Introduction

There is a growing worldwide concern over waste management. As the world’s most populous country and the fourth largest in area, China has experienced a high rate of economic growth and a change of lifestyle in rural areas. However, the Chinese government did not pay enough attention to it, which leads to the rising tide of domestic waste in rural areas in China [1]. At present, two-thirds of China’s big and medium cities are engulfed in waste, with more than...
Many previous studies have shown that public awareness and attitude are the basis of successful waste classification [6, 7]. Generally, the samples used in different studies have gotten contradictory conclusions. Based on stratified sampling to select 3047 households in Delhi, India, the public knowledge about waste management had a significant correlation with the willingness to take part in RDWC [8]. Moreover, the female, the older, the lower socioeconomic, and the highest socioeconomic had greater knowledge of waste management. Pakpour et al. found that attitudes, subjective norms, perceived behavioral control, moral obligations, self-identify, intention, action planning, and past behavior significantly predicted behaviors of RDWC obligations, self-identify, intention, action planning, and subjective norms, perceived behavioral control, moral obligations, self-identify, intention, action planning, and past behavior significantly predicted behaviors of RDWC in Iran [9]. In China, the attitude towards RDWC, subjective norms, perceived behavioral control, and experience can significantly influence public awareness [4]. Based on quota, systematic, and convenience sampling to select 200 households in Tuobodom, Ghana, Kwetey et al. found that socioeconomic characteristics such as age, education, income, and employment had no significant effects on willingness to pay for waste management [10]. Besides, the conclusions of different studies can be inconsistent even in the same country. Ma et al. applied multistage sampling to select 312 households in Guilin, China. The results show that monthly income had a positive correlation with public environmental attitudes but age, gender, and education had no significant correlation with public environmental attitudes [11]. Selecting 811 households in 59 villages from six provinces in West China, Han et al. found that education, demonstration projects and public awareness of waste treatment necessity had significantly positive effects on public willingness to participate in domestic waste management in rural areas of China. The older had a weaker willingness to participate in RDWC compared with the younger [12].

The outbreak of the novel coronavirus (COVID-19) was a global epidemic event that started in late 2019 and was declared a pandemic by the World Health Organization in March 2020 [13]. Early studies mainly focused on the risk factors of the epidemic from a personal perspective, such as age and history of smoking [14, 15]. Now, focused on environmental factors, many studies have shown that the outbreak of COVID-19 was influenced by air pollution [16], nitrogen dioxide level [17], and waste management [18]. Mol and Caldas found that the spread of the novel coronavirus may be increased by inadequate waste management, highlighting poor handling conditions associated with inappropriate use of personal protective equipment in developing countries [18]. Since RDWC is one of the main strategies for waste management, we assessed the association between domestic waste classification and the spread of COVID-19, and provide specific suggestions to public awareness and behaviors in RDWC to help reduce COVID-19.

To better understand public awareness and behaviors in RDWC and explore the relationship with novel coronavirus, we conduct a questionnaire survey in rural areas of Hangzhou, the capital city of Zhejiang Province, China, which has been practicing RDWC since 2014. It is documented that the knowledge of rules of the separate collection does not necessarily mean that residents translate these into action [19]. To better identify the significant influencing factors of RDWC awareness and behaviors, this paper applies questionnaires and probability sampling methods, which ensures the sample can represent the population perfectly and regression analyses are applied for credibility. With the focus on RDWC awareness and behaviors, the regression results show that the influencing factor of public awareness and behaviors are inconsistent. The results also reveal that the crucial influencing factors of RDWC awareness are different from the influencing factors of public behaviors. The contributions of the paper are threefold.

First, the results of this study provide an empirical reference for local governments to standardize the classification measures, strengthen the infrastructure construction, and promote publicity and education, the practical experience of which is worth strongly popularizing. Hangzhou is one of the first pilot cities of waste classification in China. In 2015, the Hangzhou government published the ‘Three-year Action Plan for Classification and Reduction of Rural Domestic Waste’. After four years of development, Hangzhou formed a series of systems for the classified deposit, collection, transportation, and disposal of garbage in rural areas [20]. Yu and Shen found that when formulating environmental regulation policies, each region should match the local economic development level and industrial structure [21]. The same is true for the RDWC policy. When formulating RDWC policies, each region should match the local cultural environment and ecological environment. This study provides specific evidence to the government for taking more effective policies and promoting the experience of RDWC to more rural areas in China, even the world.

Second, probability sampling is applied to avoid selection bias and make the results scientifically
The optimal sample size was required. This can either be to maximize the precision of the estimate subject to a specified cost or to achieve a specified precision expressed as the variance. As the variance of the population was not available, it was possible to investigate with the former option. Set one half of the length of the confidence interval of the population mean as \(5\text{CNY}\) (tolerable error \(\theta = 5\)). Set the confidence level \(\alpha\) as 0.05. When the limited value of \(V = (\theta/z_{\alpha/2})^2\), the survey was the most cost-effective. \(V\) is denoted the variance of the population mean. By taking account of the multistage sampling design and the cost of each stage, optimum sample sizes can be estimated by the following equations:

\[
  \begin{align*}
    n_2 &= \frac{\sigma_2^2 - \sigma_3^2/N_2}{\sqrt{\sigma_1^2 - \sigma_2^2/N_2}} C_2 \\
    n_3 &= \frac{\sigma_3^2 - \sigma_4^2/N_3}{\sqrt{\sigma_2^2 - \sigma_3^2/N_3}} C_3 \\
    n_4 &= \frac{\sigma_4^2}{\sqrt{\sigma_3^2 - \sigma_4^2/N_4}} C_4 \\
  \end{align*}
\]

...where \(\sigma_1^2, \sigma_2^2, \sigma_3^2\) and \(\sigma_4^2\) are denoted as the variance of the first, the second, the third, and the fourth stage. Considering the variance of the population was not available, we used our pre-survey data to estimate the variance of each stage. The results were \(C_1 = 500\text{CNY}, C_2 = 100\text{CNY}, C_3 = 10\text{CNY}\) and \(C_4 = 1\text{CNY}\). We also calculated that \(S_1^2 = 12\), by the average cost of pre-surveying each stage.

Applying the data to the four equations, we calculated the optimal sample size for each stage, \(n_1 = 3, n_2 = 3, n_3 = 4, n_4 = 9\). First, three districts were selected from eight districts in Hangzhou by Probability Proportional to Size sampling (PPS) technique using the number of farmers in each district. Then, three towns were selected from the three sample districts by the Simple Random Sampling (SRS) technique using the zoning code. Four villages were also selected from the three sample towns by the SRS technique using the urban and countryside classification code. Finally, nine participant families were selected by the SRS technique using the house number we defined by GIS-assisted mapping. For the cases where no one answered, we tried to find residents in the farmland or made a second visit later.

Data Processing

In this study, a questionnaire was designed to obtain the basic need for the analysis. First, the designed questionnaire contained a series of questions about the situation and awareness of RDWC. Then, the questionnaire followed a series of questions about the local environment and the facilities and rules of RDWC. Finally, the questionnaire surveyed the respondents’
gender, age, educational level, occupation, and monthly income. In total, 400 questionnaires were distributed to respondents. The cover letter attached to the questionnaires assured participants of their anonymity. Finally, 324 valid questionnaires were used in this research, resulting in an 81% usable response rate. The collected questionnaires were numbered and classified to use the number to retrieve the original questionnaire for reconciliation correction.

Reliability and Validity Analysis

Two tests were carried out by R. The first test was Bartlett’s Test of Sphericity (BTS), which was used to evaluate the significance of the data matrix and the second test was Kaiser-Meyer-Olkin (KMO) which measured the correlation between factors [24].

According to Jomeen and Martin, Cronbach’s alpha coefficient of 0.6 was considered as the minimum acceptable criterion for the internal reliability of the instrument [22]. Cronbach’s alpha coefficient of the survey is 0.713. Therefore, it can be considered that the information obtained through the design of the questionnaire has high reliability and can be used to evaluate RDWC in Hangzhou. The KMO value of the survey was 0.745, greater than 0.7, and the significance value was 0.00, less than 0.05, indicating that the survey results were in agreement with the facts and can be used for the following data analysis.

Results and Discussion

Demographics of Respondents

It is universally accepted that demographic structure and education level will affect the RDWC [8, 25-27]. Table 1 shows the gender, age, education, and occupation distribution in the investigated districts. For analysis, all respondents are categorized into six categories in terms of age: <19, 19 to 29, 30 to 39, 40 to 49, 50 to 59, and >=60 years old. The distributions of respondents in all categories are 3.09%, 56.17%, 10.19%, 19.75%, 6.79%, and 4.01%, respectively. The result showed that the main RDWC role of each household was mainly concentrated in the young and middle-aged people. Therefore, the young and middle-aged were the major contributors to RDWC. In contrast, their education levels were relatively low compared to residents living in urban areas. Thus, more than half of the respondents’ monthly salary was below 2000CNY. Among the respondents, the scope of occupational distribution was relatively wide. Among them, students accounted for 42.59%, housewives accounted for 12.65%, workers (including migrant workers) accounted for 10.8%, retirement or laid-off accounted for 6.17%, self-employed accounted for 6.17%, and public officials (including civil servants and public institutions) accounted for 6.17%. The above analysis of distribution of age and education level, occupations at all levels of society showed that the sample was representative.

Descriptive Statistics and Correlation Analysis

Table 2 presents the constructs, means, and standard deviations for all variables in this study. The mean of public awareness is 3.67 between neutral and agreement. To investigate the level of public
knowledge of RDWC, two questions were set up in the questionnaire to distinguish hazardous waste and recyclable waste. The data showed that the positive response rates for the two questions are 5.25% and 18.21%, respectively. We assigned points to the options: 10 points for correct answers and -5 points for wrong answers. Then we added the two question scores and standardize the total scores to get the Behavior variable. But the mean of behavior is relatively low compared to the awareness, indicating that public RDWC behaviors are not consistent with their RDWC awareness.

Subject perception reflected the perception of respondents at a village level. Concerning implementing RDWC, respondents didn’t hold a supportive attitude toward it, which had mean values 2.79 below the midpoint. However, for the satisfaction of RDWC, respondents held a fair attitude toward it, which had mean values around 3.0.

Objective factors reflected the situation of RDWC in the respondents’ village. According to the survey, only 2.69% of respondents thought the environment of their living areas was poor, while 71.38% of them thought it needed improvement. Respondents felt satisfied with the environment and waste room, both of which had mean values around 2.8. For the supervision of RDWC, most of the villagers didn’t have human supervision, which had a mean value of only 0.27.

As is shown in Table 3, the result of correlation analysis indicated that awareness of environmental issues is positively associated with the cleanliness of waste rooms (r = 0.16; p<0.01) and human supervision when handling domestic waste (r = 0.13; p<0.05). Waste classification behavior is positively associated with attitude to implementing waste management (r = 0.25; p<0.01), RDWC satisfaction (r = 0.17; p<0.01) and the environment in respondents’ village (r = 0.21; p<0.01).

Public Awareness and Behavior of RDWC

To investigate the impact factors of public awareness and behavior of RDWC, this study adopted hierarchical regression analysis. The demographic variables, which were gender, age, education, and income, in the regression model were controlled for rural residents' awareness and behavior. Each regression analysis performed the same process, differing only in the dependent variable. So the model is set as follows:

Dependent variable_i = constant value + b_1Gender_i + b_2Age_i + b_3Education_i + b_4Monthly income_i + b_5Attitude_i + b_6RDWC Satisfaction_i + b_7Waste room_i + b_8Environment_i + b_9Supervision_i + ε_i

Table 3. Correlations among the related variables.

<table>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td>Awareness</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Attitude</td>
<td>0.08</td>
<td>0.25***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDWC Satisfaction</td>
<td>0.08</td>
<td>0.17***</td>
<td>-0.02</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste room</td>
<td>0.16***</td>
<td>0.07</td>
<td>-0.01</td>
<td>0.22***</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>-0.10*</td>
<td>0.21***</td>
<td>0.00</td>
<td>0.17***</td>
<td>0.03</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Supervision</td>
<td>0.13**</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.32***</td>
<td>0.15**</td>
<td>0.08</td>
<td>1</td>
</tr>
</tbody>
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Note: *significant at 0.1 level, **significant at 0.05 level, ***significant at 0.01 level.
...where $i$ represents the individual; $\varepsilon_i$ is the random error; $b_1, ..., b_9$ are parameters.

In Table 4, Model 3 of awareness revealed that the direct effect of the respondents’ age was significantly and positively related to awareness of RDWC ($b_2 = 0.14$, $p<0.01$), indicating that the elder is more likely to have the awareness of environmental issues. Furthermore, the cleanliness of the waste room was significantly and positively related to awareness of RDWC ($b_7 = 0.11$, $p<0.1$), showing that if villages’ waste rooms were clean and classified, it could raise public awareness of RDWC. Model 2 of behavior revealed that the direct effect of the attitude to waste management was significantly and positively related to RDWC behaviors ($b_5 = 0.37$, $p<0.01$), indicating that when rural residents supported the implementation of RDWC, they were more likely to classify waste accurately. Furthermore, RDWC Satisfaction was significantly and positively related to RDWC behaviors ($b_6 = 0.19$, $p<0.01$), showing that if rural residents were satisfied with RDWC in their village, they would do the RDWC actively. After the subject factors entered, the results for Model 3 showed a significant and positive interaction between the environment in respondents’ village and waste

<table>
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<th>Behavior</th>
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<tr>
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<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>Gender</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Age</td>
<td>0.11**</td>
<td>0.10**</td>
</tr>
<tr>
<td>Education</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Monthly income</td>
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<td>-0.01</td>
</tr>
<tr>
<td>Attitude</td>
<td>0.07</td>
<td>-0.00</td>
</tr>
<tr>
<td>RDWC Satisfaction</td>
<td>0.06</td>
<td>0.00</td>
</tr>
<tr>
<td>Waste room</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supervision</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>$R^2$</td>
<td>1.70</td>
<td>1.77</td>
</tr>
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Fig. 1. The confirmed number of COVID-19 in Chinese eight cities.
classification behavior \((b_8 = 0.35, p<0.01)\), demonstrating that when the environment was cleaner, the village residents were more possible to protect the environment by their behaviors. However, human supervision was significantly and negatively related to waste classification behavior \((b_9 = -0.24, p<0.1)\), showing that human supervision when collecting RDWC couldn’t contribute to accurate waste classification behavior. And the impacts of Attitude and RDWC Satisfaction were similar to Model 2. Among the variables, subject perception is more important to awareness than the object factors, such as age, education. But for behavior, object factors seem more important. The public’s RDWC behaviors are not consistent with awareness. The age and more education may change people’s awareness but do little in the behavior. The change of behavior more relies on the external environment change than the internal changes.

COVID-19 and the Performance of Domestic Waste Classification

Domestic waste classification can cultivate the residents’ habit of civilized behavior, low-carbon life concept, and ecological environment awareness in daily life. Besides, the domestic waste classification itself is a very active measure, which can effectively prevent the spread of the virus. Many cities in China have promoted domestic waste classification, including RDWC. Their organizational structures, mobilization systems, equipment, and facilities have played a significant role in winning the battle against novel coronavirus (COVID-19). So, we suspected the spread of COVID-19 could be associated with domestic waste classification in China. Thus, we explored the association between the number of COVID-19 cases and domestic waste classification performance. The daily confirmed numbers of COVID-19 cases were obtained.
First, we compared the number of COVID-19 cases with domestic waste classification performance of different cities in the different provinces. Fig. 1 showed the confirmed number of COVID-19 in eight cities in China between January and April. These eight cities had the best performance of domestic waste classification in 2018. Municipalities directly under the Central Government are excluded here. It indicated that the cities with better domestic waste classification performance often have fewer confirmed numbers during this period.

Second, we compared the number of COVID-19 cases with domestic waste classification performance of different cities in the same province. Based on the waste classification performance rank given by Urban-Rural Development of the People’s Republic of China in 2018, a total of 13 provinces have more than one city on the list, namely Anhui, Fujian, Guangdong, Hebei, Hubei, Jiangsu, Jiangxi, Liaoning, Shandong, Shaanxi, Sichuan, Tibet, and Zhejiang. So, we compared the COVID-19 cases in the 13 provinces from January 2020 to April 2020. Fig. 2 and Fig. 3 showed the confirmed number of COVID-19 of each of the 13 provinces. We found that out of 13 provinces, 9 cities with high domestic waste classification ranks had better control of the COVID-19 epidemic situation. The trend of the epidemic situation in the same province was similar. By comparing the ranking of cities and epidemic control, we found that the greater the gap between the rankings of two cities in the same province, the greater the gap between the number of COVID-19 cases when the epidemic was stable. So, we concluded that the higher the ranking of domestic waste classification, the better the control of the COVID-19 epidemic.

In conclusion, by comparing cities in the same province and cities in different provinces, we found that there is a relationship between better domestic waste classification and better control of the epidemic. Through our study, the public’s RDWC behaviors are positively influenced by the attitude to waste classification. Therefore, during the epidemic, promoting domestic waste classification which is helpful to control the epidemic can help residents to improve their attitudes toward domestic waste classification, thus affecting residents’ domestic waste classification behavior greatly.

Conclusions

RDWC plays a significant role in the circular economy and sustainable management. However, research on public awareness and behaviors is scarce, especially using probability sampling and regression analyses. This study extends the theory of awareness

Fig. 3. The confirmed number of COVID-19 in four provinces with epidemic situation unrelated to domestic waste classification.
and behaviors, exploring the effects of attitude to waste classification, satisfaction with the situation of RDWC, cleanliness of waste rooms, environment, human supervision, and demographics on public awareness and behaviors of RDWC. In this way, we talk about the influencing factors of public awareness and behaviors, so that we can provide more targeted effective advice. The conclusions are as follows: First, the public’s RDWC awareness is positively influenced by the cleanliness of waste rooms, age, and educational level. Second, the public’s RDWC behaviors are negatively influenced by human supervision but positively influenced by the attitude to waste classification, satisfaction with the situation of RDWC and environment. Third, the public’s RDWC behaviors are not consistent with their awareness. Forth, there is a relationship between the number of COVID-19 confirmed cases and the public behavior of domestic waste classification. Compared to cities in the same province, cities with better domestic waste classification performance better-controlled COVID-19.

This study adds subject perception, object conditions, and demographic variables into the framework of the theory of awareness and behaviors, making it more complete, and proposes some specific advice for promoting the implementation of waste classification policies. However, from the survey, we find some specific problems when implementing waste classification policies.

First, the perception of the importance of RDWC is weak. Rural areas have formulated RDWC policies adapted to local conditions and provided basic waste classification facilities, but the trash cans are still mixed trash cans. Besides, the implementation of RDWC is not thorough enough. RDWC has still not received much attention.

Second, the knowledge of RDWC is irregular. The public knowledge of hazardous waste, recyclable waste, kitchen waste, and other waste is rather low and irregular. From the results of our survey, the average classification accuracy score of hazardous waste is higher than the recyclable waste. And, only 40% of the respondents participated in activities such as education on knowledge about waste classification. Insufficient publicity on the classification of RDWC may be an account of the case.

Third, the development of rural and urban areas in developing countries is unbalanced. As the world’s largest developing country, China is facing a series of imbalances, especially the imbalance between urban and rural economic development. So, RDWC in China has not been given sufficient attention. Furthermore, poor infrastructure construction and lagged policies caused the classification and management of RDWC to be much more lagged than the urban areas.

From the study, we concluded that public behaviors toward RDWC can be influenced by increasing publicity efforts, improving the local environment, and taking more effective incentive measures. Also, a strong relationship between the number of COVID-19 cases and the waste classification performance revealed that the significance of the flexibility of waste classification policy. However, the implementation of a waste classification policy should not be rushed. It’s easy to help rural residents to classify kitchen waste and other waste, but it’s not that easy to help them distinguish the difference between hazardous waste, recyclable waste, kitchen waste, and other waste. So, the government should implement the appropriate RDWC methods and supporting infrastructure facilities fitted to the different rural areas step by step, publicize RDWC methods to improve public awareness, and provide an atmosphere beneficial to good collection habits and ecological environment perception.

RDWC is an essential part of waste management in a country, while, in rural areas of many countries, RDWC has not been paid much attention. Therefore, the patterns and experience of RDWC in Hangzhou are widely applicable. Promoting RDWC in developing countries can be achieved by appropriate incentive policies and supporting infrastructure in the short term. However, to cultivate durable public awareness and behaviors in RDWC, it is significant to change residents’ subject perception of RDWC through proper publicity and education. For future research, the comparative analysis of the differences between rural and urban areas could be considered. And the quantitative analysis of the relationship between RDWC and COVID-19 may be discussed further.

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Conflict of Interest
The authors declare no conflict of interest.

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