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Developing a monitoring method facilitating continual improvements in the sorting of waste at recycling centres

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Abstract

Beneficial use of waste relies on efficient systems for collection and separation. In Sweden, a bring system involving recycling centres for collection of bulky, electr(on)ic and hazardous waste has been introduced. A significant share of this waste is incorrectly sorted, causing downstream environmental implications. At present, however, there is a lack of affordable and accurate monitoring methods for providing the recycling centres with the necessary facts for improving the sorting of waste. The aim of this study was therefore to evaluate the usability of a simplified and potentially more suitable waste monitoring method for recycling centres. This method is based on standardised observations where the occurrence of incorrect sorting is monitored by taking digital pictures of the waste which then are analysed according to certain guidelines. The results show that the developed monitoring method could offer a resource-efficient and useful tool for proactive quality work at recycling centres, involving continuous efforts in developing and evaluating measures for improved sorting of waste. More research is however needed in order to determine to what extent the obtained results from the monitoring method are reliable.

Key words: Household waste, waste management, waste collection systems, waste composition methods

1. Introduction

Beneficial use of waste depends on efficient systems for collection and separation (Ayres, 1997; Reijnders, 2000; Krook et al., 2007). Only if the waste is separated into well-defined material categories can the environmental potential of recycling strategies be fully realised. In Sweden, there are three main collection systems for household waste (The Swedish Association of Waste Management, 2008). The main part of the waste is collected in a kerbside system involving trucks emptying the bins at people's residences. Then, there are two so-called "bring" systems, where people take waste to collection sites for sorting. In one such system, waste for which the producers are responsible for collection (e.g. packaging and paper) is brought to recycling stations. The other type of bring system is a recycling centre with facilities for sorting of bulky, electr(on)ic or hazardous waste such as demolition waste, bicycles, furniture, garden waste, computers and paint. At these facilities, a team of staff guides and controls the sorting done by individuals (Engkvist et al., 2008), which offers a relatively high capacity to influence waste

separation efficiency. In the kerbside system, on the other hand, waste disposal is uncontrolled and therefore the separation efficiency achieved is much more dependent on individual knowledge and good will (Petersen, 2004).

Each year almost five million tonnes of household waste are generated in Sweden, of which 30% is collected at recycling centres (The Swedish Association of Waste Management, 2008). How accurate the waste is sorted at these facilities largely determines the quality of the collected waste and thus also the conditions for subsequent treatment and resource recovery (cf. Schachermayer, 2000; Tanskanen, 2000). Previous research indicates that as much as 20% of this waste is incorrectly sorted, causing downstream environmental implications (Krook and Eklund, 2009a). Scarce resources such as metal and plastic are lost, for instance, when they unintentionally end up in waste being landfilled and efficient resource use is also impeded by the incorrect sorting of materials suitable for recycling in waste flows intended for incineration (cf. Björklund and Finnveden, 2005). In addition, the fact that hazardous substances are frequently mixed with non-hazardous waste both causes increased emissions to the environment and prevents beneficial use of the waste due to high contamination levels (Reijnders, 2000; Lindqvist-Östblom and Eklund, 2001; Krook et al., 2006).

Incorrect sorting where people deposit waste into wrong containers may be due to various factors, such as the overall layout and structure of the collection system, lack of information, staffing levels, waste terminology issues, citizens' knowledge and attitudes, and so on (Petersen, 2004; Engkvist et al., 2008). Within the field of quality management, it has been demonstrated that such complex quality problems must be tackled in a systematic and thorough way. One essential element of such quality work is that it must be based on facts (Klefsjö et al., 1999). Investigations illuminating the reasons behind incorrect sorting are therefore crucial, since it is only on the basis of such facts that effective measures can be developed. Another fundamental element is that the results of implemented measures must always be monitored in order to evaluate why they were effective or not (ibid.). Such knowledge facilitates the development of new, even more effective measures. This type of proactive approach to solving quality problems in organisations through systematic and continuous investigations is often referred to as Total Quality Management (Thomsen et al., 1996).

At present, there is a lack of suitable methods for continuous monitoring of the quality of sorting achieved at recycling centres, i.e. how accurate the waste is sorted according to stated guidelines. Without such an empirical basis it is difficult to identify the various cause-effect relationships of incorrect sorting and thus to develop effective improvement measures. The only available methods involve collecting and analysing physical samples of the waste (Dahlén and Lagerkvist, 2008). Such methods could provide detailed and reliable information of the waste composition but are reliant on expert knowledge and far too resource- and time-consuming for continual evaluations (e.g. The Swedish Association of Waste Management, 2005a; Dahlén et al., 2007).

They are for such reasons primarily used in larger research projects. A simplified and thereby potentially more suitable method for continuous monitoring of the sorting of waste at recycling centres was therefore developed in a pre-study (Krook and Eklund, 2009b). This method is based on standardised observations where the occurrence of incorrect sorting is monitored by taking digital pictures of the waste which then are analysed according to certain guidelines.

1.1 Aim

This study aims to assess if the standardised observation method could offer a useful tool to obtain the necessary facts for continual improvements in the sorting of waste at recycling centres. In doing so, the usability of the method was tested in practice focusing on evaluating its resource requirements, precision and reliability.

2. Background

The standardised observation method was developed at a recycling centre in the city of Linköping, Sweden. Four types of waste, all of which represent large flows at recycling centres, were included in the development process: combustibles (intended for energy recovery), metal (material recycling), wood waste (energy recovery) and non-recyclables (landfilling). At recycling centres, such bulky waste is collected in large containers, i.e. 30 m^3, which typically are placed in a long row, one after the other, and on a lower ground level than the disposal area from which people throw their waste into the containers, Fig. 1.

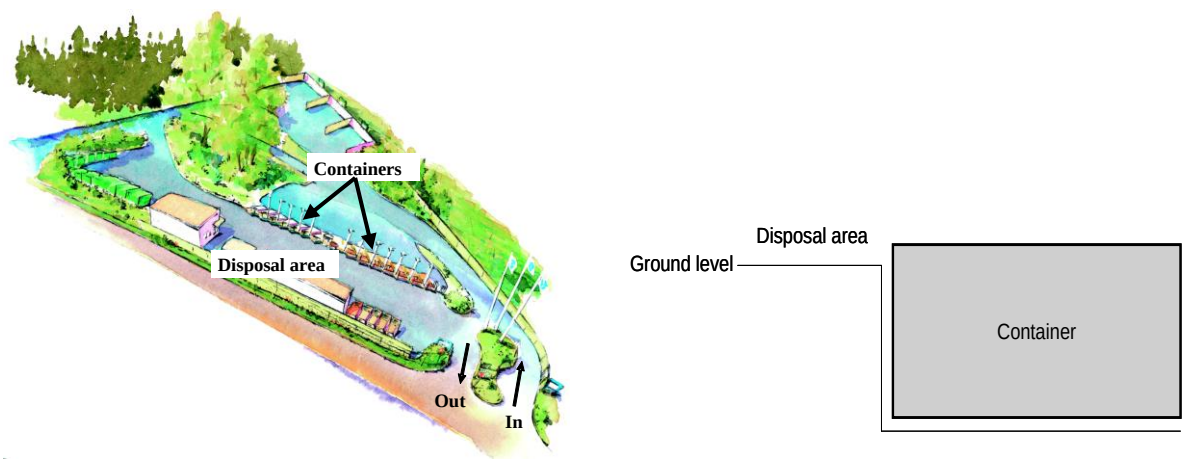

Fig. 1. Typical arrangement of containers for bulky waste at recycling centres in Sweden.

2.1 The standardised observation method

Each measurement with the developed monitoring method involves three main steps: (1) sample selection and photographing of waste in the container; (2) inventory of the picture taken; and (3) documentation of the results. The sample selection (1) is made by an aluminium device consisting of a square sample area of 1.5 m^2 and a two-metre-long handle to which a crossbar is attached, indicating the exact position from which the pictures should be taken, Fig. 2. This sample area represents 10% of the total surface area of the container. By holding the long handle, the sample area is lowered into the container and placed flat, directly upon the waste and always in the same position in the container. Such a procedure, where a fixed sample area is used, is often referred to as selected sampling (Thompson, 2002; Henderson, 2003). It provides relative estimates of the occurrence and intensity of incorrect sorting in the waste and allows for comparative investigations among similarly collected samples. Once the sample area is in place, a picture of the waste within the square is taken using a digital camera. Due to the selected position in the container, it is possible for one person to keep the sample area in place and at the same time photograph the waste while standing beside the container.

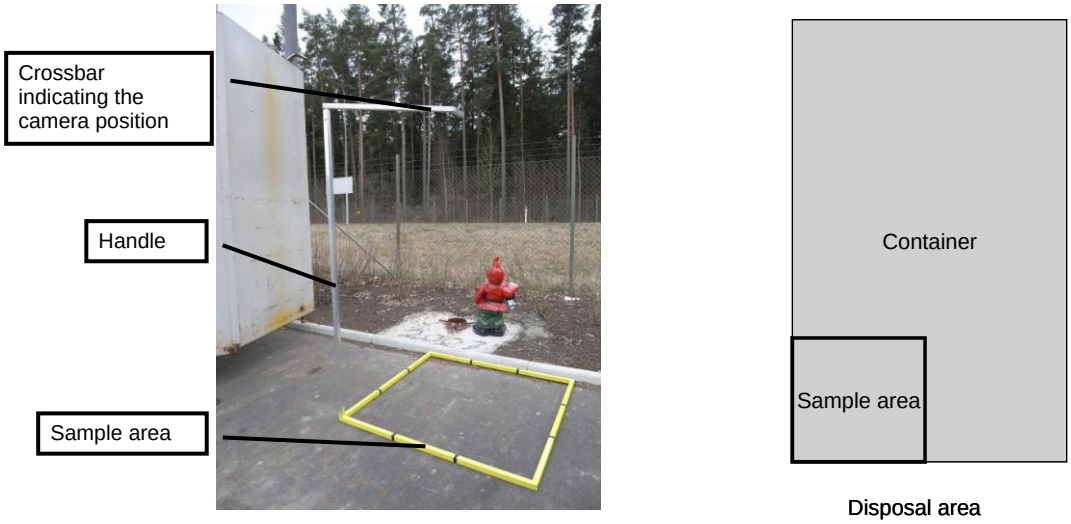

Fig. 2. A picture of the developed aluminium device for sample selection and the fixed position of the sample area in the container seen from an above view.

(2) The inventory of the pictures involves identification and counting of all incorrectly sorted waste items within the square sample area. In Table 1, the desired contents of the studied types of waste at the recycling centre are presented and all other kinds of items occurring within the sample area are thus regarded as incorrectly sorted and counted during the inventory. For items consisting of several different materials, standardised guidelines are used to determine if they are to be regarded as incorrectly sorted. These guidelines were developed together with the operator of the recycling centre. An example of such a guideline for items occurring in the container for

wood waste is as follows: *the item is incorrectly sorted if ten weight percent or more consists of a material that the wood waste should not contain, e.g. metal, plastic and gypsum.* Also items which material composition can not be determined are counted during the inventory such as wrapped waste in sacks, bags and cardboard boxes.

Table 1. The different types of waste included in the study and their desired composition at the recycling centre.

Type of waste	**Desired content in the container**
Combustibles	*soft plastic, paper except packaging and publication paper, styrofoam, textile and plastic composites*
Wood	*sawn timber, building boards (e.g. particle board, plywood, masonite), wooden doors and furniture, window frames without glass, wooden pallets*
Metal	*all metals except packaging and electr(on)ic products such as bicycles, roofs, cables, bathing tubes, heat boilers and furniture*
Non-recyclables	*glass except packaging, mineral wool, china ware, gypsum, brick, tile and concrete*

It is important to point out that only the items visible in the picture, i.e. the surface layer of the waste in the container, can be monitored during the inventory. In order to facilitate identification of items, the inventory is preferably made using computer software, offering basic functions such as zooming and adjustment of brightness and contrast of the pictures. The square sample area represents the boundary for each measurement and items any part of which appears within this area are included in the inventory.

Table 2. Pre-determined categories for incorrectly sorted waste items used during the inventory (based on Krook et al., 2009a). Which categories are relevant for each of the studied types of waste are also indicated.

Categories of incorrect sorting	**Main constituents**	**Occurrence in different types of waste**			
		Combust.	**Wood**	**Metal**	**Non-recycl.**
Cardboard	*packaging boxes for varying products*	x	x	x	x
Publication paper	*newspapers, magazines, brochures*	x			
Wood	*sawn timber, wooded boards, furniture*	x		x	x
Plastic	*all sorts of plastic materials*		x	x	x
Hard plastic	*construction materials, furniture*	x			
Plastic packaging	*food packaging*	x			
Metal	*all sorts of metal products*	x	x		x
Metal packaging	*paint cans, food tins*			x	
Hazardous waste	*paint, solvents, chemicals, batteries*	x		x	x
Inorganic materials	*bricks, gypsum, china ware, insulation*	x	x		
Garden waste	*grass cuttings, plant residues, fruit*	x			
Pressure-treated wood	*sawn timber used in terraces, fences*		x		
Electr(on)ic waste	*household electr(on)ic equipment*		x	x	x
Glass	*windows and mirror glass*			x	
Glass packaging	*drinking bottles, food jars*				x
Textile	*clothes, carpets, pillows*			x	x
Unknown	*mainly bagged waste*	x	x	x	x

(3) Finally, the result of each inventory is documented in a protocol. The number of incorrectly sorted items identified during the inventory is then divided into pre-determined waste categories, Table 2. For example, all identified newspapers, magazines and brochures within the sample area are summarised and the total number of such items specified in the "Publication paper" category. Incorrectly sorted items consisting of several different materials are placed in the category that corresponds most closely to their material composition while the number of items being difficult to assess is documented in a separate "Unknown" category.

3. Method

In order to evaluate the usability of the standardised observation method, a full-scale field test was conducted at the recycling centre in Linköping, involving more than 90 measurements of the four studied types of waste. Twice every week, a picture of the waste in each container was taken and analysed according to the procedure described above. At the recycling centre, there were several containers available for each of the studied types of waste and in total 20 measurements were performed with method every week during the field test.

Based on the results of the field test, the standardised observation method was evaluated regarding its resource requirements, precision and reliability. The time and labour demands were successively documented and analysed during the field test. Since each measurement with the standardised observation method only covers a small share of the total amount of waste in the containers, it is not likely that a single measurement will accurately address the incorrect sorting in the waste. The idea, however, was that conducting several, independent measurements could provide such data. When evaluating the precision of the method emphasis was therefore primarily on determining the number of measurements at which no additional information about the incorrect sorting in the waste was obtained. Such knowledge is essential for the usability of all waste monitoring methods since it indicates how many samples, or in this case measurements, are needed in order to obtain saturation in the provided information (Sfeir et al., 1999; The Swedish Association of Waste Management, 2005b; Sharma and McBean, 2007).

In order to facilitate validation of the reliability of the obtained results from the standardised observation method, a reference value for the "real" composition of the monitored waste was needed for comparison. A physical sample of one of the largest and most complex waste flows at recycling centres, i.e. combustibles, was therefore collected and analysed in detail. This involved sorting through a full container from the recycling centre (2,860 kg of waste), dividing it into different waste categories and weighing each category in order to determine the total waste composition (see Dahlén and Lagerkvist (2008) for a thorough review of waste composition analysis methods). A central methodology issue was whether this sample size was large enough to cover the variation in the composition of combustibles, thus constituting an accurate reference value for validation. At the recycling centre, the average number of visitors is 2,800 per week and each week approximately 10 full containers of combustibles are collected. Previous research has

shown that 60% of the visitors to recycling centres, i.e. 1,680 visitors per week, throw waste in containers for combustibles (Porsborn, 2004). This means that almost 170 different visitors have thrown waste into the analysed container, which in turn indicates that most of the variation in waste composition should be covered. The analysed amount of waste is also of a similar order of magnitude as the sample size used in other waste composition studies of household waste (e.g. Petersen, 2004; The Swedish Association of Waste Management, 2005a; Dahlén and Lagerkvist, 2008).

3.1 Using the standardised observation method for monitoring the total sorting quality of waste

During the field test, the standardised observation method was primarily used simply to list and rank the different categories of incorrect sorting that occurred in the waste at a certain time. This type of information is essential for proactive quality work at recycling centres but does not say much about how accurately the waste is sorted in an absolute sense, i.e. how much of the waste is sorted both correctly and incorrectly. Such data on the total sorting quality could be useful however for evaluating the overall performance of recycling centres (cf. Sharma and McBean, 2007). For one of the studied types of waste, i.e. combustibles, the capacity of the developed method to provide such an estimate of the total sorting quality was therefore evaluated in the study. Based on the measurements from the full-scale field test, an intensity estimate of the total sorting quality was calculated and expressed as the percentage share of the items within the sample area that are sorted either correctly or incorrectly. However, since only the incorrectly sorted items had been addressed during the full-scale field test, it was necessary to conduct re-inventories of pictures taken of the waste in order to determine the share of the items within the sample area that were correctly sorted. For this type of application too the result from the standardised observation method was validated by comparing it to the total waste composition obtained from collecting and analysing a physical sample of the monitored waste.

4. Results from the field test

4.1 Number of measurements needed with the developed method to survey incorrect sorting

All waste composition studies involve limited resources, which in practice means that the information provided must always be balanced against efforts invested in terms of labour, time and financial resources. During the field test, a number of different categories of incorrect sorting were identified by the standardised observation method. Combustibles contained the largest number (9), closely followed by metal (8) and non-recyclables (8), whilst the least number of categories of incorrect sorting occurred in wood waste (6), Fig. 3. In addition, items of bagged waste such as loaded sacks and cardboard boxes were identified in all of the studied types of waste, but were most frequently occurring in the container for combustibles. After 6–7 measurements with the method, no additional category of incorrect sorting was identified in the metal and non-recyclable waste. For combustibles and wood waste, a slightly larger number of measurements were required to obtain such saturation, i.e. 10 and 11 measurements respectively.

The number of measurements needed to accurately survey the occurrence of incorrect sorting can vary between different recycling centres, types of waste and occasions. However, the results from the field test indicate that approximately 10 measurements with the standardised observation method are a good estimate of the effort required for a complete survey. Simply by continuing to take more measurements, some new categories of incorrect sorting might eventually be recognised. However, the results suggest that sufficient effort has already been expended in order to record the majority of categories that can be identified by the method.

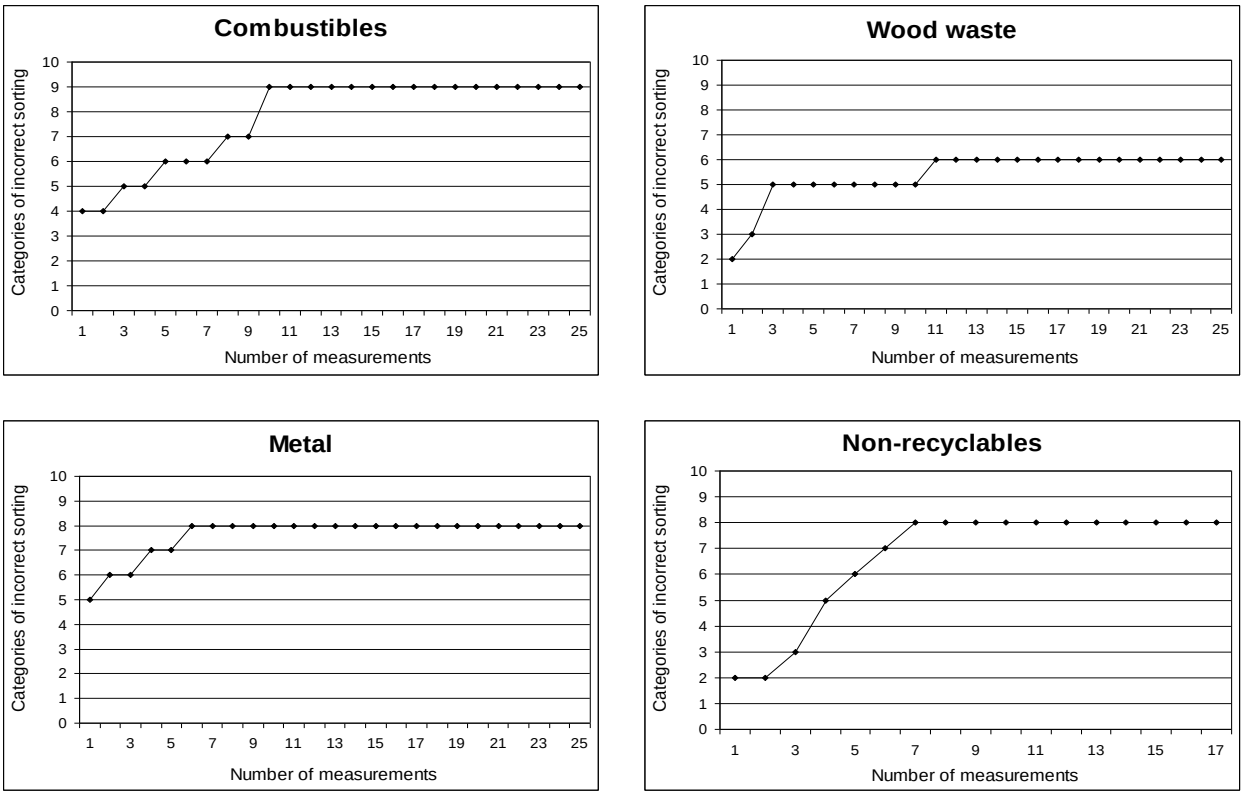

Fig. 3. Accumulative number of identified categories of incorrect sorting by increasing number of measurements with the standardised observation method in combustibles, wood waste, metal and non-recyclables. The "Unknown" category, i.e. wrapped waste in bags, sacks and cardboard boxes, is not included in the figure since it is difficult to identify what such items contain during the inventory and thus to assess whether or not they are incorrectly sorted.

4.2 Ranking the intensity of incorrect sorting

In order to facilitate prioritising of improvement measures at recycling centres, the identified categories of incorrect sorting can be ranked according to their intensity of occurrence. Such a ranking could be based on frequency, i.e. the share of measurements with the standardised

observation method in which a certain category of incorrect sorting occurred, Fig. 4. In this respect too, approximately ten measurements are enough to attain saturation in the provided information. If the ranking is based on more measurements, the differences in frequency among the identified categories become more apparent, but this only results in minor changes in the original ranking. For all of the studied types of waste, five measurements or less were required during the full-scale field test in order to identify the five most frequently occurring categories of incorrect sorting.

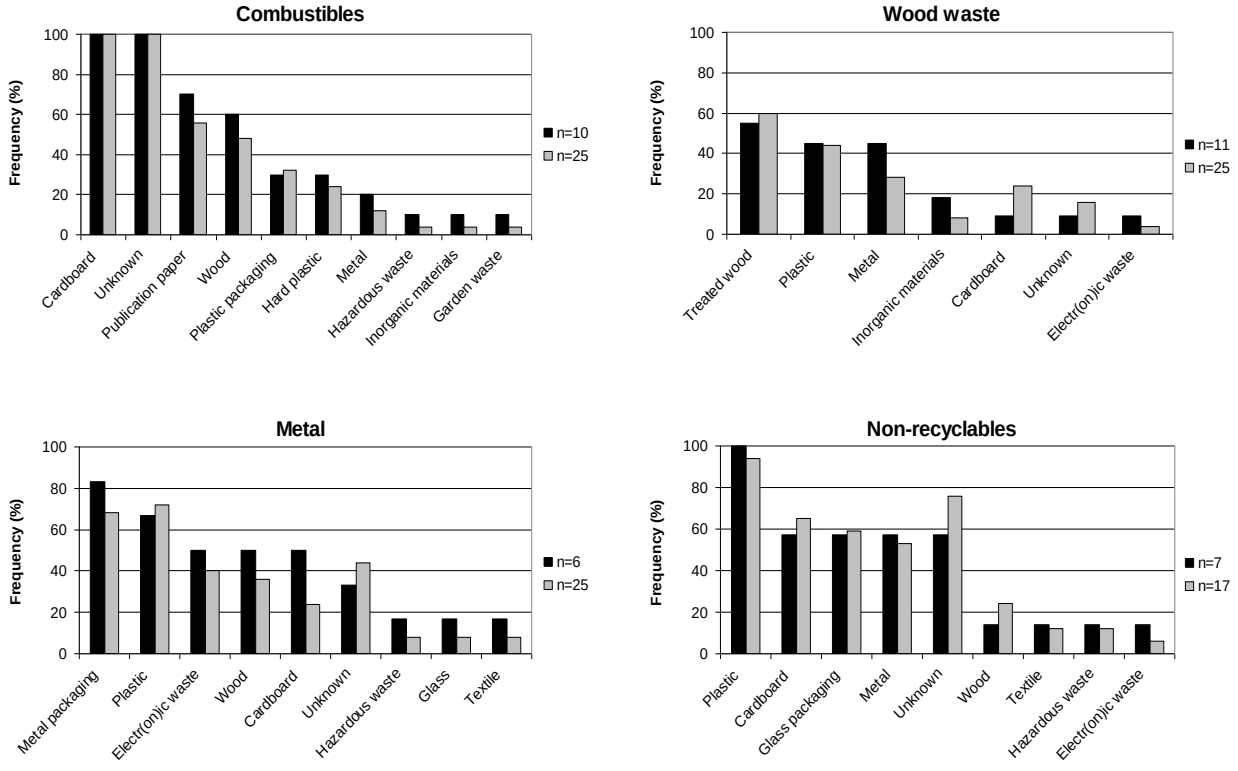

Fig. 4. Identified categories of incorrect sorting presented in descending order regarding frequency of occurrence, i.e. the percentage share of measurements with the standardised observation method in which a certain category occurred. The "Unknown" category represents items of wrapped waste such as loaded bags and sacks, which material composition could not be determined during the inventory. The lowest number of measurements (n) corresponds to the required amount for identifying all categories of incorrect sorting in the waste and the highest number all measurements conducted during the full-scale field test.

An alternative to frequency is to develop the ranking based on the share of the identified items accounted for by a certain category of incorrect sorting. Such a ranking introduces a new dimension, since apart from frequency it also considers the amount of incorrectly sorted waste. Regardless of whether frequency or number of items is used, the relative position of the different

categories of incorrect sorting remains similar, Fig. 5. Some categories, however, switch positions. When the ranking is based on number of items, certain categories also become much more dominant than if frequency is used. Such results can be observed for publication paper and cardboard in combustibles, preservative-treated wood in wood waste, metal packaging in metal and plastic in non-recyclables. What these categories of incorrect sorting all have in common is thus that when they occur in the waste they often occur in large numbers.

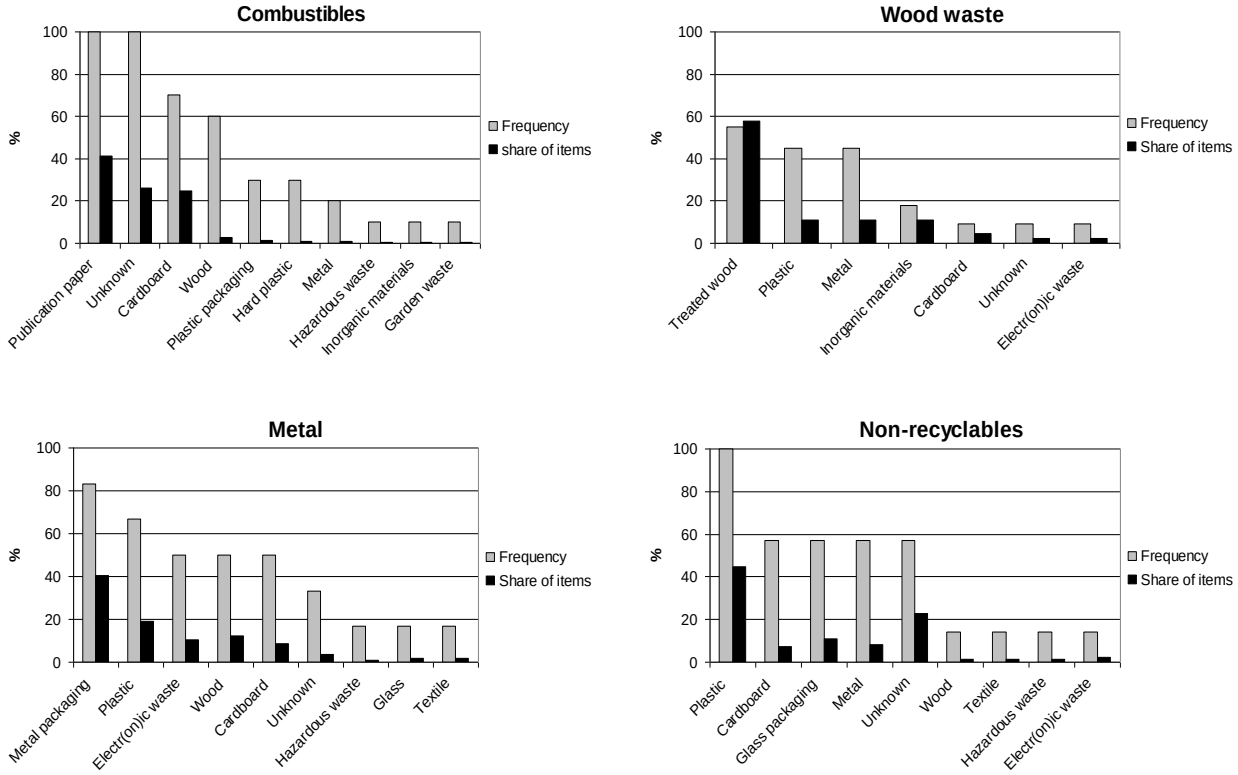

Fig. 5. Comparison of the ranking of identified categories of incorrect sorting with the standardised observation method based on frequency of occurrence (i.e. the percentage share of measurements in which a certain category occurred) and share of identified items (i.e. the percentage share of the total number of identified items accounted for by a certain category). The "Unknown" category represents items of wrapped waste such as loaded bags and sacks, which material composition could not be determined during the inventory. The number of measurements corresponds to the required amount for identifying all categories of incorrect sorting in the waste during the full-scale field test: Combustibles (n=10), Wood waste (n=11), Metal (n=6) and Non-recyclables (n=7).

The "Unknown" category represents items of bagged waste, which content could not be assessed during the inventory of the pictures. Such items could, however, contain almost anything, thus representing an uncertainty regarding the waste composition.

5. Reliability and resource requirements of the standardised observation method

5.1 Identification and ranking of incorrect sorting using two different monitoring methods

Regardless of whether a physical sample of the waste is collected and analysed in detail or the standardised observation method is used, the identified categories of incorrect sorting in combustibles are virtually the same, Fig. 6. The only real difference is the occurrence of glass packaging (a few drinking bottles), which was only identified when a physical sample of the waste was analysed. Interestingly, the relative ranking of the intensity of incorrect sorting is also almost identical for the two methods despite the fact that they use a totally different basis for the positioning, i.e. weight, frequency and number of items.

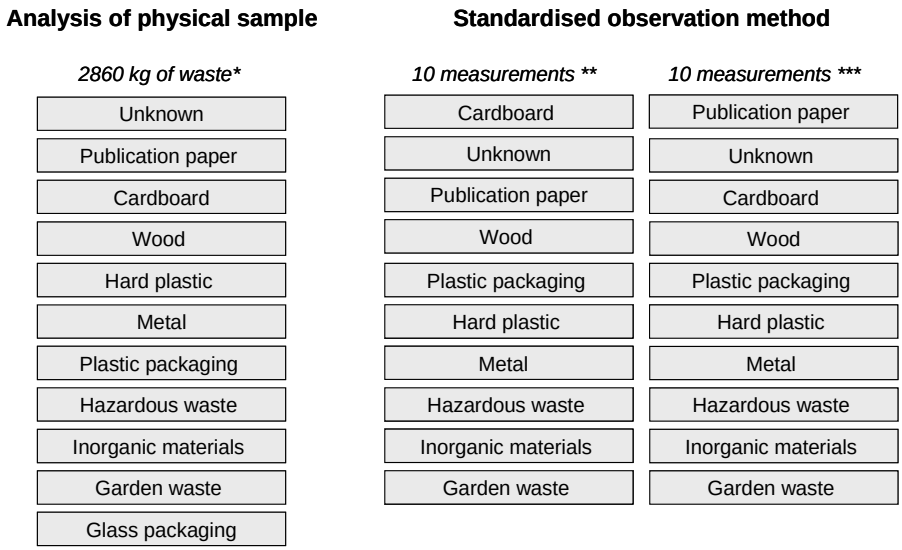

Fig. 6. Ranking of the identified categories of incorrect sorting in combustibles based on the analysis of a physical sample of the waste and the measurements with the standardised observation method. The categories of incorrect sorting are presented in descending order of intensity of occurrence, from the most to the least.
* Relative positioning based on weight
** Relative positioning based on frequency of occurrence
*** Relative positioning based on number of items

5.2 Assessing the total sorting quality of waste

Common praxis to determine the sorting quality in absolute terms is to collect and analyse a physical sample of waste and express the total composition in weight percent (Dahlén and Lagerkvist, 2008). The standardised observation method, however, disregards weight and simply provides an intensity estimate of the total sorting quality which is based on the number of waste items being either correctly or incorrectly sorted. Comparing the total sorting quality of

combustibles obtained from using these two different monitoring methods reveals some differences, Fig. 7. For certain categories of waste in combustibles, i.e. publication paper and cardboard, the share is substantially higher when based on number of items. Such waste items thus occur in large numbers but due to their relatively low density they do not have as large an effect on the total waste composition in terms of weight percent. In contrast, the share of high-density waste occurring less frequently in combustibles such as wood, hard plastic and metals is underestimated when using the standardised observation method to assess the total sorting quality. Despite the fact that the standardised observation method involves clear restrictions on addressing the total sorting quality of waste, it is still capable of providing a rough estimate of how much waste that in total is either correctly or incorrectly sorted, i.e. is it 10%, 50% or 100% of the waste that is incorrectly sorted?

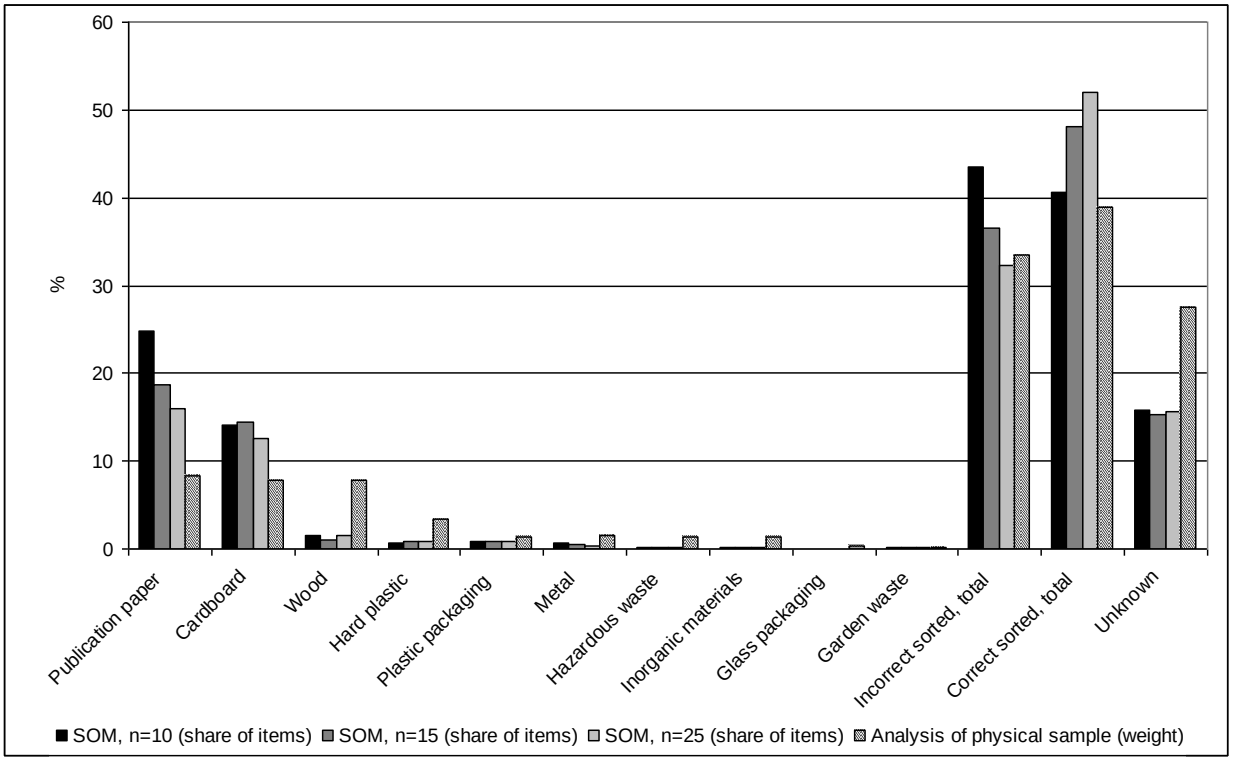

Fig. 7. Total sorting quality of combustibles based on measurements with the standardised observation method (SOM, n=number of measurements) and the analysis of a physical sample of the waste (2,860 kg of waste). For the standardised observation method the total sorting quality is expressed as the percentage share of the total number of items within the sample area and for the analysis of the physical sample in weight percent of the analysed amount of waste.

5.3 Resource requirements for the standardised observation method

The results from this study show that that it takes approximately ten measurements with the standardised observation method to perform a complete survey of the occurrence and relative intensity of incorrect sorting. During the field test, an employee at the recycling centre did the sample selection and photographing of the waste and the time demand for taking such a series of pictures (ten pictures) was on average half an hour. The inventory and documentation of these pictures took approximately 1.5 hours and the time demand for the subsequent analysis of the results was close to one hour. A complete survey thus requires approximately three hours of work, expressed as actual working hours for one person. However, in order to assure independent measurements, i.e. making sure that the same waste items in the containers are not monitored several times, the pictures need to be taken over a longer time period. This period could range from a few days to weeks depending on the turnover of the waste in question at the recycling centre.

The total time demand for the standardised observation method can be compared to the collection and analysis of the physical sample of combustibles, which took more than 20 man-hours to conduct. Only the transportation, site preparation, unloading of waste and cleaning up of the site when the analysis was completed took more than two man-hours. However, the main part of the time demand involved the actual sorting and weighing of the waste, which kept two persons busy for more than one working day. This was despite the fact that these persons were experienced and well aware of exactly what kind of waste the combustibles should consist of.

Since the standardised observation method is as simple and fast as it is, it is much easier to implement within ordinary working activities than conducting analyses of physical samples of waste. Employees at recycling centres can do the measurements when it best suits their present working schedule. If a waste engineer has a few minutes to spare, that is enough for performing an inventory of a picture, or else a whole series of pictures could be collected and the main results analysed within a few hours. Collecting and analysing physical samples of waste, on the other hand, requires all sorts of resources such as trucks for transportation, dumpers for unloading and re-loading and site preparation, a large cleaned-up and paved site (at least 50 m^2), numerous containers for different waste categories, a weighing machine, and so on. The time demand is also almost one order of magnitude larger and valuable staff members, often needed elsewhere in the organisation, have to be engaged in the analysis for whole working days.

6. Discussion

Facilitating proactive quality work at recycling centres does not necessarily require detailed information about the total composition of waste. The results from this study show that the simplified monitoring method, which solely focuses on the incorrectly sorted waste, could provide useful information for developing and evaluating improvement measures. It is, however, important to point out that the conducted validation of the results from the standardised

observation method only included combustibles. This type of waste consists of a wide range of different products and materials, which is why it also has one of the most complex compositions at recycling centres (Engkvist et al., 2008). It could therefore be argued that if the method is useful for assessing incorrect sorting in combustibles it is likely that it can also be used to do so for other types of waste, involving less complex compositions. If that is the case, however, remains to be confirmed in future empirical studies. Furthermore, the reference value for the composition of combustibles, used for the validation of the method in this study, only involved one sample, i.e. one full container. Such a reference value was considered sufficient in this introductory study, where the potential of the developed method was tested for the first time. However, in order to arrive at more reliable results regarding to what extent the method provides accurate information, extended empirical studies are needed involving the collection and analysis of several reference samples corresponding to the taken pictures.

An important limitation of the standardised observation method is that the composition of bagged waste can not be assessed. Such uncertainty regarding the waste composition could be addressed by collecting and analysing the content of a large number of loaded sacks from the containers at recycling centres. Based on such empirical research, a generic material composition of the bagged waste could be developed and used during evaluation of the results from the standardised observation method.

Since the economy of Swedish recycling centres is already constrained (The Swedish Association of Waste Management, 1998), the possibilities for conducting proactive quality work are limited. The usability of a waste monitoring method therefore strongly relies on that it is simple enough to be integrated into ordinary working activities (cf. Lindahl, 2005). The standardised observation method is straightforward and much more resource efficient than traditional waste composition methods, involving the collection and analysis of physical samples. Such characteristics facilitate continuous and systematic efforts for improved sorting of waste at recycling centres. It is important to point out, however, that a monitoring method is only a tool for obtaining necessary facts. In order to achieve structured and proactive quality management, the owners of recycling centres must consider this to be important, have a high ambition for continual improvements and thus provide enough financial and human resources for developing, implementing and evaluating effective measures (Thomsen et al., 1996).

6.1 Useful applications of the standardised observation method

Developing effective improvement measures at recycling centres depends on first surveying and identifying the actual reasons behind incorrect sorting (cf. Klefsjö et al., 1999). Applying the standardised observation method provides useful data regarding what categories of incorrect sorting occur in the waste at a certain time. However, although such information is essential for identifying cause-effect relationships, it is also insufficient, since in practice many factors could influence how the waste is sorted, such as the layout and structure of the collection sites, design

and terminology of informational signs for sorting, staffing levels for guidance and control, individual attitudes and knowledge, and so on (cf. Engkvist et al., 2008; Garcés et al., 2002). It is therefore always necessary to relate the obtained results from the standardised observation method to existing knowledge about such influencing factors. In the literature, generic conclusions regarding basic requirements for individuals to participate in waste management and recycling programs and to sort the waste correctly can be found (e.g. Tukker, 1999; Garcés et al., 2002; Petersen, 2004; Engkvist et al., 2008). Such general overviews, together with the specific experiences at the collection site in question, could provide valuable input to the synthesis of the results from the standardised observation method. The identification of cause-effect relationships of incorrect sorting could also be further facilitated by thoroughly planning the monitoring of the waste (cf. Klefsjö et al., 1999). By performing comparative investigations taking place under different circumstances and operational conditions at recycling centres (e.g. variations in visitor loads and staffing levels), the relative importance of the factors influencing the sorting of waste could be assessed.

When the reasons behind a certain kind of incorrect sorting have been assessed, the next working task is to develop measures that effectively solve the problem. At recycling centres, for instance, this could involve changing the arrangement and location of containers, improving the terminology used on informational signs for sorting, educating employees or conducting information campaigns to citizens (cf. Engkvist et al., 2008). In order to determine whether a measure is capable of solving the problem and thus should be permanently implemented, or whether additional measures are required, there is a need for evaluation (Thomsen et al., 1996). Performing sequential measurements with the standardised observation method, i.e. before and after implementation, makes it possible to directly assess whether the intended effect of an introduced measure was obtained. Such evaluations are also essential for identifying unintended side effects, i.e. the measure solves the target problem but causes other kinds of incorrect sorting instead, thus avoiding sub-optimisations (cf. Raadschelders et al., 2003).

In Sweden, the importance of recycling centres for waste collection is continuously increasing and these facilities are still immature in the sense that there is no standardisation in their design (Engkvist et al., 2008; The Swedish Association of Waste Management, 2003; 2008). In this respect, the standardised observation method could offer a way to benchmark recycling centres, involving different layouts and operational conditions, regarding the achieved sorting of waste. Such information will be especially relevant for actors engaged in developing new recycling centres but will certainly also facilitate improved conditions for sorting of waste at existing facilities.

7. Conclusions

It can be concluded that the standardised observation method could offer a resource-efficient tool for monitoring the sorting of waste achieved at recycling centres. Applying the method provides useful information for proactive quality work at recycling centres, involving continuous efforts in

developing and evaluating measures for improved sorting of waste. However, in order to determine to what extent the obtained results from the standardised observation method are reliable more empirical research is needed.

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