thus, the authors designed a total of 510 survey households for this study, with 30 households in Group 1 to Group 3 and 50 households in Group 4 and Group 5. The authors selected more samples in Group 4 and Group 5, because these two groups only have very few communities (*i.e.*, 1 community in Group 4 and 2 communities in Group 5). Ultimately, this survey received 505 completed surveys, with 116, 152, 94, 53 and 90 surveys in Group 1 to Group 5, respectively. The characteristics of the sample residents (*i.e.*, income, age and education) in each group are shown in Table 3 in the following Section 3.1, and these are consistent with the features (*i.e.*, economic level, age and education) of each group, as shown in Table 1. It is indicated that the sample in each community group is representative. The characteristics of the 505 samples are shown in Table 2.

Table 2. Demographic profile of the sample.

Social demography variables	Survey sample		Suzhou average * (Percentage, %)
	Frequency	Percentage (%)	
Gender	**n = 503**	-	-
Male	226	45	49
Female	277	55	51
Age (year)	**n = 486**	-	-
18–24	53	11	
25–34	159	32	66
35–44	67	14	
45–54	53	11	
>=55	154	32	22
Income (RMB per month)	**n = 493**	-	-
<=2000	166	34	26
2000–4000	188	38	45
4000–6000	84	17	16
6000–8000	33	7	8
8000–10000	11	2	2
10000–20000	8	2	2
>=20000	3	1	1
Education (year)	**n = 499**	-	-
Primary School	63	13	23
Junior High School	96	19	41
Senior High School	93	19	20
Junior college/College	216	43	15
Graduate/Professional	31	6	1

Note: * calculated according to Suzhou Statistic Yearbook (2013); Age and education is a value of 2010; gender and income is a value of 2012.

Table 2 shows that the distribution of gender, age and income is largely consistent with the average level of the whole of Suzhou. However, the survey sample also has a sample bias caused by the community's inherent characteristics. Specifically, the whole sample of residents has a higher proportion of female, elderly and lower income people. Attention needs to be paid to the different education level between the sample residents and all residents in Suzhou. The education data for all residents is from the sixth census of Suzhou in 2010. From then on, the education level in Suzhou increased quickly, due to the "Expansion of Higher Education" policy in China since 1999 [28,29].

2.3. Survey Design and Administration

A structured questionnaire was used in this study. An open-ended method, a two-alternative forced-choice method, a multiple choice method and a Likert rating scales method were used for the questionnaire design. The questionnaire includes three main sections of twenty questions. The first part includes eight questions about respondents' HSW knowledge, HSW source separation behavior and perceptions of the current HSW source separation system in Suzhou. The second part includes seven questions about respondents' attitudes regarding HSW source separation, their willingness to work to

improve the present HSW source separation system and their recommendations for improving the system. The third part includes five questions relating to respondents' demographic information. These questions were administered to all of the respondents in the five community groups. Before the survey was launched, a pre-test was administered to 15 participants in Suzhou to identify potential problems with the questionnaire and to prevent biases.

Surveyors conducted the intercept survey in selected communities, from 8 January 2014 to 20 March 2014. Surveyors first screened potential participants for inclusion based on whether they had heard about HSW source separation and were older than 18. Anyone who met this criterion was allowed to take the consumer questionnaire. The respondents can fill in the questionnaire by themselves or can ask the surveyor to read all of the questions to them and write down their choice. Surveyors remained nearby the respondents to answer any questions during survey completion. The survey was administered on both workdays and weekends to collect as broad a range of respondent types. The survey received a total of 505 valid respondents, with a response rate of 10%.

When designing the twenty questions for the questionnaire, the authors emphatically considered variables that may be closely related to the community's HSW source separation level and the residents' HSW source separation behavior. These variables were then used in an ordered probit regression model in the following analysis. Two dependent variables and 17 independent variables in three aspects were determined. One dependent variable is the "group No. of the community groups" (Com_type), ranking from 1 to 5, denoting community Group 1 to Group 5. The other dependent variable is "Number of waste separation categories" (separation), ranking from 0 to 3, denoting that residents' separated out 0 to 3 categories of waste from HSW.

The three aspects of independent variables were determined on the basis of previous studies, the actual situation of Suzhou and the availability of data, and they were: residents' demographic characteristics, perceived HSW source separation facilities/activities and residents' attitudes and willingness for HSW source separation. The two dependent variables and the seventeen independent variables are summarized in Appendix. All of the 17 independent variables in Appendix were involved in the ordered probit regression for separation, but only 11 variables on two aspects (residents' demographic characteristics and perceived HSW source separation facilities/activities) were involved in the ordered probit regression for Com_type.

2.4. Ordered Probit Regression Model

The two dependent variables of this study (*i.e.*, "Com_type" and "Separation") have an ordinal scale (see Appendix for details). We know that along with the increasing outcome of "Com_type", the communities have done HSW source separation better and better. Additionally, along with the increasing outcome of "Separation", residents separated out more kinds of waste from the HSW. However, the difference between 2 and 1 may differ from that between 3 and 2, because it simply indicates a ranking. This means that linear regression techniques are not appropriate in this case, and an ordered response model should instead be used [30]. For this reason, an ordered probit model is used here.

To discover the impact of the independent variables on the two dependent variables, ordered probit regression was performed both on "Com_type" and "Separation". The benefit of choosing "Com_type" or "Separation" is characterized by the latent variable y^*. Thus, we have:

$$y_i^* = \beta' x_i + \varepsilon_i$$
$$y_i = j \text{ , if } y_{j-1} < y^* < y_j \tag{1}$$

With the above equations, empirically five community types can be observed, indexed by y_i = 1, 2, 3, 4, 5; and four kinds of HSW source separation categories can be observed, here indexed by y_i = 0, 1, 2, 3 (see Appendix for details). Additionally, i indexes the subject of the survey. Consequently, the probability of alternative j is the probability of latent variable y^* between two boundaries, y_{j-1} and y_j. The vector x_i for "Com_type" contains 11 variables on residents' demographic characteristics and perceived HSW source separation facilities/activities. The vector x_i for "Separation" contains 17 variables on residents' demographic characteristics, perceived HSW source separation facilities/activities and residents' attitudes and willingness for HSW source separation.

The vector β is the coefficients that are estimated by means of maximum likelihood methods. The error term, ε_i, is assumed to be normally distributed. The estimation of the ordered probit model has been performed using the software, Stata 12.0.

A variable's significance, p, for the 17 variables in Appendix is calculated by the ordered probit regression with Stata. A variable's significance, p, for other variables is calculated by the one-way ANOVA test with SPSS.

3. Results and Discussion

3.1. Differences among the Five Community Groups

The Suzhou government has implemented a series of measures for promoting people to do HSW source separation, focusing on carrying out pilot programs in residential communities. In 2012 and 2013, the government carried out HSW source separation pilot programs in 221 residential communities. In all the communities with pilot programs (*i.e.*, Group 2 to Group 5), the government has done the same with "install HSW source separation kiosks" and "layout HSW separate collect trash bins", but has done differently with "carry out HSW source separation campaigns", "give separation bins to residents for free" and "give separation bags to residents for free". The government has not done any HSW source separation activities for the community, Group 1.

The HSW management in the communities with pilot programs is the same: the waste collection frequency is 1–2 times per week for recyclable, 1–2 times per month for hazardous waste and 2–3 times every day for food waste and other waste. The collection frequency for the mixed HSW in community Group 1 is 2–3 times every day.

To discover residents' perception of the facilities/activities in their community, the question "As you know, for the following facilities/activities, which one do you know have been carried out in your residential community" was designed. Residents' demographic characteristics and results from this question were then summarized as 11 variables. Thus, the authors used Table 3 to compare the five community groups with these 11 variables.

First, Table 3 lists the variable values of the five community groups. Secondly, to discover the exact relationship between the community groups and the above 11 variables, this study made an ordered

probit regression, with "Com_type" as the dependent variable and the above 11 variables as independent variables.

Table 3. Differences among the five community groups.

Variable	Variable value						Ordered probit regression Results
	Total sample	Group 1	Group 2	Group 3	Group 4	Group 5	
Residents' Demographic characteristics	-	-	-	-	-	-	-
Gender (Percentage of female, %)	55	66	51	49	62	53	0.17 (0.117 [a])
Education (Average education, year)	11	12	14	10	8	10	−0.108 ** (0.073 [a])
Income (Average income, RMB/month/cap)	3398	4540	3972	2376	2585	2578	−0.001 (0.054 [a])
Age (average age, year)	43	42	32	49	46	54	0.215 *** (0.049 [a])
Knowledge (know how to separate-collect HSW, %)	43	39	31	52	66	43	0.06 (0.044 [a])
Perceived HSW source separation facilities/activities (percentage of "1 = have", %)	-	-	-	-	-	-	-
Sep_Kiosk	47	0	40	57	85	86	0.182 (0.141 [a])
Sep_bin	65	0	81	79	91	91	0.355 *** (0.141 [a])
Bin_free	28	0	9	26	83	64	0.572 *** (0.18 [a])
Bag_free	28	0	6	33	60	76	1.083 *** (0.189 [a])
campaigns	23	0	14	26	32	58	0.479 *** (0.168 [a])
Enough_bin	57	17	48	70	91	92	0.159 *** (0.044 [a])

Note: [a] the standard Error; ** significant at $p < 0.05$; *** significant at $p < 0.01$.

As discussed in Section 2.2, the survey sample is largely representative of the gender, age and income of all of the people in Suzhou. However, residents in the five community groups have significant differences. Among the demographic variables, the coefficient on residents' age is positive and significant, while the coefficient on residents' education is negative and significant. It is indicated that the communities that have performed HSW source separation well are very likely to host a higher proportion of older and less educated people. The positive impact of age on HSW source separation is consistent with previous findings [12,13]. However, the negative impact of education on HSW source separation is inconsistent with the previous works [11,12]. This is closely related to the actual education situation of China. Since 1999, the Chinese government has carried out the "Expansion of Higher Education Plan" for solving the expanding economic and employment problem. From 1998 to 2012, the number of students admitted to Universities in China increased from 1.16 million to 7.47 [28], and the gross tertiary enrollment rate increased from 6% to 27% [29]. Some researchers have found that people's age and education have had a very close negative relationship in China during the higher education expansion period. It is indicated that elderly people have a much lower education level than

younger ones in China at present [31,32]. Thus, the difference of residents' education level is consistent with the difference of residents' age among the five community groups.

Most of the respondents are not satisfied with the current HSW source separation system in Suzhou. On the one hand, only 43% of the respondents thought they knew how to separate HSW. On the other hand, the ratios of residents who have accessed HSW source separation facilities/activities are low, with the highest of 65% for separate bins and the lowest of 23% for HSW campaigns.

The coefficient on the six variables for facilities/activities, except "Sep_kiosk", is positive and significant; indicating that the communities that have performed HSW source separation well have significantly better HSW source separation facilities provided by the government. The specified value of the five variables also indicated the same result.

3.2. Residents' Attitudes and Willingness for HSW Source Separation

This survey designed two types of questions to estimate respondents' attitudes and willingness for HSW source separation. First, the surveyors designed three attitudinal statements about HSW source separation. Respondents can describe their attitude using a five-point scale, with answers ranging from "1 = totally disagree" to "5 = totally agree". Second, the authors designed three questions about residents' willingness to work to improve the current HSW source separation system one by one in progression. The results are illustrated in Table 4.

Table 4. Residents' attitudes and willingness for HSW source separation.

Attitudes and willingness	Percent (Totally agree + agree, %)
I want to do HSW source separation very much	88
I would see if there is a sign for HSW source separation when I throw out HSW	78
I would separate HSW when I stand near separated trash bins	78
Question one: Would you like to install a draining funnel trash can in your kitchen? (Very much like + Like)	86
Question two: If you would like to install the draining funnel trash can in your kitchen, would you also like to install an electronic scale in your kitchen and weigh the waste before throwing it out? (Very much like + Like)	55
Question three: How long do you think you would continue draining and weighing food waste? (More than one year)	46

Table 4 shows that respondents have a very positive attitude about the HSW source separation. The ratio of respondents who want to do HSW source separation and to install a draining funnel in their kitchen at home is nearly 90%. The popularity of HSW source separation in this study is consistent with previous findings [6,33]. However, when the improved measures are difficult to implement (*i.e.*, installing both a draining funnel and an electronic scale in their kitchen and weighing the waste before throwing it out) or require a long-term commitment (*i.e.*, continue draining and weighing food waste for more than one year), the residents give up more easily. How to encourage people to persevere and develop the habit of HSW source separation is an important issue [34,35].

3.3. Residents' HSW Source Separation Behavior

3.3.1. Current Behavior

According to the current HSW source separation system in Suzhou, three kinds of waste should be separated out from the HSW: recyclable, food waste and hazardous waste. Residents are required to separate the three kinds of waste with different procedures. For recyclables, residents first store them at home and then sell them to waste buyers or throw them into the community separated garbage bins. For food waste, residents separate this out at home and throw it into the community separated bins. For hazardous waste, residents first store this at home and then throw it into the community separated garbage bins.

The respondents' current HSW source separation behavior is illustrated in Table 5. For all of the respondents, only 23% have source separated HSW according to the present HSW classification method in Suzhou; 21% have not source-separated HSW at all; and the remaining 56% have partially separated out one or two kinds of waste from HSW.

When considering the three kinds of waste that should be separated out, the separated ratio of recyclable is the highest because of the economic benefits, but still only 65%. The ratio for food waste and hazardous waste is less than 50%. Much attention should be paid to encouraging residents to separate hazardous waste and food waste in the future.

Table 5. Residents' current HSW source separation behavior.

HSW source separation behavior at home	According to age groups					
	Total (%)	Group 1 (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)	Group 5 (%)
Separating recyclables at home	65	62	55	65	75	80
Separate kitchen waste at home	49	31	39	55	77	66
Separate hazardous waste at home	40	11	33	49	57	72
Mixed all the HSW together at home	21	29	14	10	5	8
Separate out one kind of waste from HSW	27	28	32	10	18	23
Separate out two kinds of waste from HSW	29	31	26	32	29	23
Separate out three kinds of waste from HSW	23	13	29	48	48	47
HSW source separation behavior at home	According to age groups					
	Total (%)	18–24 (%)	25–35 (%)	36–45 (%)	46–55 (%)	≥55 (%)
Separating recyclables at home	65	47	58	82	72	70
Separate kitchen waste at home	50	43	35	54	58	62
Separate hazardous waste at home	42	32	29	45	51	53
Mixed all the HSW together at home	21	26	28	10	17	16
Separate out one kind of waste from HSW	27	34	33	22	17	21
Separate out two kinds of waste from HSW	29	30	27	43	34	24
Separate out three kinds of waste from HSW	23	9	11	24	32	39

Residents' HSW source separation behavior may be influenced by many factors. Table 5 shows that community type may be an important factor. Nearly 50% of all of the residents in community Group 3

to Group 5 separated out three kinds of waste, while the ratio in Group 1 is as low as 13%. To discover the relationship between community types (Com_type) and residents' separation behavior ("Separation"), the authors made an ordered probit regression for these two variables, with "Separation" as the dependent variable and "Com_type" as the independent variables, and it was found that the coefficient is positive and significant (Coefficient = 0.301, $p = 0.000$).

Though the coefficient does not reflect the community type's marginal impacts on separation, it does indicate that the residents' separation behavior is positive and significantly related to community type. Concurrent with the implementation of HSW source separation programs, the residents' HSW source separation behavior improved. Residents in community Group 5 have done the best at separating HSW, and residents in Group 4 have done the best at separating food waste. Community Group 1 has the highest proportion of people who mixed all of the HSW (29%). This implies that the current HSW source separation pilot program in Suzhou is useful in improving residents' source separation behavior and can be spread to more communities.

Table 5 also shows that residents' HSW separation behavior may also be influenced by residents' age. Nearly 40% of the elderly people (+55) have separated out three kinds of waste from HSW, while the ratio for younger people (18–24) is only 9%. Thus, we have the question "What are the main determinants for residents' HSW source separation behavior". To find answers for this question, this research made an ordered probit regression, with "Separation" as the dependent variable and 17 variables in three aspects as independent variables. The results are listed in Table 6.

Table 6. HSW source separation behavior estimation with an ordered probit regression.

Separation	Mean	Coefficient	Standard Error	$p > |z|$
Residents' demographic characteristics		-	-	-
Gender	1.549	−0.0636	0.159	0.688
Education	3.112	0.0465	0.0942	0.621
Income	2.130	0.00356	0.0722	0.961
Age	3.198	0.114	0.0663	0.087
Knowledge	2.868	0.00576	0.0605	0.924
Perceived HSW source separation facilities/activities		-	-	-
Sep_Kiosk	0.469	0.756	0.202	0.000
Sep_bin	0.648	0.317	0.184	0.084
Bin_free	0.277	0.502	0.281	0.074
Bag_free	0.277	0.287	0.27	0.288
campaigns	0.226	0.167	0.233	0.472
Enough_bin	0.571	0.0259	0.0695	0.709
Resident's attitudes and willingness for				
HSW source separation		-	-	-
Want_sep	4.414	0.0333	0.116	0.774
See-sign	4.139	−0.0312	0.108	0.773
Stand_bin	4.095	0.0759	0.106	0.472
Draining	3.414	0.18	0.198	0.364
Elc_weight	3.194	0.108	0.164	0.512
Continue	2.592	0.019	0.0718	0.791

Among all of the demographic variables, only the coefficient on age is positive and significant, the coefficient on gender, education, income and knowledge on source separation is negligible. This indicates that residents' HSW source separation behavior is significantly influenced by residents' age. People who have done HSW source separation well are very likely to be older. Middle-aged and older people (36+) have done better at HSW source separation than younger people. This is consistence with many previous studies [12,13]. Thus, in the following parts of the paper, the authors divided all of the respondents into five age groups: youth (18–24 years old), young and middle-aged people (25–34 years old), middle-aged people (35–44 years old), middle-aged and elderly people (45–54 years old) and elderly people (55 years old and older).

Installing HSW source separation kiosks and garbage bins in the community has a strong positive impact on residents' HSW source separation behavior. The better the residents' perception of these facilities, the more they will do HSW source separation. Thus, constructing and improvement of HSW source separation infrastructure are the primary tasks for the government. Distributing HSW separation bins freely to residents is useful for improving residents' separation behavior at the very beginning. However, special attention must be paid to considering the long-term cost, residents' psychological dependence and rebellious attitudes when this ceases someday.

Attitudes and willingness do not have significant impacts on residents' HSW source separation behavior, as the coefficient of all of the six variables is negligible. This indicated that although residents in Suzhou have a very positive attitude about HSW source separation as discussed, their willingness has not transferred into real behavior. According to the theory of planned behavior, behavior intention is considered to be the immediate antecedent of a real behavior. Additionally, the behavior intention is based on three aspects: attitude toward the behavior, subjective norm and perceived behavioral control [36,37]. Thus, more measures should be implemented to improve the social and subjective norms (e.g., forming a social consensus that does not carry out HSW source separation is shameful) and perceived behavioral control (e.g., having enough and convenient separation bins) on HSW source separation.

3.3.2. Reasons for HSW Source Separation or Not

Along with their HSW source separation behavior, 407 respondents provided reasons why they separate all or a portion of HSW at home, and another 256 respondents provided reasons why they do not separate HSW or only separate a portion of HSW at home. The main reasons that respondents source separate HSW at home are almost the same among different community groups and different age groups. According to importance, the four main reasons are: to decrease the pollution of the environment (68%), to earn money by selling recyclables (60%), to avoid dirty HSW from polluting clean HSW (45%) and because it is a good quality for residents (40%). This implies that most of the respondents have a high awareness of the environmental problems caused by HSW and are willing to work to resolve these problems.
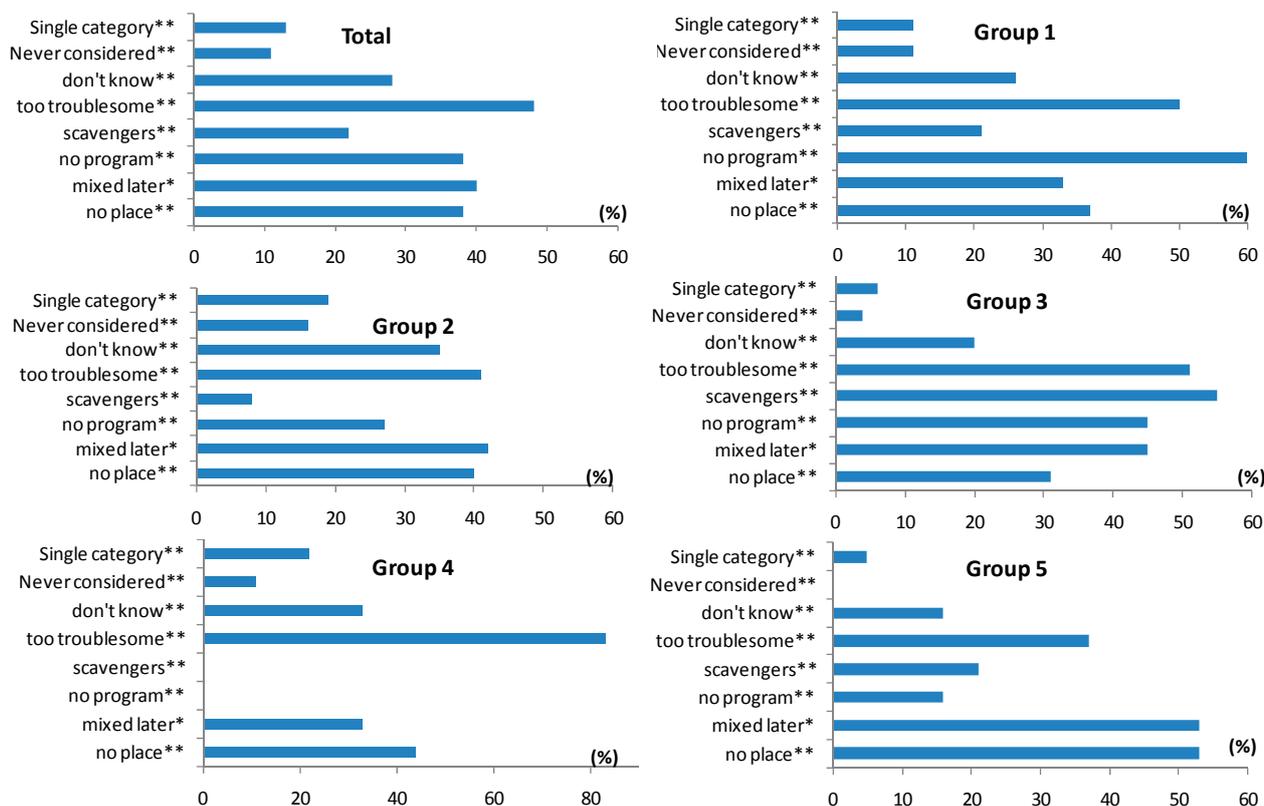
The reasons that respondents do not source separate HSW at home, according to importance, are as follows: HSW source separation is too troublesome (48%), the waste I classified will be mixed later (40%), do not have a place to put the classification trash bins at home (38%) and the community does not

carry out a HSW source separation program (38%). However, the reasons why residents do not source separate HSW are significantly different among the five community groups, as in Figure 1.

For compact exhibition, the following abbreviations are used in Figures 1 and 2, for the reasons why residents do not source separate HSW:

"Single category" for "single category of HSW at home, do not need to separate";

"Never considered" for "never considered about HSW source separation";

"Don't know" for "do not know how to source separate HSW";

"Too troublesome" for "HSW source separation is too troublesome";

"Scavengers" for "scavengers will separate the mixed HSW";

"No program" for "the community does not carry out a HSW source separation program";

"Mixed later" for "the waste I classified will be mixed later";

"No place" for "do not have a place to put the classification trash bins at home".

Figure 1. Reasons why residents not source separate HSW according to community groups.
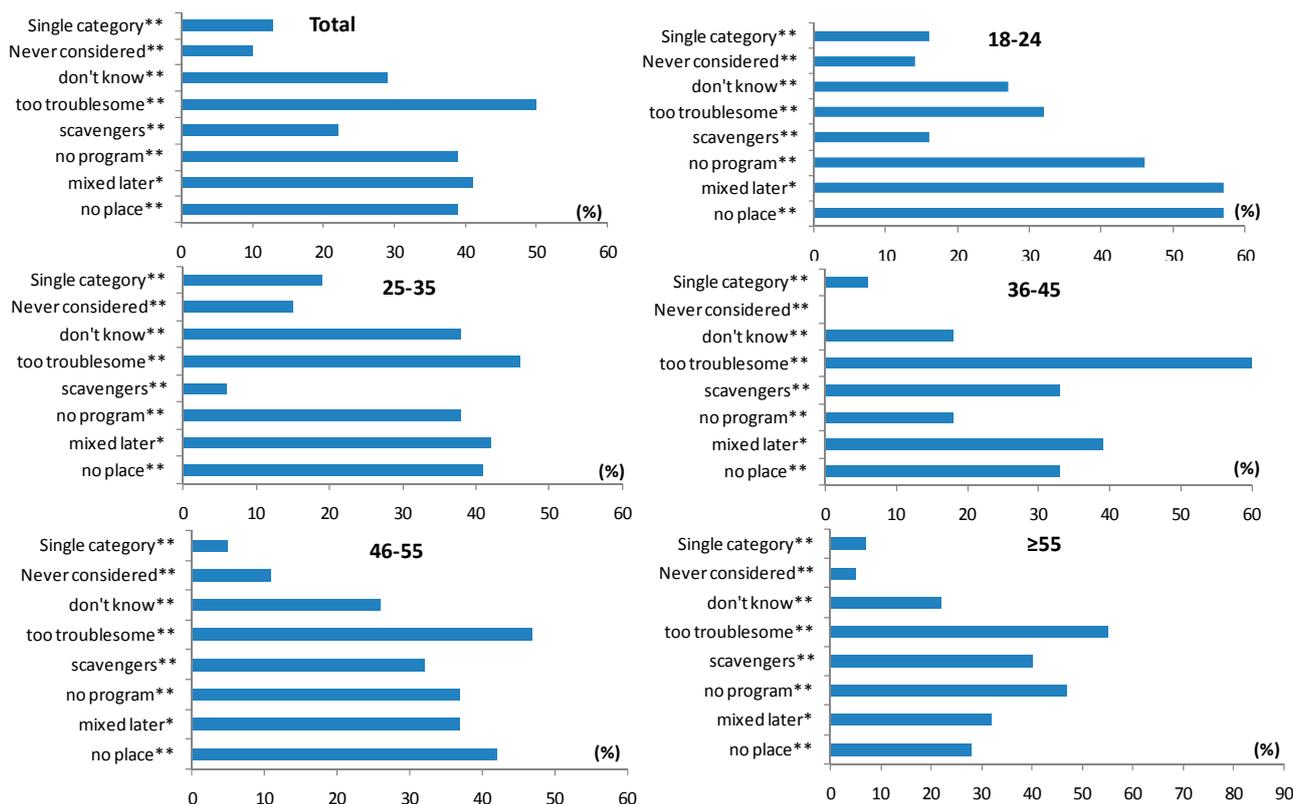

Note: Respondents could select more than one option; * significant at $p < 0.1$ (one-way ANOVA); ** significant at $p < 0.05$ (one-way ANOVA).

Figure 1 shows that in community Group 4 and Group 5, which have done HSW source separation well, residents do not source separate HSW mainly because "HSW source separation is too troublesome", "do not have a place to put the classification trash bins at home" and "the waste I classified will be mixed later". In the community Group 1, Group 2 and Group 3, where HSW source separation has not developed well, the residents do not source separate HSW mainly because "the community does not carry out a HSW source separation program", "HSW source separation is too

troublesome" and "do not know how to source separate HSW". This indicated that with the implementation of HSW source separation programs, the reasons for not source separating changed from facilities/knowledge issues to opportunity cost and system matching (*i.e.*, matching HSW source separation and the follow-up source separation-transportation-disposal chain) considerations.

In addition, the reasons that respondents did not source separate HSW are also significantly different among the five age groups, as in Figure 2.

Figure 2. Reasons why residents not source separate HSW according to age groups.

Note: Respondents could select more than one option; * significant at $p < 0.1$ (one-way ANOVA); ** significant at $p < 0.1$ (one-way ANOVA).

People younger than 36 report a much higher proportion of "do not have a place to put the classification trash bins at home", "the waste I classified will be mixed later" and "single category of HSW at home, do not need to separate". This may be associated with their lifestyle. At present, most of the young adults live together with their schoolmates, workmates and friends of their own age [38–40]. Therefore, they generated fewer HSW categories at home and also have not enough space for HSW source separation. Respondents aged 35 to 44 report a much higher proportion of "HSW source separation is too troublesome", which could mainly be because this group of people experiences more life and work pressure than the other groups [41,42], and so, they do not have enough time and patience to do detailed HSW source separation. Thus, more targeted measures should be taken for different age groups, for example establishing simple public classification trash bins in young people's gathering areas (e.g., college dormitories, apartments).

3.4. Recommendations for the Current HSW Source Separation System

The surveyors designed a list of measures that may encourage the residents to perform HSW source separation and that allowed the respondents to provide a five-point scale answer for evaluating the effectiveness of these measures, ranging from "most effective" to "not effective at all". The results are illustrated in Table 7, according to different age groups. The proportion in Table 4 is the sum of people who answered with "most effective" or "effective".

Table 7. Effectiveness of the measures for promoting HSW source separation.

Effectiveness of the measures (According to age groups, Most effective + Effective)	Total (%)	18–24 (%)	25–35 (%)	36–45 (%)	46–55 (%)	≥55 (%)
Give you a detailed HSW source separation manual	54	47	56	53	61	51
Always carry out HSW separate campaigns in your community *	67	55	67	73	69	67
Gradually conditioned your children to source separate HSW **	76	66	81	85	78	69
Place enough HSW separate bins in your residential community *	72	70	74	65	78	73
Government ensures that separated HSWs will not be mixed later **	56	64	69	55	51	42
Let you supervise the government on HSW source separation **	39	51	50	38	24	29
Give you HSW separation bins for free **	75	66	79	83	71	70
Give you HSW separation bags for free	73	68	76	76	73	71
Government workers first do HSW source separation and make it publicly transparent **	66	66	73	77	65	56
Give you 50 RMB when you separate 100 kg of recyclables correctly **	62	62	66	59	57	61
Punish you 50 RMB when you mix or separate HSW incorrectly **	53	58	63	61	51	36

Note: Respondents could select more than one option; * significant at $p < 0.1$ (one-way ANOVA); ** significant at $p < 0.1$ (one-way ANOVA).

This shows that for all of the respondents, the most effective measures are as follows: gradually condition your children to source separate HSW, give you HSW separate bins for free, give you separate HSW bags for free, always carry out HSW separate campaigns in your community and government workers first do HSW source separation and make it publicly transparent. The effectiveness of other measures is relatively weaker.

The effectiveness of the economic reward or punishment measures is low. Many respondents have not considered economic measures in HSW source separation and think it impossible to be implemented. However, economic measures have been popular in many developed countries in HSW management and have achieved great success, such as in Japan and Germany. The Suzhou government may consider carrying out some economic measures in HSW management in the future.

The effectiveness of measures differs significantly among age groups. For people aged 18 to 24 years old, "gradually conditioning your children to separate HSW" is much less effective than the average, because most people in this group do not have children yet. However, this measure is very effective for people aged 25 to 54, as most people in this group already have children or are going to have children very soon. Due to the One Child Policy, there is only child in the family for most of these persons. These parents have paid much attention to their children's education, and in response, their children also have an important influence on them [43–45]. For people aged 25 to 54, "their children" refers to children and young adults. Therefore, in the future, the government should gradually train both children and young adults to develop the habit of HSW source separation, thereby affecting themselves and their parents, instead of paying much attention to children, but ignoring the training of young adults, as it is now.

The HSW source separation follow-up infrastructure has greater influence on people under 36 years old than on people over 36. The mismatch of HSW source separation and the follow-up, separate collection-transportation-disposal chain will greatly undermine the young respondents' confidence about the success of the HSW source separation system. Thus, the government should take the lead in HSW source separation and develop strict requirements for the follow-up infrastructures for matching the whole chain, instead of focusing on the construction of infrastructures, as they do now.

4. Conclusions and Accommodations

Suzhou has had an HSW source separation system since 2000. However, no studies have researched the HSW source separation system from the residents' aspect in Suzhou. This study conducted a survey in Suzhou on residents' HSW source separation activities.

Overall, the study found that the accurate HSW source separation rate in Suzhou is only 23%. Though the respondents have a very positive attitude about HSW source separation, it has not transformed into separation behavior. The main determinants of residents' HSW source separation behavior are residents' age, HSW source separation facilities and government preferential policies. Attitudes and willingness do not have significant impacts on residents' HSW source separation behavior. The empirical findings of this study are consistent with theoretical predictions, although these show that education has a negative impact on HSW source separation. The accessibility to waste management service is particularly important.

The current HSW source separation pilot program is useful in improving residents' source separation behavior, and more pilot program should be carried out in Suzhou. However, the current HSW source separation programs can be improved by training both children and young adults to develop HSW source separation habits, using some preferential policies in the initiation period, carrying out targeted publicity activities according to the characteristics of different age groups and developing strict requirements for the follow-up infrastructures for matching the HSW source separation-collection-transportation-disposal chain.

Though this study has the above findings, it also has limitations. As our research seeks to understand the HSW source separation activities, a longitudinal study would have been more appropriate in capturing the change in behaviors over time. However, this was not feasible, due to the study's restricted time and financial budget. In the future, the authors will try to avoid this limitation.

Acknowledgments

Appendix

Table A1. Descriptive statistics for the variables used in the ordered probit model.

Variable	Definition	Coding	Sample	Min	Max
Dependent variables		-	-	-	-
Com_type	Group No. of the community groups (1–5)	1 for goup1, to 5 for group5	505	1	5
separation	Number of waste separation categories (0–3)	0 for zero category of waste were separated out from HSW, to 3 for 3 category of waste	505	0	3
Independent variables		-	-	-	-
(1) Resident's Demographic characteristics		-	-	-	-
gender	Gender (1–2)	1 for male, to 2 for female	505	1	2
education	Education level (1–5)	1 for Primary School, to 5 for graduate	499	1	5
income	Income (1–7)	1 for ≤20K, to 7 for ≥200k	493	1	7
age	Age (1–5)	1 for 18–24, to 5 for 55+	486	1	5
knowledge	I Know how to separate HSW (1–5)	1 for totally disagree, to 5 for totally agree	492	1	5
(2) Perceived HSW source separation facilities/activities		-	-	-	-
Sep_Kiosk	HSW separate collection kiosk		505	0	1
Sep_bin	HSW separate collection bin		505	0	1
Bin_free	Provide HSW separate bins freely	0–1, 0 for have not perceived it in the community, to 1 for have perceived it in the community	505	0	1
Bag_free	Provide HSW separate bags freely		505	0	1
campaigns	Campaign on HSW source separation		505	0	1
Enough_bin	Enough bins for HSW		495	0	1
(3) Attitudes and willingness for HSW source separation		-	-	-	-
Want_sep	I want to source separate HSW very much		503	1	5
See-sign	I would definitely see if there is a sign for HSW source separation when I throw out HSW		498	1	5
Stand_bin	I would definitely separate HSW when I stand near separated trash bins	1–5, 1 for totally disagree, to 5 for totally agree	496	1	5
Draining	I would like to install a draining funnel trash can in my kitchen		497	1	5
Elc_weight	I would also like to install an electronic scale in my kitchen and weigh the waste before throwing it out		500	1	5
Continue	I would continue draining and weighing food waste	1–4, 1 for a week, to 5 for more than one year	444	1	4

Author Contributions

Conflicts of Interest

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