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The disposal and willingness to pay for residents' scrap fluorescent lamps in China: A case study of Beijing

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ABSTRACT

The generation of scrap fluorescent lamps in China has increased greatly in recent years, and the improper disposal of mercury-containing waste has posed a major risk to residents' health. This paper describes research based on a sample from China to investigate the disposal and willingness to pay for scrap fluorescent lamps in households. We estimated that 4.19 million scrap fluorescent lamps are generated from households in Beijing per year. Most residents cannot recycle due to a lack of recycling facilities, and 34.7 kg scrap mercury is out of control. We found that 68.6% of Beijing residents are willing to pay extra fees to dispose of scrap fluorescent lamps safely, and the average value is 1.98 CNY/lamp, which is twice the value of the subsidiary standard that the government gives to treatment plants. We found that the length of residence period, cognition of hazardous waste and the understanding of extended producer responsibility (EPR) are the dominant factors that affect residents' payment decisions. Governmental departments should consider establishing a special fund to ensure the safe disposal of household scrap fluorescent lamps by installing recycling facilities in communities and by subsidizing recycling enterprises.

1. Introduction

The total number of fluorescent lamps (CFLs) exceed 1 billion in China in 2011 because of the implementation of the "green lighting" project from 2008 (Reynolds et al., 2012; Yang and Ji, 2014). With the following phase-out plan of incandescent lamps (ILs) issued by National Development and Reform Committee (NDRC) (NDRC, 2011), the ownership of FL has almost reached a level equal to levels in developed countries (Zhao et al., 2012). This is leading to a large quantity of scrap fluorescent lamps (FLs) from household. The FLs save energy and reduce emissions (Lee et al., 2014; Schleich et al., 2014), but the mercury in FLs is a type of highly toxic heavy metal (Cain et al., 2007). The actual amount of mercury in each FL (Zhou and Bukenya, 2016), which is produced with traditional liquid mercury injection process, is approximately 60–120 mg in China (Sun and Liu, 2003). If discarded improperly, one scrap FL can pollute at least 30 tons of water, which will cause great harm to the soil, the atmosphere and the human body (Pant and Singh, 2014; Guo et al., 2013). So scrap FLs has been listed as HW29 mercury waste in the "National hazardous waste list" (EPA, 2008).

However, scrap FLs generated from households were not disposed properly, which became a potential environment risk. When compared to other Waste Electrical and Electronic Equipment (WEEE), the economic value of scrap FLs is relatively low, which is unattractive to recyclers (Cheng and Hu, 2012). So most of the scrap FLs were combined with household garbage as ordinary household waste. Many FLs are broken during transport, landfilling or incineration; therefore, large amounts of mercury elements flow into the environment (Hu and Cheng, 2012).

There is no technical difficulty in the treatment of scrap FLs (Kujawski and Pospiech, 2014; Manomaivibool, 2015; Wu et al., 2014). However, the difficulty lies in how carry out uniform reclaim, who can afford the disposal costs and how much they should be subsidized for each scrap FL (Zhang et al., 2016). Some scholars have noted that, according to the "polluter pays" principle in China, producers and users that cause environmental pollution should be responsible for recycling (López-Mosquera et al., 2015; Peng et al., 2014). Regarding disposal expenses, China should refer to the disposal experiences of hazardous wastes in developed countries (Lee et al., 2015; Saphores and Nixon, 2014) and subsidize professional

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recycling organizations with household garbage disposal fees that are paid by residents (Silveira and Chang, 2011). However, some environmental economists think that it is difficult to implement a law to stipulate that the consumer should pay for the disposal of scrap FLs (Ying et al., 2015). Based on the conflicting opinions about the disposal fund, we considered that as the main users of FLs and the direct disposers of scrap FLs (Asari and Sakai, 2011), residents play an important role in the process of recycling(Afroz et al., 2013; Babaei et al., 2015).

The ownership of FLs in Beijing, as the capital of China, is enormous but unknown, and the scrap FL treatment system is also ineffective (Liu et al., 2015; Zheng, 2010). We conducted a survey on households in Beijing. First, we gathered information on the current recycling situation of household scrap FLs in Beijing, which mainly included the source. Then, we collected and analyzed the data to investigate the current users of FLs in Beijing households, their recycling behaviors, the awareness to participate in and the willingness to pay for recycling. Finally, we provide suggestions to implement FL recycling policies.

2. Methodology

2.1. Questionnaire Design

2.1.1. Explanation of the subject of the Research

Research team members carried out the questionnaire survey in the central business district of Beijing in July 2015. To provide respondents with a clear knowledge of the concept of FLs and to avoid misunderstandings, we provided a distinction between FLs and other types of lamps. Detailed interpretations of the various types of lamps are listed in the questionnaire, as shown in Fig. 1.

2.1.2. Selection of Research Subjects

Currently, the scrap FLs that generated from government institutions and state-owned enterprises in Beijing are transported to hazardous waste disposal centers through unified collection (Zheng, 2010). However, scrap FLs from households, which is the main source of scrap FLs, became the main problem due to a lack of unified recycling. Therefore, "household" is set as the basic research unit in this research.

2.1.3. Design of Questionnaire

The questionnaire has four parts. Part one describes the socioeconomic characteristics of residents and families, and it includes respondents' gender, age, the number of people in the family, the household income, individual income and the resident period. Part two describes the current disposal situation, which includes the number of all types of lamps in the household and the disposal mode of scrap lamps. Part three inquires about recycling awareness, which includes household understanding of FLs and recycling, the cognition of the danger of FLs and the attitudes to participate in recycling. Part four explores the willingness to pay, which includes the acceptance to pay extra fees for recycling scrap FLs and to use certain payment modes, the reasons for refusing to pay, the relationship between identity and the willingness to pay and the limit of average willingness to pay.

2.1.4. Survey mode

Many traditional methods can conduct this survey, such as face-to-face interview, telephone interview, and mail (Yoo and Kwak, 2009). The study cost of these methods descends orderly, but the quality of return questionnaire also falls sequentially. To achieve the highly reliable results, we choose the face-to-face interviews with well-trained interviewers. Through direct explaining, our interviewers help the respondents fill the questionnaire and avoid some misunderstanding or missing. Moreover, we recheck the questionnaires after they are returning from the interviewers.

2.2. Sample Size and Distribution

The research area is limited to six districts in downtown Beijing, which are in the central area of Beijing. According to the Beijing Statistical Yearbook in 2015, these typical regions of Beijing have 2.871 million residents (BJMBS, 2015). To obtain the random sample of the general study objective, it is first assumed that the overall distribution of the survey has a normal distribution. The computation formula adopted in this research is as follows:

For repeated sampling or infinite population sampling without repetition

$$n = \frac{{Z_{1-\alpha}}^2 \cdot p \cdot (1-p)}{d^2} \tag{1}$$

For the limited population

$$n = \frac{N \cdot {Z_{1-\alpha}}^2 \cdot p \cdot (1-p)}{(N-1) \cdot d^2 + Z_{1-\alpha}^2 \cdot p \cdot (1-p)} \tag{2}$$

where α is the significance level, $Z_{1-\alpha}$ is the corresponding quartile at different confidence levels under normal distribution. p is the value that can be chosen by requirement, d is the value of confidence interval, and N is the overall total. It is easy to draw the conclusion that, when N approaches infinity, the result of Formula (2) approaches the result of Formula (1).

Because the number of households is known and there is no sample repetition in this study, the calculation method of Formula (2) should be used. Based on the calculation of the sample size calculated at a 95% confidence level, the total number of households in the six main urban areas in Beijing is expressed as $d = 5\%$, $Z_{1-\alpha} = 1.96$, $p = 0.5$, $N = 2.871$ million. According to final result, the sample size should be at least 385(384.1087). We gave out 500 questionnaires to achieve better results and to account for the possibility that some of the questionnaires that are returned may be invalid.

2.3. Estimation of scrap generation

We estimate the scrap generation of FLs based on our survey data. Many previous studies predicted the WEEE generation amount based on the data for their sales and lifetime, such as marketing supply method(A), Stanford method, consumption and use approach, time-step method. (Araújo et al., 2012; Li et al., 2015; Song et al., 2016; Tan and Li, 2014) However, the sale and consumption records of FLs are unavailable from the official statistics department. So based on the sample data for the household ownership and lifetime of FLs, we choose to estimate the scrap FLs generation with the stock-based model. (Tian et al., 2015; Zhang et al., 2012) It is assumed that there are n kinds of FLs, and the stock of in-use FLs has reached a stable level. The G_t represent the scrap generation of one city in year t and is given by Formula (3):

$$G_t = \sum_{i=1}^{n} \frac{S_t^i \cdot}{L^i} \cdot H_t \tag{3}$$

where S_t^i represent the average stock of FL i per household in year t, the H_t represent the number of households in year t, and L^i represent the average lifetime of FL i.

2.4. Analysis of Factors that Influence Willingness to Pay

To obtain the influencing factors of the willingness of households to pay for scrap FLs, we used the binary logistic regression