

DEVELOPING A PRACTICAL FRAMEWORK FOR USE IN THE SEPARATION OF ALUMINIUM WASTE FROM RESTAURANTS AND ESTIMATION OF POTENTIAL BENEFITS

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Article Info:

Received:
25 January 2018
Revised:
27 March 2018
Accepted:
25 June 2018
Available online:
4 July 2018

Keywords:

Aluminium waste
Waste separation
Sari city
Practical framework
Waste Management
Restaurants

ABSTRACT

Population growth, urbanization and technological progress have resulted in an increased generation of various types of wastes. However, a series of different techniques have been developed for use in the segregation of waste components, with waste being separated either at source or at the disposal site. In Iran, waste separation at the disposal site is more popular than source separation due to a lack of public collaboration. The city of Sari is located in the northern part of Iran and is the largest and the most populous city in Mazandaran province. Per capita waste generation in Sari city is 1 kg/person⁻¹ day⁻¹. Due to a high population density but also to the presence of tourist attractions, a significant amount of waste is generated in the city, particularly by restaurants. Whilst the majority of wastes generated is constituted by aluminium drink cans, this study aims to develop a practical framework for the source separation of aluminium waste and to estimate the advantages represented by recovery. Data were collected from 25 restaurants by means of questionnaires and interviews. The results showed that the majority of restaurant owners and staff had been made aware of the need for source separation of waste via social media. However, no source separation had been implemented. The pilot study showed how approx. 320 million USD could be obtained through the recovery of aluminium waste produced by the restaurants studied per year.

1. INTRODUCTION

Population growth has resulted in the generation of a series of different types of wastes which require appropriate management (Abbasi and El Hanandeh, 2016). A key strategy in waste management is the source separation of waste (Meng et al., 2018; Rada et al., 2018; Roustae et al., 2017; Seyring et al., 2016). Nowadays, a wide series of different techniques are available for use in waste separation. In general, waste separation methods are classified into two groups including waste separation at source and waste separation at the disposal site (Seyring et al., 2016). Waste separation at source is of greater interest to developed countries than separation at the disposal site due to the lower cost involved, shorter time required, low contamination of recyclable waste, absence of mixing with other waste, and consequently lower treatment costs. In addition to the health and financial benefits, goods manufactured using the resulting recycled materials will be cleaner, and a large part of the cost of collecting and organizing waste and of washing and disinfection can be eliminated (Bartelings and Sterner, 1999; Rada et al., 2018; Watson, 1999).

In Iran, 20% of total municipal waste is made up of recyclable materials such as paper, carton, plastic, glass, and metals, approx. 70% of which are compostable materials; therefore, the implementation of source separation would introduce a fundamental change in the management of solid waste (Hassanvand et al., 2008).

Although the advantages of waste separation are evident, few studies have addressed this issue to date. A pilot study was carried out by Zhuang et al. to separate garbage or household waste in the city of Hangzhou in the centre of Zhejiang state in China (Zhuang et al., 2008). They proposed a new source separation framework based on the classification of household waste into three groups including food, dry and harmful waste. In another study by Tai et al., a pilot program was conducted focusing on separation of municipal solid waste (MSW) from eight megacities in China (Tai et al., 2011). Moreover, they provided an analysis of collection of separated municipal solid waste in China. The results demonstrated that implementation of collecting separated MSW at source was relatively successful only in the cities of Beijing and Shanghai. According to the results obtained in this study, implementation of the



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proposed framework should be the main focus in China in order to encourage people to separate kitchen waste and recyclable materials at source. They also pointed out the main challenges of waste separation which included a lack of legislation, lack of inter-institutional coordination, and lack of public awareness. Branstad et. al. (2011) evaluated the life cycle assessment of separating solid household waste at source in Sweden. Since 2001, families have been able to separate waste into six categories in Sweden. The present condition of waste separation was compared with an ideal scenario in which families entirely separate all waste at source, and with a scenario with no waste separation. The results show that under the current conditions, the source separation of waste yielded significant environmental benefits in comparison with non-separation. Zhang et al. (2012) studied popular views of municipal waste separation in Shanghai, China. In this study, face-to-face interviews and questionnaires were used to collect information about waste separation. The main outcome of this study was that only limited numbers of people separated their wastes, although they were familiar with the environmental need for waste separation.

Nowadays, a large percentage of formerly bottled drinks are supplied in metal cans, generally made of aluminium or steel. According to statistics provided by industrial analysts, 80 percent of the market is devoted to drink cans, indicating a high consumption of these compounds compared to other goods worldwide (Pinkham, 2002). This trend is expected to continue in the future, with beverage industries using metal cans for packaging (Chen and Graedel, 2012). Zartabi (2008) investigated the possibility of separation and recycling of drink bottles at the food courts located in Tehran city council zones 1, 2, 5 & 6. The results showed that approx. 75% of bottles were not separated, largely due to the high volume of bottles. This pilot study was implemented in four regions. As a result, an integrated household waste management system, a recycling system, and a mechanical water absorption system for food waste were developed to promote the separation of waste at source. Geographically, Asian and European countries have represented the largest market in recent years, with Asia expected to dominate the metal can market in the future (Sahota, 2009). Indeed, the production of aluminium from recycled aluminium requires 90% less energy than production from ore, and the recovery of aluminium reduces contamination by up to 95% (Green, 2007). If one ton of aluminium is separated from waste and re-used, 400 tons of ore and 700 kilograms of coke and bitumen will be saved (Quinkertz et al., 2001). It is therefore possible to efficiently reduce the respective contaminations and costs by implementing complete separation of this type of waste. Since cans disposed of by restaurants, this would correspond to rendering all restaurants a source of minerals for can manufacturers. To date, no efforts have been made to separate waste cans at source.

The main aims of this study were to investigate the possibility of improving management of separation of aluminium packaging and addressing the challenges, and to determine the amount of waste aluminium cans generated by restaurants and examine the financial benefits to be

gained from separation of this type of waste.

2. MATERIALS AND METHODS

2.1 Case Study

Sari, the capital of Mazandaran province, generates the highest amount of commercial waste in the province. Sari is the largest and most highly populated city in Mazandaran, Iran, with a population of 296,417 persons according to a 2011 census. The per capita waste generated in this city reaches an average of one kg person⁻¹ day⁻¹ waste (<http://saricity.ir/En/HomeEn?OrgId=21>). Currently, 250 to 300 tonnes of waste are produced per day in Sari. Due to its proximity to the sea, the forest and tourist attractions, Sari is served by a large number of restaurants which generate a considerable amount of waste aluminium cans.

2.2 Data collection and pilot study

The study was conducted at 25 restaurants located in Sari city. Both questionnaires and face-to-face interviews were used for data collection. Questionnaires A and B were prepared to understand the challenges of implementing can waste separation at source and to provide an estimate of the number of aluminium drink cans present in restaurants. The questionnaires used in this study are provided in the supplementary information.

To investigate the feasibility of implementing the separation plan, the pilot study was conducted in a restaurant located in Sari during 25 days. This pilot was implemented in agreement and coordination with the restaurant staff. Two restaurant staff were initially trained, and one waste bin equipped with a compactor was provided in which to place empty metal cans; finally a request was made to inform us once the waste bins were full for collection. During the study period these bins were collected seven times and the contents were sold. In conducting an economic analysis, we considered the average price of aluminium waste of 2.82\$ per kg.

3. RESULTS AND DISCUSSIONS

3.1 Results obtained from questionnaire A

The first sections of the questionnaire contained information relating to awareness of the need for waste separation at source. The results derived from the first section of the questionnaire are shown in Figures 1 and 2. Most respondents were familiar with the need for waste separation at source, with media playing an effective role in informing the public. The results demonstrated that only 8% of respondents admitted to a lack of knowledge to this regard.

Figure 3 illustrates the results of facilities provided for waste separation at restaurants by the Sari city council. As seen in Figure 3, only 4% of respondents confirmed that the council provided the required facilities for waste separation, whilst the rest received almost no services. The satisfaction of restaurant owners with waste collections is shown in Figure 4. The information obtained revealed a relative degree of satisfaction with the current waste management system.

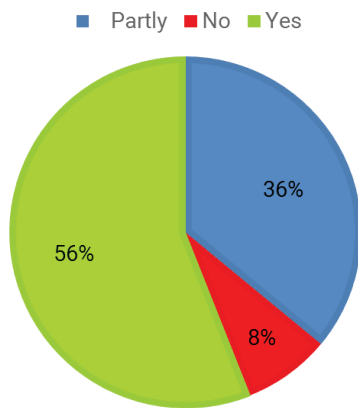


FIGURE 1: Public awareness of the importance of the source separation of wastes.

The next sections of the questionnaire examined the reasons underlying the lack of waste separation at restaurants. Inadequate facilities and the huge volumes of waste were indicated as the most important problems, with solutions identified by the restaurant owners relating to the provision of waste bins equipped with a compactor and an increased waste collection frequency. The majority of restaurant owners tended to obtain their information from brochures and staff training courses.

To implement a waste separation plan, the use of incentives was identified as the most successful approach

aimed at increasing the participation of commercial sectors such as restaurants in waste separation programs.

64 percent of respondents agreed with the use of incentives, whilst 52 percent indicated punitive measures as an effective approach for the implementation of waste separation at source (Figure 5). Punitive measures included stopping waste collection services, the payment of fines, and tax increases. As shown in Figure 6, training was suggested as the best option to enhance the awareness and participation of restaurant staff in executing such a plan.

3.2 Results obtained from questionnaire B

An estimated 48 kg of waste cans is generated on average per day in the Sari restaurants. Maximum waste can generation was 140kg and the lowest 15kg (Figure 7).

Considering the positive correlation between the number of customers and generation of waste cans, the number of customers were measured at each restaurant. Figures 8 and 9 demonstrate daily generation of waste cans and the number of customers per season at each restaurant. It is estimated that 233g waste is generated per customer per day. The highest numbers of customers were observed in summer with an average of 535 persons per day. Subsequently, the highest amount of waste cans was generated in the summer, followed by the spring, corresponding to an estimated average of 529 customers (Figure 10). As shown in Figure 10, aluminium containers constituted the largest portion of the collected waste cans, corresponding

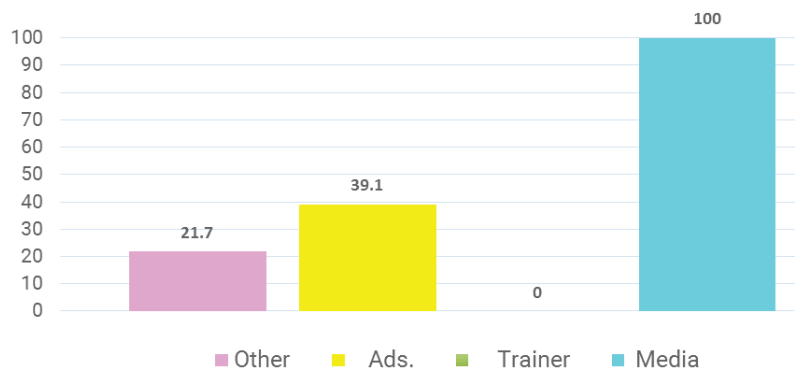


FIGURE 2: Means of increasing awareness of the need for source separation of wastes.

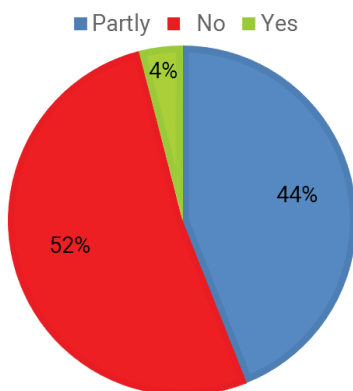


FIGURE 3: Restaurants equipped with facilities for waste separation.

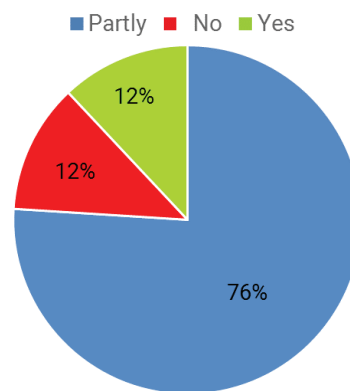


FIGURE 4: Satisfaction of restaurant owners with current waste collection.

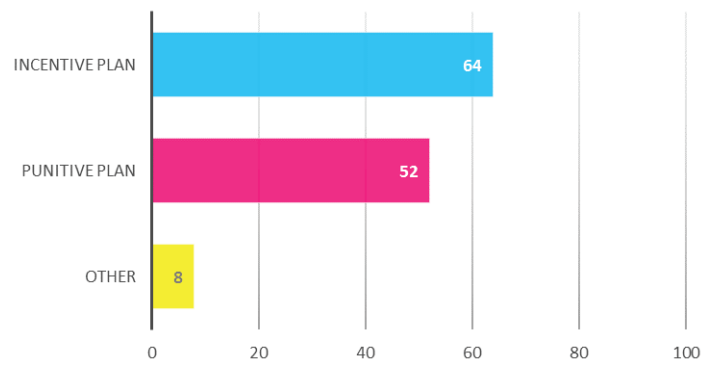


FIGURE 5: Legal solutions for implementation of a waste separation plan.



FIGURE 6: Suggested solutions to increase awareness and participation of restaurant staff.

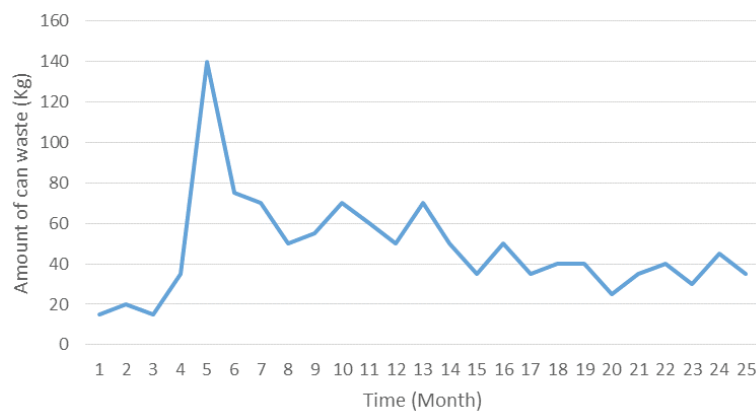


FIGURE 7: Daily generation of waste cans at the restaurants.

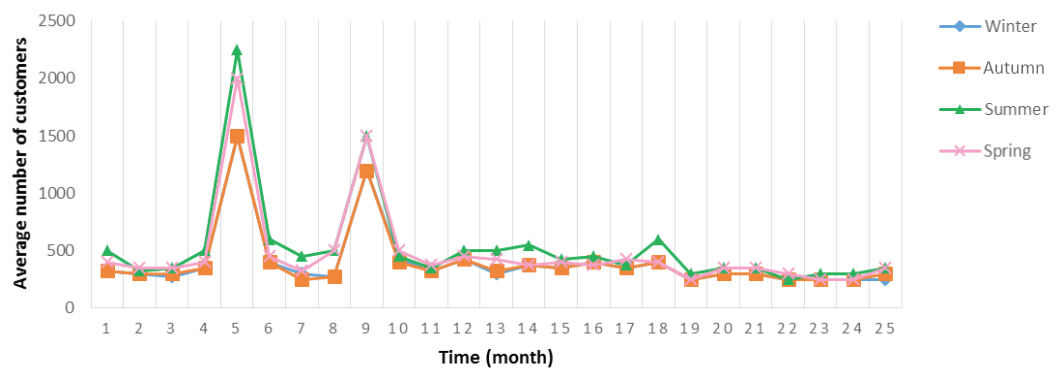


FIGURE 8: Number of customers per season at each restaurant.

to 52% of total container wastes. In addition, no separation of waste cans was conducted.

Statistical analysis revealed that the generation of waste cans peaked in the summer with an average rate of 8750 cans per day for a total weight of 140 Kg. The total amount of waste generated in the restaurants studied was estimated to be approx. 350 Kg per day.

3.3 Results of pilot study

The pilot study was carried out over a 25-day period from 27/04/2017 to 21/05/2017 at the Atishe restaurant in Sari. The results of this study are summarized in Table

1. By separating waste aluminium cans, 78.3 Kg of waste cans was collected and sold for 220\$.

3.4 The challenges of the source waste separation program in Sari city

3.4.1 Lack of coordination between relevant organizations

In order to implement and carry out waste separation at source, an effective dialogue and coordination between organizations in charge of waste collection and separation, such as the government, the city council, and finally the private sectors should be facilitated.

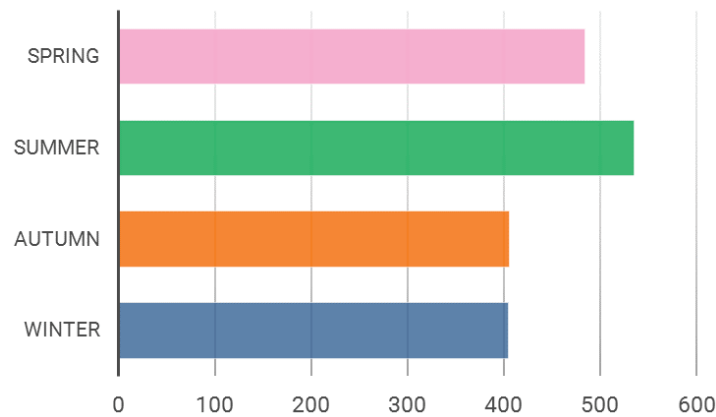


FIGURE 9: Average daily number of customers throughout the different seasons.

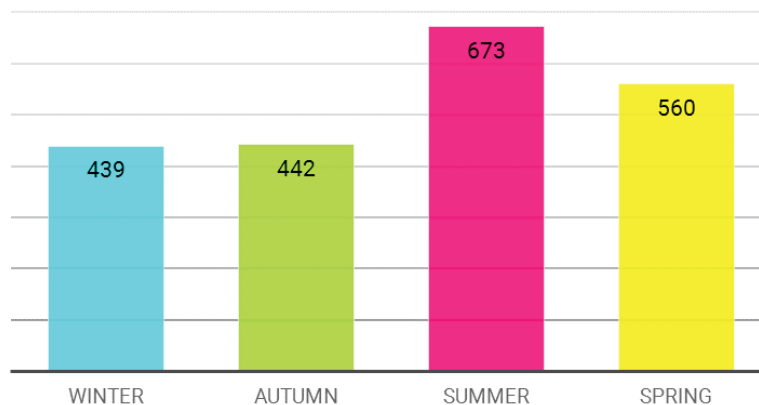


FIGURE 10: Daily average of waste cans generated at restaurants per season.

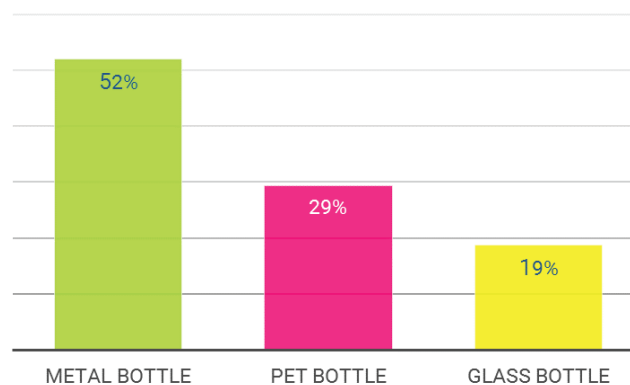


FIGURE 11: Types of drink bottles discarded at restaurants.

TABLE 1: Results of pilot study of separation of cans at Atishe restaurant in Sari city.

Date of collecting	Weight (Kg)	Selling price
28/04/2017	9.200	25.944
03/05/2017	11.700	32.994
05/05/2017	8.600	24.252
10/05/2017	14.600	41.172
12/05/2017	8.500	23.97
17/05/2017	13.800	38.916
21/05/2017	11.900	33.558
Total	78.300	220.806

3.4.2 Regulation and environmental policy

The government plays a major role in supporting and implementing comprehensive plans for waste management and waste recycling. In Iran, the waste management system has been heavily affected by the absence of environmental regulation, with legislation at times being so generic or obsolete that huge issues may be encountered in waste management programs. The promulgation and enforcement of new legislation would contribute towards fostering the implementation of source separation programs for waste aluminium cans.

In Sari, the city council is responsible for waste management services. Incentives and punitive measures might be applied by the council in an attempt to galvanize the commercial sectors into performing waste separation at source. This would contribute towards reducing the amount of collected waste, landfill size and the cost of waste management.

3.4.3 Lack of facilities

The effective provision of the necessary equipment would increase the participation of restaurant staff in separating waste cans. The use of designated trucks for the collection of separated waste, waste bins equipped with compactors, a suitable timetable for the collection of waste cans and training are the suggested main requirements of implementing any waste separation program.

4. CONCLUSIONS

The source separation of waste represents a priority strategies in any waste management system. Sari city, in the centre of Mazandaran province in Iran, generates the largest amounts of waste throughout the province. Due to the presence of tourist attractions, numerous restaurants are present in the city, and are responsible for generating huge quantities of waste aluminium cans. A pilot study was thus conducted to collect data relating to the amount of waste cans generated and to obtain information on waste separation and the challenges involved. Accordingly, data were collected from 25 restaurants by means of interview, field studies, and questionnaires. The results

showed the generation of waste aluminium cans peaked in the summer with an average rate of 8750 cans per day. The total amount of waste generated in the restaurants studied was estimated in approx. 350 Kg per day. The pilot waste separation study collected 78.3 Kg of waste aluminium cans, which were then sold for 220\$. A lack of coordination between the relevant organizations, insufficient legislation and lack of environmental policy, together with lack of facilities represented the main challenges to be overcome in implementing a waste separation program in the restaurants in Sari, Iran.

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