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EVALUATION THE INHABITANTS' PARTICIPATION IN SEPARATION AT SOURCE BY WASTE CHARACTERIZATION

K. Rousta[1], M.K. Moghadam[2], P.H. Karimkhani[3], T. Richards[4]
1 Kamran Rousta, Resource Recovery, University of Borås, Sweden, Kamran.Rousta@hb.se
2 Mitra Kaeni Moghadam, University of Borås, Sweden, mitra_kaeni@yahoo.com
3 Parima Haji Karimkhani, University of Borås, Sweden, parima_hk@yahoo.com
4 Tobias Richards, Resource Recovery, University of Borås, Sweden, Tobias.Richards@hb.se

ABSTRACT
In Borås, a modern municipality solid waste management (MSWM) has been established since 1988 which is working based on separation at source. The citizens of Borås have a central role in the fulfilment of the sustainable goals for the MSWM by separating several waste fractions at their home.
There are many factors such as education, convenience, information, responsibility, attitude, culture, etc. which affect the citizens recycling behaviour as well as their participation in separation at source. The goal of the present study was to identify the guidelines for further research in inhabitants' recycling behaviour. Therefore, evaluation of the present situation regarding wastes sorting at source was considered. This study analysed the collected waste in black and white bags in three different neighbourhoods in Borås. The household waste in these areas were collected randomly from different types of dwelling and households in spring 2010 and characterized into 21 different fractions based on its origin. This study measured how active the inhabitants were in a source separation system. The results identified some barriers and drivers in the system which can affect the citizens' participation in source separation. The results of the study also showed some factors such as convenience and situational, culture and the type of distributed information which needs to be investigated further. A comparison of the results from this study with a previous one from 2000, showed both improvements and declination in different areas during these ten years.

Keyword: Solid waste management, Borås, recycling behaviour, source separation, waste characterization

INTRODUCTION
Due to the rapid growing of waste production worldwide, treating various streams of waste, e.g. industrial, agricultural and household waste, become serious issues for each municipality [1]. For waste treatment, sustainable and environmental friendly methods should be applied to minimize the environmental impact. To reach a sustainable waste management it is necessary to design and apply a system which moves towards the top of the waste hierarchy, Fig. 1. The 3Rs in waste hierarchy, Reduce and Reuse (source reduction), and Recycle (recycling), show the main strategies in waste management regarding to their importance and desirability [1,2]. Fuel production (e.g. biogas and bioethanol) and energy recovery comes next and as the last choice, when there is no other option; some waste such as hazardous waste can go for waste disposal [2]. Frequent steps in a waste treating organization are: collecting from waste production location, transporting to pre-treating or processing facility, and disposing the remained part. The waste can be compressed, sorted, separated, dried, packed or stored in the pre-treatment step and thereby get prepared for future processing or transportation. It is common to collect the household waste once a week in Europe and it depends on the amount of waste production per inhabitant in that area and waste collection facilities of the municipality [3]. There are many methods to establish a waste management system for a community and it can be tailor-made for each community [4]. The selection of system can be based on e.g. participating of the inhabitant, sorting at source, and technology. Separation at source is one of the most effective ways to facilitate reuse of material in a solid waste management system [4]. Applying waste separation at source in MSWM puts the inhabitants in a key position in which the system is working more efficient by low cost in the collection system [5].

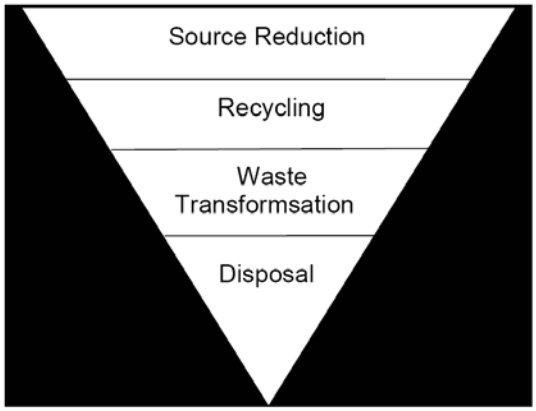

Fig. 1. Waste management hierarchy [4].

Borås, a city in the south west of Sweden with about 100,000 inhabitants has applied a MSWM for households based on separation at source which is called the Borås system in Sweden [6]. Since 1992 this system has decreased the total amount of landfilling from 100 ton to less than 10 ton per year in 2010 which was mostly soil [7]. In the Borås system, there are two plastic bags for the separation of biodegradable and combustible waste, black and white respectively (Fig. 2). All food waste go to the black one and the light plastic, the small papers, different wastes which are not sorted in the sorting place should be put in the white bags [6].

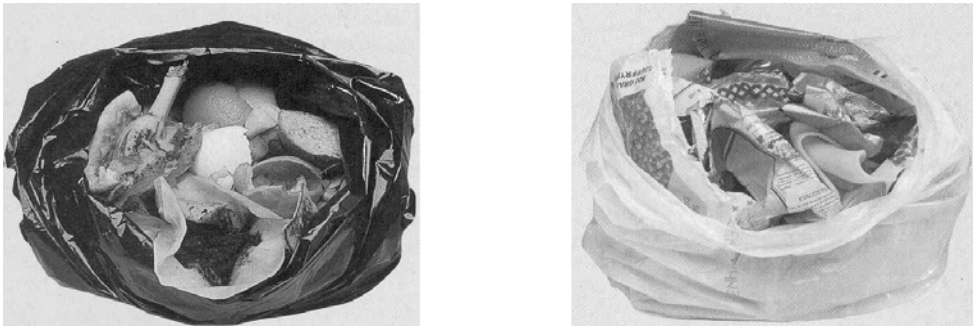

Fig. 2. Black bags; organic food waste and white bags; combustible waste.

Approximately 80 recycling facilities for collecting the packaging with producer reasonability is present in the city. They consist of six-chamber-recycling stations for recycling newspaper, paper, plastic, glass and metal packaging and are placed in each neighbourhood. There are also boxes for collecting small batteries [8]. These stations are managed through the producer responsibility, which means that producers of e.g. electronics, batteries, papers and packages must provide means for recycling.
The city of Borås has also five recycling centres. Two of them are in the main city of Borås, while the others are in the smaller communities Viskafors, Dalsjöfors and Fristad. These centres are responsible for collecting electronic waste, hazardous waste, bulky waste, used furniture and landfill fraction. The inhabitants are responsible to carry these types of waste to these stations without paying any fees.
In such a system, the inhabitants play very essential roles in the waste management. All solid waste should be sorted at source by them. Therefore, studies on the recycling behaviour and understanding the barriers and opportunities in this field can help the decision makers to develop the system as much as possible towards sustainability. The present study was done to identify the guidelines for further research in the inhabitants' recycling behaviour. Therefore, evaluation of the present situation regarding wastes sorting at source in black and white bags was considered. This study analyses the collected waste in black and white bags in three different neighbourhoods in Borås in order to compare the recycling behaviour in these three districts as well as finding the important factors for further research in this field.

METHODS AND MATERIALS

During week 14-21, 2010, waste samples from three selected areas, Hestra, Kristineberg and Norrby, in Borås were collected. These three areas were the same areas which were used in a previous study

and consist of 120 villas in Hestra, 339 flats in Kristineberg and 144 flats in Norbby. Since there was no long holiday or any national day during this period of time, waste generation during this season were stable and could be considered generally acceptable for most of the year. The selected unit was wheeled bin for both houses and apartment blocks. Independent random sample (IRS) was used for villas and houses, and stratified sampling used for apartment buildings where each flat constitutes a stratum. If the filling in a wheeled bin was less than 50% it was not representative of the multi-housing unit. Instead, another bin was selected randomly.
The collection analysis was preceded by weighting the bags using an electronic wave balance (TANITA model BSE, capacity 50 kg ± 0.05 kg) with a measurement accuracy of 50 grams. The numbers of black and white bags were counted, and the weights of bags were recorded. It is important to note that this study was limited to pick analyze of the black and white plastic bags. The other fractions of the waste which could be generated and transferred to the recycling stations were not considered. In total, 2440 kg of waste were analyzed and sorted into 21 different fractions (Table 1).

Table 1. Numbers and weights of the samples from different districts

	Hestra		Kristineberg		Norrby	
	Black	White	Black	White	Black	White
Number	273	501	239	607	259	582
Weight [kg]	370.2	436.2	252.1	517.6	317.6	545.6
Total Weight [kg]	806.4		769.7		863.2	

These 21 fractions were classified in four categories:

1) Hazardous waste: bulb, battery, electronic waste and other hazardous waste
2) Recyclable waste: soft and hard plastic, cardboard, paper, paper packaging, multilayer packaging, metal packaging, metal packaging with deposit, glass packaging, glass packaging with deposit, PET and metal scrap
3) Combustible waste: other food packaging, diapers and tissues, combustible trash and others
4) Food waste: any food waste

RESULTS

Three main evaluations were made, 1) evaluate the proportion of the fractions in white and black bags, 2) analyze the different type of recyclable material in white bags and 3) comparison of the results with the previous study in 2000.

Waste Fractions Related to Black and White bags

Figs. 3 and 4 show the proportion of each four categories in white and black bags in the three areas.
Sorting of waste in the black bags in all three areas is acceptable for the biogas production process. In Hestra almost 90% of the bag contents were food waste whereas in Norrby it came down to 75% and in Kristineberg 80%. The amount of recyclable materials in the black bags for Kristineberg and Norrby are larger than Hestra. The combustible fractions, which should not be sorted in black bags for all three areas are about 12%. However, the result from the white bags was not pleasing. 15% to 30% of food waste was placed in the white bags in different areas where Norrby was the worst. About 35% of recyclable materials were found in white bags in which only the combustible waste should be placed.

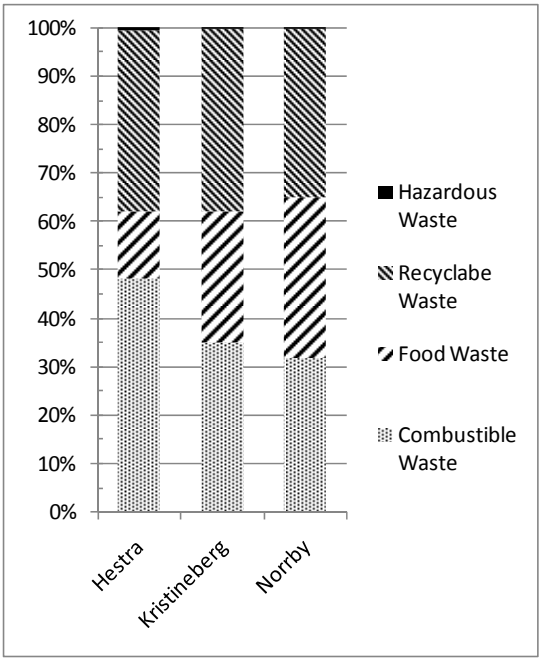

Fig. 3. Proportion of four categories in white bags.

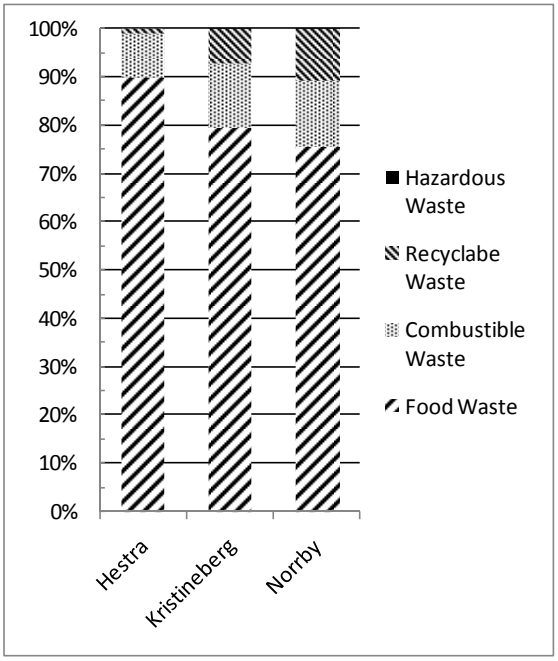

Fig. 4. Proportion of four categories in black bags.

In the Fig. 5, the total waste fractions both in white and black bags are shown.

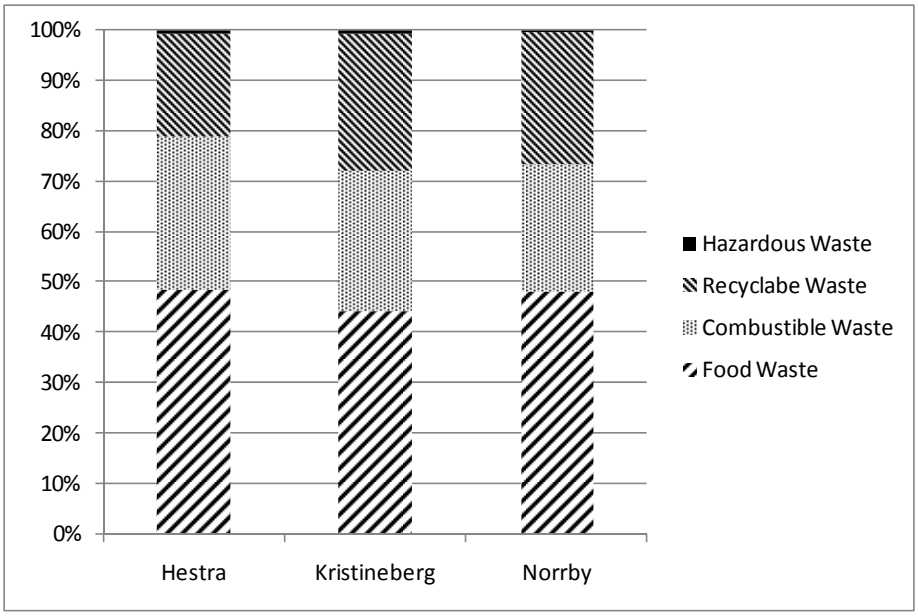

Fig. 5. Proportion of four categories in total waste generation (white and black bags).

The results showed that all three areas generated more or less the same fractions of waste with different levels of sorting and less than 1% of the total waste in black and white bags was hazardous waste.

Recyclable Materials in White bags

The high amounts of recyclable material in the white bags were further analyzed. Fig. 6 shows the proportion of each fraction of recyclable materials in the white bags. Almost no packaging with deposit was found. The most fractions in all three districts were plastic, paper (including newspapers and advertisement papers), multilayer and paper packaging. Hestra showed less papers and Norrby had less multilayer and paper packaging in comparison to the other districts. The amount of metal packaging and metal scrap was more than 5% in all areas. The Hestra area showed the lowest fraction of glass packaging and cardboard.

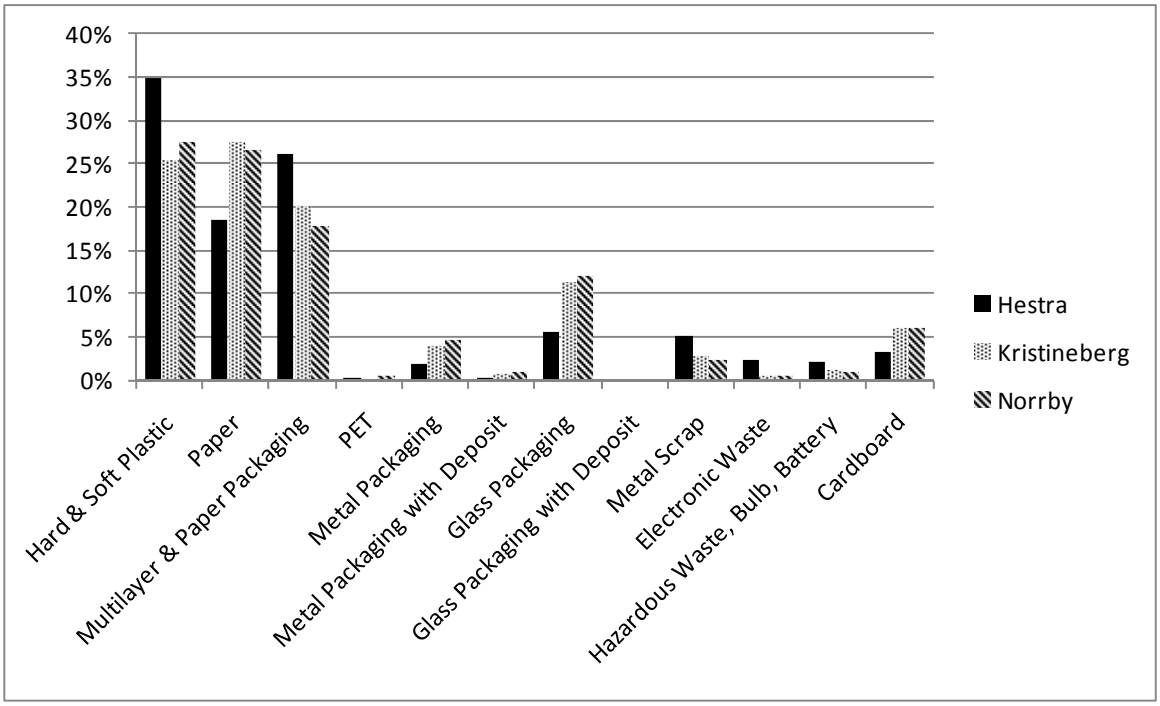

Fig. 6. Proportion of material in recyclable waste in white bags

Comparing Classification of Fractions with Previous Study in 2000

The new results from this investigation with respect to the manual sorting in white bags were compared with the previous case study which was performed in the year 2000. In the last study only the fractions in the white bags were analyzed [9]. Therefore, Fig. 7 shows the proportion of four categories only in the white bags in 2000 and in 2010.

The results showed that Hestra had a good improvement regarding reduction of the food waste in the white bags. However, there was no obvious improvement in Norrby. The amount of recyclable material in the white bags was more or less the same as 10 years ago.

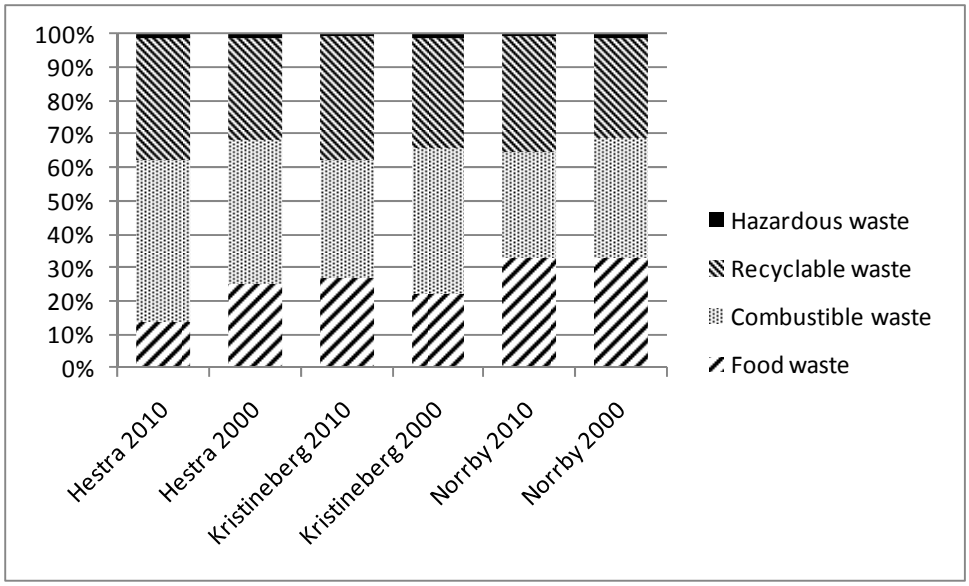

Fig. 7. Comparison of fractions in white bags between 2000 and 2010

DISCUSION

The results show that the problem of mixing food waste and combustible waste in the two different plastic bags is worst in Norrby, moderate in Kristineberg and Hestra is better than the others. By looking at the immigrants background statistics in these three districts, Norrby with 25% has more than Kristineberg with 20% and Hestra with 8% [10]. This can express the need of information for sorting

guides in different languages. Also all three areas put about 35% recyclable materials in the white bags which it is not desirable. The main reason can be the lack of information for inhabitants in how to sort their waste. In other words, the available information system does not work properly. Comparing the results with the previous study in 2000 can be another evidence for this, because the amount of the recycling materials in white bags is more or less the same as in 2010.
Logistics and access to recycling station should be considered as motivation factors for recycling behavior [11]. A good system should facilitate a better participation for the citizens. The convenience factors can motivate the people to participate in the sorting system. For example, the results from this study show that the most recyclable parts in the white bags are plastic, paper, paper and glass packaging. There are two main reasons for that. The first one can be the distance and the access to recycling stations. The other reason is that these fractions have just a small part of the total waste generation that the people do not care to sort them [12].
Even the type of houses can affect to sorting behavior. There are enough inside spaces to have sorting bags for different recyclable fractions in villas (type of houses in Hestra) where there are not in flats (type of the houses in Kristineberg and Norrby). Meanwhile based on the legislation in Borås, houses with inadequate sorting are going to be punished by extra fees [6]. Where each villa has its own waste bin, it is easy to identify which waste belongs to which villa but for the multi flats this is not possible. This legislation can be one of the reasons that Hestra sort better than the others. The results also showed that there are no PET, aluminum cans and glass packaging with deposit in the bags. The return systems, which is available in Sweden and works based on deposit, is the main reason. More than 90% of such material goes to recycling each year in Sweden [13]. This can prove that economical incentives can play a major role to motivate the people to participate in the recycling system.

CONCLUSION

The results of this study are guidelines for future research in order to modify the waste management system in Borås towards the top of the waste hierarchy. Based on these results and discussion, it can be concluded that the factors such as information, convenience, and economical incentives are important to motivate the citizens to participate in the waste separation system.

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