Sorting waste in apartment buildings: facts and possibilities

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Abstract

Waste handling is a major challenge in today's society. The amount of waste is increasing despite numerous, waste-system related improvements. In other domains of interest for sustainable development, researchers have recently started to investigate the user's role instead of keeping a systems perspective that excludes the human factors. To investigate the use of existing waste-sorting infrastructure available at apartment buildings, this paper reports on a case study carried out in two buildings in Gothenburg/Sweden. Results from the study reveal mismatches between user needs and what the system offers. The aim was to identify a strategy that housing companies could take to allow for more effective sorting of household waste in rental housing areas, with special focus on the biodegradable fraction. The resulting strategy consists of practical solutions that can be implemented by housing companies with similar conditions.

1. Introduction

Waste handling remains a major challenge for society. Despite enormous efforts in research and improvements towards more sustainable urban waste systems El-Haggar [7], Ludwig et al. [13], the amount and complexity of waste continues to increase Basel Convention [2]. The motivation behind improving the waste system now is not just to contain waste in one location (i.e. landfills) in order to avoid pollution and improve public health, but also to be able to

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use material resources in a more sustainable way Wilson et al. [19]. Advocates of closed-loop systems Foundation [9], McDonough and Braungart [14] often argue that waste management should evolve into resource management, for effectively serving as a channel for discarded materials into new production. In order to achieve this, urban waste flows need to be sorted to allow for their reuse and recycling. This is already done in many ways (e.g. source separation systems, material recycling facilities), depending on several factors that vary greatly between one city (or even district) to another Dahlén and Lagerkvist [5]. This variety of influential factors leads many researchers to state that no single waste sorting solution will fit all situations Gallardo et al. [10], Griffiths et al. [11], UN Habitat [18]. UN Habitat [18] even concludes:

> A reliable approach is to be critical and creative; to start from the existing strengths of the city and to build upon them; to involve all the stakeholders to design their own models; and to "pick and mix", adopting and adapting the solutions that will work in any particular situation.

This need for adapting solutions for particular situations requires engaged and knowledgeable actors to improve their own waste sorting solutions, balancing what is required from them by policy with what particular actors and even households are willing and able to do.

Urban waste systems are fairly complex and include everything from collection to final disposal Ludwig et al. [13], Seadon [16]. Throughout the entire waste system, several actors are responsible for different stages and have varying degrees of freedom to determine how best to perform their task. For example, a municipal regulation may state how waste collection is to be done, while private waste companies execute this task with the technological means they have at their disposal. That, in turn sets requirements for residential areas and housing companies to determine how to set up the infrastructure needed to collect household waste. Finally, each household owner decides how to organize their home to gather and dispose the waste that they generate. Given the extension and complexity of waste systems, they are usually divided in subsystems in order to be studied and even designed. Source separated collection is just the initial part of a complete waste system, but it can be regarded as a subsystem on its own right and thus studied independently Gallardo et al. [10].

Each stage of the waste management process affects others, even though appropriate communication and feedback between these stages may be lacking. It is often the case that a change improving the treatment of waste has implications for how the waste is to be collected, but the changes in the waste collection stage do not necessarily follow. As an example is the city of Gothenburg (Sweden), where it was previously required that people sort out hard plastic and soft plastic separately, given that the treatment facilities to recycle both types of plastics were different. This changed when, all plastics where shipped to recycling facilities in China that do not require separation between soft and hard plastic. Although this change took place years ago, there are still sorting facilities in the city that require users to perform this no longer necessary separation.

Recent years have seen progressive increments in material recovery targets to be achieved within the EU. As a consequence, localities all over the EU are aiming to improve their waste systems towards increased recovery. Regarding biodegradable waste specifically, composting is expected to increase significantly while anaerobic digestion is expected to become an important source of renewable energy EU [8]. This brings forward the need to advance in the separation of the biodegradable fraction considerably.

In order to reach the mentioned targets, changes to the waste system should also incorporate user participation and sorting behaviour. In other domains of interest for sustainable development (e.g. energy use), researchers have started to investigate the users' role instead of keeping a systems perspective only, that excludes the human factors. This has also been done in waste research Andersson et al. [1], Refsgaard and Magnussen [15], Henriksson et al. [12] often resulting in general recommendations for the improvement of the waste management system. Uncommon however are case studies that take the results of behavioural research into implementation of practical solutions. In addition, much of the research has focused on how to motivate households to separate their waste, but not so much has looked into how these dynamics are affected by if the households belong to separate houses or apartment buildings. Specific policies aimed at waste prevention may work well in individual houses, might not have the same effects in apartment buildings. As an example, the introduction of a weight based billing system has been reported to have a positive effect in reducing waste quantities in some Swedish municipalities Dahlén and Lagerkvist [6]. However, areas with individual houses are more affected by this policy (since it is the same tenants that both generate waste and pay these fees) than households that belong to larger apartment buildings (where the housing company pays the waste fee).

Weight based billing systems has been introduced for mixed waste in different locations around Gothenburg/Sweden. In housing companies, this has lead to an increased interest in how to better engage tenants in sorting their household waste. Special attention is given to the biodegradable waste fraction, since it is suspected to be the heaviest fraction currently not sorted out of the mixed household waste. Also, the municipality has recently installed a bio-gas generation facility. This allows the waste system to contribute with this renewable energy source to society, which is highly promoted by local authorities. This appreciation for bio-gas means in practical terms that correctly sorted biodegradable fractions are collected without additional charge.

This set up has lead housing companies to strive to improve source separation of waste in order to reduce their waste handling costs. A usual setting in an apartment building in Gothenburg is that tenants have access to a garbage disposal room, where they find several containers for the different fractions that the district collects. This setting is known to have strong variations in the quality and quantity of waste collected in different districts.

This article describes a case study dedicated to investigate source separated collection and how it influences waste sorting behaviour in apartment buildings. The aim of the study is to identify a strategy that could allow for more effective

sorting of household waste in apartment buildings, with special focus on the biodegradable fraction. The resulting strategy consists of practical solutions that can be implemented by housing companies with similar conditions.

Through the collaboration with a local housing company, two of their buildings (with 46 apartments each), located in a suburb of Gothenburg/Sweden were targeted for this research. This district is known to have problems in engaging its tenants in source separation, obtaining worse outcomes than other districts on base of the same collection system.

2. Material and Methods

The entire research will study the existing source separated collection system in practice by waste weight data collection, a waste composition study, field observations, a user survey and a potential focus group. After the gathering and analysis of this data, the researchers together with the housing company will design and implement an improvement strategy for their source separated collection system. This will be followed by further monitoring activities: continued waste weight data collection, a second waste composition study and a user acceptance survey.

2.1. Delimitations

This article only includes the results of the waste weight data collection, waste composition study and field observations. These provide enough information to begin to define the improvement strategy. Additional information about users opinions and preferences will be taken in at a later stage and complement the initial results presented in this paper, in order to be reconsidered at the implementation phase of the research project.

2.2. Layout and existing infrastructure

The housing company administrates 28 buildings in this area, all of which are 2 to 5 floor apartment buildings, organized in blocks around central yards with access to one garbage disposal room per yard. This block configuration around a yard is considered as a building unit, despite that each building around the yard has different configurations (i.e. the type and amount of apartments) and are otherwise independent from each other. These building units will be referred to as yards within this study. Two yards with the same amount of apartments and similar layout have been chosen for the study (further referred to as yards A and B). Each of these yards consists of 46 apartments, details of what type of apartments and their sizes can be found in table 1.

Both yards have a garbage disposal room, referred to in this study as waste room, where the tenants have access to several containers to dispose of their household waste. These rooms are 3.26 meters wide by 10.12 meters long and are accessible by the narrow sides (i.e. from the inner yard or the street). Tenants have keys to be able to access these rooms, that are otherwise locked

N° of Apartments	Rooms	Square meters
3	1 room + kitchen	42sqm.
6	2 room + kitchen	64sqm.
16	3 room + kitchen	77.3sqm.
21	4 room + kitchen	96.6sqm.

Table 1: Number and type of apartments present in the studied yards.

N° of Containers	Volume	Material collected	Abbreviation
5	660 Lt	Mixed waste	MW
2	660 Lt	Paper packaging	PP
2	370 Lt	Plastic packaging	PLST
2	370 Lt	Newspaper and print	NP
2	190 Lt	Glass packaging (coloured and transparent)	GP
1	370 Lt	Metal packaging	MP
3	140 Lt	Biodegradable waste	BW
3	24 Lt	Batteries, traditional light bulbs and energy efficient light bulbs respectively	HZD

Table 2: Containers available in the waste rooms

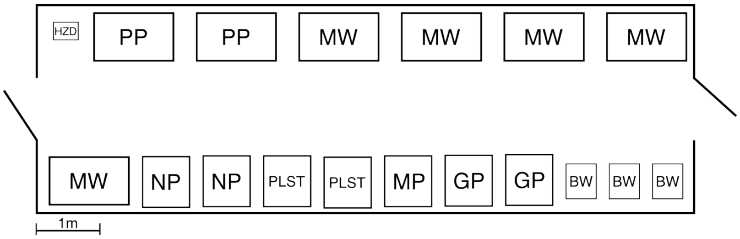

Figure 1: Layout of the waste rooms included in the study.

Figure 2: Information for sorting waste at the waste rooms

to the public. The layout for these waste rooms can be seen in figure 1, while the amount of containers and their details can be found in table 2.

The three 24lt containers for hazardous waste are piled vertically, one on top of the other. Currently the collected mixed waste is much more than the biodegradable waste (with a weight ratio of approx. 10:1[1]), which corresponds to the big difference in the available containers for these fractions.

The containers for mixed waste normally get filled with closed bags that come from different households. Loose items are also found in these containers, that can have fallen out of a ripped bag, or simple discarded separately by the users.

Tenants have information about how to sort their waste located on the walls of these waste rooms. This information consists of illustrations and short descriptions of what should be discarded into what container (figure 2). Tenants also receive this information, summarized in a small brochure, when they move in. As of now, all information is provided in Swedish, despite the fact that many non native Swedish speakers (who's comprehension of the language can vary greatly) live in this area.

The schedule for cleaning the waste rooms and the collection of the different fractions of waste is also displayed on the walls of the room and can be seen in

[1] Obtained from the waste weight data collection, described further in section 3.1.

	M	T	W	Th	F
Mixed	x			x	
Biodegradable					x
Newspaper					/x
Glass Packaging				x/	
Paper Packaging				x	
Plastic Packaging					x/
Metal Packaging					x/
Cleaning	x			x	

Table 3: Weekly schedule for cleaning and collecting waste from the waste rooms

table 3 [2].

Besides the waste room facilities, the tenants have the possibility to discard bulky and electronic waste in separated rooms specially dedicated for this. Initially, these rooms were open for tenants to access by themselves, but after some problems of getting mixed waste and rubbish discarded there, the housing company decided to limit access. Now tenants must first contact one of the maintenance personnel to gain access to discard bulky and electronic waste.

2.3. Waste weight data collection

The studied district started to work under the weight based billing system in January 2012. Now the waste company registers the weight of the waste for every collection. The waste collection trucks are equipped with electronic scales that log the weight input and time they emptied for each container. This log also includes comments if containers are not collected because they were not in place when the truck came. The waste data obtained in this way shows exclusively the amount of waste collected from this location, not the amount of waste generated there (there could be discrepancies between these two parameters, but for the purpose of this study, we will consider them as equivalent). The gathered information is later delivered to the housing company aggregated quarterly in waste collection invoices. Open access to the data collected by the trucks is a possibility still being discussed, however that information is still managed internally by the collection company and the municipal recycling office. Through a collaboration with the municipal recycling office, access to the detailed information was granted for the period of this study.

Currently the housing company has no information regarding the amount of people that live in these apartments, nor any demographic information. This will latter be addressed with a voluntary survey, but at the moment all waste data obtained will only be able to be estimated in kilograms per household per day (kg/hh/day) as opposed to the more commonly used unit of kilograms per capita per day (kg/cap/day).

[2]The symbol x/ stands for odd weeks and /x for pair weeks.

2.4. Waste composition study

The waste composition study was designed following recommendations in Dahlén and Lagerkvist [3] when possible. It was not possible to follow their procedure for extracting the samples from the total studied waste, given that the space designated for this task was too small. An alternative method was chosen and is described further in section 2.4.2. The aim of this study was to determine:

- From the mixed fraction, how much waste is:
  - Biodegradable
  - Packaging and print
  - Hazardous

(All fractions measured as % of total mixed fraction weight)

- From the biodegradable fraction, how much waste is:
  - Non-Biodegradable (of which)
    - Packaging and print
    - Hazardous

(All fractions measured as % of total biodegradable fraction weight)

The fractions considered in the study are shown in table 4. This covers all the material fractions that the tenants can sort in these waste rooms, plus their non packaging equivalents. On top of this, three other groups were added that are currently not accounted for, but that have been present within the existing waste flows (i.e. wood, textiles and more types of hazardous waste) and a group for the materials that do not fit in none of the afore mentioned categories.

2.4.1. Delimitations

This study focuses on improving the sorting of biodegradable waste and to avoid it being discarded into the mixed waste fraction. That is why only the biodegradable and mixed waste fractions were characterized herein. The packaging waste fractions may even contain biodegradable waste incorrectly sorted. However, this study did not aim at quantifying the total amount of biodegradable waste produced, nor to improve the sorting of packaging waste. Nevertheless, checking if there are mixed waste bags wrongly placed into the packaging containers was done together with each sampling.

The seasonal variation of waste generation is only going to be regarded though the review of the waste amounts generated during the year 2012 (kg/month). Seasonal variation does not only affect the total amount of waste generated, but also the composition of the waste flows. Therefore, not accounting for this when performing the waste composition studies, is a source of error. Unfortunately,

Paper	Packaging
	Non packaging
	Newspaper & prints
Plastic	Packaging
	Non packaging
Glass	Packaging
	Non packaging
Metal	Packaging
	Non packaging
Hazardous	Light bulbs
	Batteries
	Small appliances
	Impregnated Wood
	Larger WEEE
	Other
Biodegradable	
Wood	
Textile	
Others	Combustible
	Non Combustible

Table 4: Fractions to be measured in the study.

due to time and monetary restrictions, it is not possible to perform waste composition studies during all seasons; this must be considered when analysing the data.

Given the fact that the study aims for normal common day behaviour at home, the sampling avoided holidays and vacation periods.

2.4.2. Procedure

Sampling was done over a six week period of time, starting in January 2013. In order to have samples that cover a full week of waste production, each sample consisted of two partial samples, one taken on Mondays (collecting the waste generated on weekends) and one taken on Wednesdays. Each partial sample was sorted and processed on the same day of it's extraction, using the facilities that the housing company assigned for this task (referred to further on as the garage).

For each partial sample, the sorting personnel took all biodegradable waste into one of the three containers and took that one to the garage. For the mixed waste, they went through all the mixed waste containers, placing every fifth bag in an empty container to include it in the sample. If there were any loose items in the mixed waste container (that were not bulky waste), the sorting personnel gather a few items and counted them as if they were one bag. The obtained sample container was then taken to the garage. On two occasions (30th of January and 6th of February) there was considerably less waste in the

waste rooms. In order to still obtain a sample fraction of approximately half a container, the sorting personnel opted for selecting one of every three bags. This was duly noted in the data collected and later in the analysis.

Once the samples were established, the procedure to follow was the same for both fractions. The samples were maintained in four distinct groups: mixed waste from yard A (Mix A) biodegradable waste from yard A (Bio A) mixed waste from yard B (Mix B) biodegradable waste from yard B (Bio B).

For each of these four groups the following steps were taken:

1. The sample was sorted in the defined fractions.
2. The weight for each fraction in the sample was registered into the corresponding space in measurement sheet (figure 3).
3. If anything unusual appeared in the category Others, photographic documentation was taken using the corresponding sample identification card (i.e. Mix A, Bio A, Mix B or Bio B).
4. Everything else that seemed unusual or remarkable was further documented with pictures.

After finalizing the measurements, the sorted waste was collected into common bags and disposed of in the nearest waste room that was not part of the study. For the biodegradable fraction however, the sample was taken back to it's corresponding waste room, separating with a marking paper the waste already analysed. This was necessary because of the reduced space for biodegradable fractions in the waste rooms.

2.4.3. Sources of Error

Based on the theory of sampling and sources of error for waste composition studies presented in Dahlén and Lagerkvist [4], the chosen procedure addresses the seven sampling errors in the following way:

1. Long-range heterogeneity fluctuation error. This error represents the spatial change in the material, meaning that a sample from one part will not be the same as in another. This has been addressed by aggregating into one sample several smaller samples (i.e. every fifth bag) obtained from different sections of the total waste group.
2. Periodic heterogeneity fluctuation error. This is the error introduced by periodical changes in the waste flows. As mentioned in section 2.4.1, seasonal variations will not be able to be covered with this study, being therefore a persistent source of error. However, holiday and vacation periods were avoided. Also, the variations between weekdays and weekends have been addressed by taking samples every Monday (covering the waste generated in the weekend) and Wednesday (covering waste generated on weekdays). In the analysis these samples were added to show a weekly total. Given that the waste company collects the mixed waste on Monday and Thursdays, Thursdays is a day of waste generation that is not covered by the samples taken. This might be a source of error, but it is assumed for this study that waste generation on Thursdays is comparable to the waste generated on other weekdays.

3. Fundamental error. This error represents the variation in particle size, shape, density, etc. When sampling solid waste, it is relevant to identify the elements discarded into the waste, there for grinding the material to a homogeneous particle size is undesirable. This study did not go into analyzing smaller particles present in the waste, sorting was done on an "object level". The only way to reduce this error is to have a large enough sample. This, however, has time and monetary restrictions.
4. Grouping and segregation error. This error shows that particular groups or sections may not be representative of how material is distributed over the whole waste group. This was addressed by taking smaller samples from different sections of the waste. It can be argued that by taking closed bags of waste, those bags, were representing only the waste generation of one household. But, given that the total sample was conformed by several bags from different sections, many different households end being represented in the total sample. The study also excluded bulky and electronic waste found directly in the containers, since these fractions were considered to be less frequent and not a part of the constant waste flow. They are addressed in more detail in section 2.5.
5. Increment delimitation error. This error exists when sampling is done by physically separating sections of a larger waste pile. This is not present in this study given that the separation is not done from a pile, but rather by taking out elements from the containers. However, this introduces a bias that should be considered. When the sorting personnel is going though the containers the order in which they choose the bags or items determines what gets collected into the sample. They are encouraged to do this without "thinking too much about it" but inevitably some bags may be chosen or avoided.
6. Increment extraction error. This is when some particles belonging to the sample are lost. To avoid this, the sample was transported to the location where it was sorted in a closed container. The sample was sorted, measured and documented in the same location, minimizing the possible loss of material. After processing the sample, the same personnel cleaned up the location, ensuring that no items were left behind when measuring. If something was found during clean up it was accounted for and added to its corresponding category.
7. Preparation error. This is when the sample gets contaminated by external elements, when there is an error in sorting or when chemical or physical changes occur (e.g. moisture loss). To avoid this the samples were processed on the same day of their extraction and sorting personnel was trained to the procedure by performing the sorting with the researchers on a couple of occasions, here all questions and doubts were addressed directly.

2.5. Field Observations

In parallel to collecting the samples for the waste composition study, the sorting personnel was asked to observe if there was bulky waste discarded in

the waste room. They were also asked to observe for any wrong sorting in the containers. This included the containers for mixed waste (waste that was not included in the sample) and the containers for packaging waste. If any of this occurred, they were asked to notate it and additionally documented it with a picture. This resulted in a frequency of occurrence chart and in extensive photographic documentation.

3. Results and Discussion

3.1. Waste weight data

In order to obtain the actual amount of waste generated during the study period, the weight of the samples were added to the waste data generated by the collection company for mixed waste, while this was not done for biodegradable waste. On average the samples covered 19% of the total mixed waste generated in yard A (varying between 16% and 24%) and 18% for yard B (varying between 11% and 31%). The largest sampled fractions correspond to the weeks where sorting personnel increased the sampling from 1/5 of the bags to 1/3, only for yard A. The highest sampling rate in yard B is a week before this occurred.

A marked difference between volumes generated on weekends and weekdays (collected on Mondays and Thursdays respectively) was only noticeable in yard B during January. Yard A had a rather even generation pattern.

The mixed waste generated in the studied buildings is of an average of 1.2 kg/hh/day in yard A and of 1.4 kg/hh/day for yard B. The biodegradable waste collected had an average of 0.2 kg/hh/day and 0.1 kg/hh/day respectively.

Assuming that we have an average of two people per household in these apartments, the data for mixed waste would be consistent with the Swedish national average for waste generations (with 0.6 kg/pp/day of mixed waste)Sverige [17]. However, considering that in the case study we are not accounting for the bulky waste disposed of in other ways than via the waste room, this figure could be considered a bit higher that the national average. Since data for family sizes and the afore mentioned fraction are missing it is not possible yet to draw more definite conclusions about the total waste volumes for the case study. The biodegradable fraction is lower in the case study than in the national average (0.2 kg/pp/day), obtaining the same amount per household in the case study, than per person on the national average. This reflects the concern of the housing company that they have not managed to engage the majority of the tenants in sorting out their biodegradable fractions.

3.2. Waste Composition Study

From the mixed waste generated, the composition study shows that little over 40% is biodegradable waste (i.e. 42% in A yard and 41% in B); more or less a quarter is packaging that is not sorted out correctly (i.e. 26% in A and 22% in B) and only one third corresponds to other mixed waste (i.e. 32% in A and 37% in B). From the unsorted packaging, the largest amounts were plastics (i.e. 37% of total packaging in A and 36% in B) and paper packaging (i.e. 29%

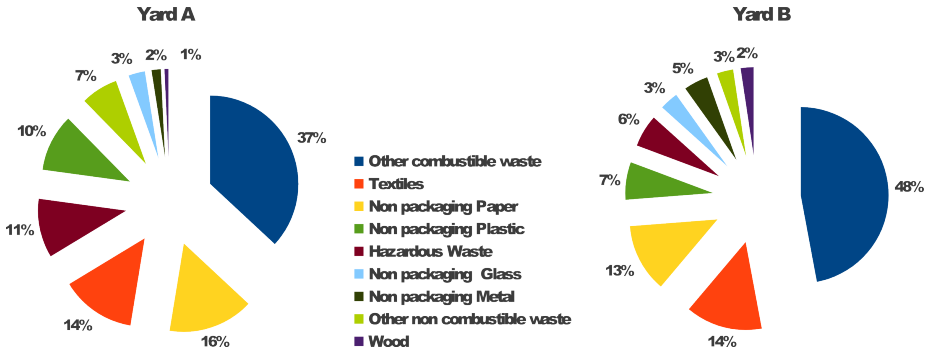

Figure 3: Detailed composition of mixed waste per yard

in A and 33% in B). From the mixed waste that is neither biodegradable nor packaging waste, the largest identifiable fractions are textiles, non packaging paper, non packaging plastics and hazardous waste. However, the main part of these other mixed waste corresponds to mixed combustible materials with no particular category. More detailed information of the composition in this mixed waste fraction can be observed in figure 3.

On the other hand, almost 100% from the sorted biodegradable fraction corresponds to biodegradable material. In yard A only 0.3% corresponds to packaging waste (an average of approx 3 grams from a total of 8.3 kg) while in yard B it is closer to 1% (i.e. approx 20 grams from 29.2 kg). However, this does not mean that the sorting of biodegradable waste is without problem. On two occasions, personnel found hazardous waste in the biodegradable fraction (i.e. one medicine package with half a pill and one empty inhalator). Figure 4 shows food wrappings often found in this fraction. In all cases the found materials are very light in comparison to the biodegradable waste, so these figures normally do not show up when comparing only weight. That is why we have chosen to complement this measure with the frequency with which wrong sorting occurred in the biodegradable fraction for each yard. In yard A there was wrong sorting in 10 of the 12 occasions, where as in yard B this occurred on every occasion. This measure only observes if wrong sorting occurs, regardless of its volume. Photos were taken to document the found volumes for each yard on every occasion, showing that plastic and aluminium wrappings are the most common wrongly sorted materials.

The total amount of biodegradable waste generated in both yards (considering both the biodegradable fraction sorted out as such and the one that is disposed of with the mixed waste) is roughly the same with an average of 100 grams/hh/day (the equivalent of approx 31 kg/week per waste room). The proportion of this waste that gets sorted out correctly is in both yards (26% in A and 16% in B) significantly less than what is found as part of the mixed waste (74% in A and 84% in B). Yard A is slightly better at sorting out its biodegradable waste, collecting an average of 8.2 kg/week, as opposed to the 5.2 kg/week,

Figure 4: Plastic and Aluminum fractions from the sorted biodegradable waste in yard B, on the 9th of January.

which are collected in yard B.

3.3. Field Observations regarding bulky waste and wrong sorting

The field observations were registered by the sorting personnel as notes on the forms they filled out in each occasion, as well as by photographic documentation. This resulted in table 5 that shows the frequency of occurrence for both the presence of bulky waste in the waste rooms and wrong sorting in the packaging containers (i.e. first two rows of table 5). This is complemented with the following rows of table 5 by showing the number of what containers had incorrectly placed elements. When more than one item was misplaced in a given container, this was only counted as one incorrect container. As table 5 shows, the behaviours observed were quite similar between both rooms.

3.3.1. Bulky Waste

When presenting the results from section 2.5 to the housing company they commented that they did not consider this bulky waste as a problem. As long as the bulky waste fitted into the large containers available at the waste rooms, it did not matter to them if it was disposed of in this manner or via the room designated for bulky waste. All the material that is disposed of in that separate room, ends up being treated in the same way as the mixed waste, regardless of how they are collected. The only difference is that they have to order it to be collected on demand, rather than on a regular basis.

Currently there is no control of how much bulky waste gets sorted into the mixed waste containers. During the study period, personnel just observed if it occurred but did not measure it in any way. It was intentionally left out of the sampling, given its more irregular generation. These kilos of bulky waste that are anyway led into the mixed waste stream, generates peaks in the weight data used, introducing another error source in the estimations of the composition study presented in section 3.2.

Room A	Collection Dates	1	2	3	4	5	6	7	8	9	10	11	12	Totals
Occurrence	Bulky Waste	1	1	1	1	1				1		1		7
	Wrong sorting		1	1	1	1		1		1	1	1	1	9
Number of containers with wrong sorting	Paper Packaging		1		1	1					1			4
	Newspaper & prints					1		1						2
	Plastic Packaging			1	1					1		1		4
	Glass Packaging			1	1	2						1		5
	Metal Packaging			1	1	1							1	4
	Hazardous									1			1	2
	Total wrong containers/day	0	1	3	4	5	0	1	0	2	1	2	2	21

Room B	Collection Dates	1	2	3	4	5	6	7	8	9	10	11	12	Totals
Occurrence	Bulky Waste	1	1	1		1				1	1	1	1	8
	Wrong sorting		1	1	1	1	1			1	1	1		8
Number of containers with wrong sorting	Paper Packaging		1		1	1				1		1		5
	Newspaper & prints		1			1								2
	Plastic Packaging		1				1				1	1		4
	Glass Packaging			2		1								3
	Metal Packaging		1			1					1			3
	Hazardous				1					1	1	1		4
	Total wrong containers/day	0	4	2	2	4	1	0	0	2	3	3	0	21

Table 5: Frequency of occurrence for bulky waste and wrong sorting in packaging containers

3.3.2. Quality of sorted packaging

From the field observations it was possible to identify two types of wrong sorting behaviour: material related sorting and unrelated sorting. Material related sorting mistakes are when a tenant uses the available packaging containers to dispose of waste that is not packaging but that is made of the material specified in the sorting container (e.g. metal tube in metal packaging container, figure 5a). Unrelated sorting mistakes occur when a user discards something that has no relation with the specific sorting container (e.g. textiles and shoes in paper packaging container, figure 5b).

Material related sorting mistakes have been discussed in the literature and correspond to

> "...the structural mismatch between the layman logic and the logic of the waste system that causes uncertainty." Henriksson et al. [12]

The "layman logic" is that users expect that it would be beneficial to place the waste in that container anyway, given that the material fits the description, despite the discard not being packaging, assuming that it would get recycled for its material. There is no clear layman explanation to why people should not sort non packaging material in the packaging containers, but this is not how the waste system is designed to work, making this type of sorting behaviour a mistake from the systems perspective, but not necessarily from the user's perspective.

An observed behaviour that could be considered as a material related sorting mistake is when electronic discards are incorrectly placed in the buckets for light

(a) Material related sorting mistake (b) Unrelated sorting mistake

Figure 5: Examples of wrong sorting in packaging containers, taken on the 9th of January

bulbs or batteries. In this case, the error lies in interpreting the buckets for light bulbs, as containers to place all types of electronic waste. Users correctly associate electronics and bulbs as hazardous waste, considering this broader category to be covered by this container. Again, here the layman logic groups in a different way than the waste system perspectives implies.

Unrelated sorting mistakes seem random, with no particular reasoning behind them, as if was an accident, result of disinterest, lack of attention or sloppiness from the users side. Some of these mistakes are related to discards that have no dedicated container (e.g. wood, textiles), while others correspond to materials that would be correctly sorted in one of the other bins beside it (e.g. plastic bag in paper packaging container).

4. Concluding recommendations

Given the results from the case study presented herein, it is possible to start defining some possible strategies for the housing company to improve their source separated collection. The suggestions presented below will be further evaluated once the results from the survey and from eventual focus groups are known.

If users are expected to sort out most of their biodegradable waste, the containers currently available do not have enough volume to hold the amount of biodegradable waste generated. The housing company should increase the volume of biodegradable containers while reducing the amount of containers for mixed waste. This should be linked to a strong information and motivation campaign to get the tenants more actively involved in sorting biodegradable

Figure 6: Reuse room in another district office managed by the same housing company

waste. How to inform and motivate the tenants is something that will be further explored with the survey and focus group interviews, given that the user's input is vital for the acceptance of these tools when later applied.

One of the mixed waste containers could be specially designated for bulky waste. This would make it clear for the tenants that they are allowed to dispose of bulky waste in this manner, as long as it fits in the containers. Hopefully this would reduce the amount of times that bulky waste gets left on the floor on the waste room. If the waste they wish to discard is larger, they should contact the maintenance personnel to gain access to the room for especially bulky waste.

Another option to reduce the bulky waste is to offer a space to dispose bulky objects that users wish to discard but that are otherwise in good conditions to use. This could be done in a constant physical space (like a reuse room that the same housing company has in a different district, figure 6), or organized temporarily like a yard garage sale or flea market as a free-cycle event where tenants could bring their discards for other people to take. If there are materials left over from these events, a second hand organization can be contacted to take care of these materials, at no cost for the housing company.

A container solely dedicated to electronic waste should be made available. This fraction has to undergo a different types of treatment once it is collected and should not be sent to incineration with the rest of the mixed waste. Special and hazardous materials present in electronic equipment should be collected in a special manner. Currently it is still the user's responsibility to dispose of them correctly. Today it is very common that these fractions end up in the mixed waste containers, in some packaging container or even on the floor of the waste room. The housing company has the possibility to facilitate this task to the users by providing separate sorting for electronic and hazardous waste.

Despite that today the municipality does not require households to sort out textiles, they are commonly present in the mixed waste stream and could be reused or recycled. If a housing company would want to facilitate this procedure for its tenants, a container for textiles and shoes could also be made available. They could choose to have separate containers for clothes that could be reused and another one for textiles that should just be recycled. The company then

would have to contact a second hand organization that would be interested in taking the discards collected in the first container, while sending the contents of the second directly to a textile recycling facility.

This case study shows, in line with previous research, that there are mismatches between the technical system and the user's perspective. The discrepancy between what users think of how to discard their waste and how the waste system actually works is generating the problems observed. Housing companies today are a middle man between the waste system and their tenants. This gives them the responsibility to facilitate and improve how the users interact with the system. Given that housing companies manage higher volumes of material than regular households, this allows for certain economy of scale that should be taken into account and used for the improvement of the source separated collection, even beyond what is required from them by legislation and local authorities.

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