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Increasing the Efficiency of Material Recovery Facility through Source Separation of Residential Solid Waste, the case of Duhok city

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ABSTRACT: This study investigates the separation of residential solid waste at the household level in Dohuk city and its potential impact on the capacity of material recovery facility (MRF) in Kwashe fabric. With a rough daily capacity of 500 tons of municipal solid waste (MSW), this facility is currently able to process only 50% of this quantity – manually using hired laborers. The unprocessed waste is usually disposed of in a nearby open dumpsite. In addition, the limited capacity of Kwashe facility is further hampered by the need for more labor force, which makes the sorting process not be cost-effective and of health hazards to the workers.

This study's results, which targeted 26 households in two economically different neighborhoods (Baroshke and Gre-sor), reveal that household waste is not separated, and the proportion of wet waste is much higher than the dry waste (65% vs. 35%). This indicates that this finding has no co-relation with the residents' living conditions level but with the cultural habits – eating freshly cooked food and cooking more than they need. They also reveal that dry wastes such as batteries and dying materials contain Cadmium, a chemical that contaminates recyclable materials.

Hence, one of the effective strategies to increase Kwashe facility's capacity is to separate the residential solid waste at the source, as the wet waste can be directly converted into compost, which is 65% in average of the total residential waste. In contrast, dry waste can be separated and recycled in a more cost-effect manner with fewer health risks to the workers and better quality of the outputs.

KEYWORD: Wet and Dry Waste Sorting,Waste Generation Rate, Dry Waste Quality, Capacity of Material Recovery Facility

Background of Kwashe Material Recovery Facility/ Sorting Plant

Kwashe MRF is located in Summel within Kwashe area, a mix of residential and industrial zoning. Kwashe MRF is approximately 20km northwest of the capital of the city of Duhok.

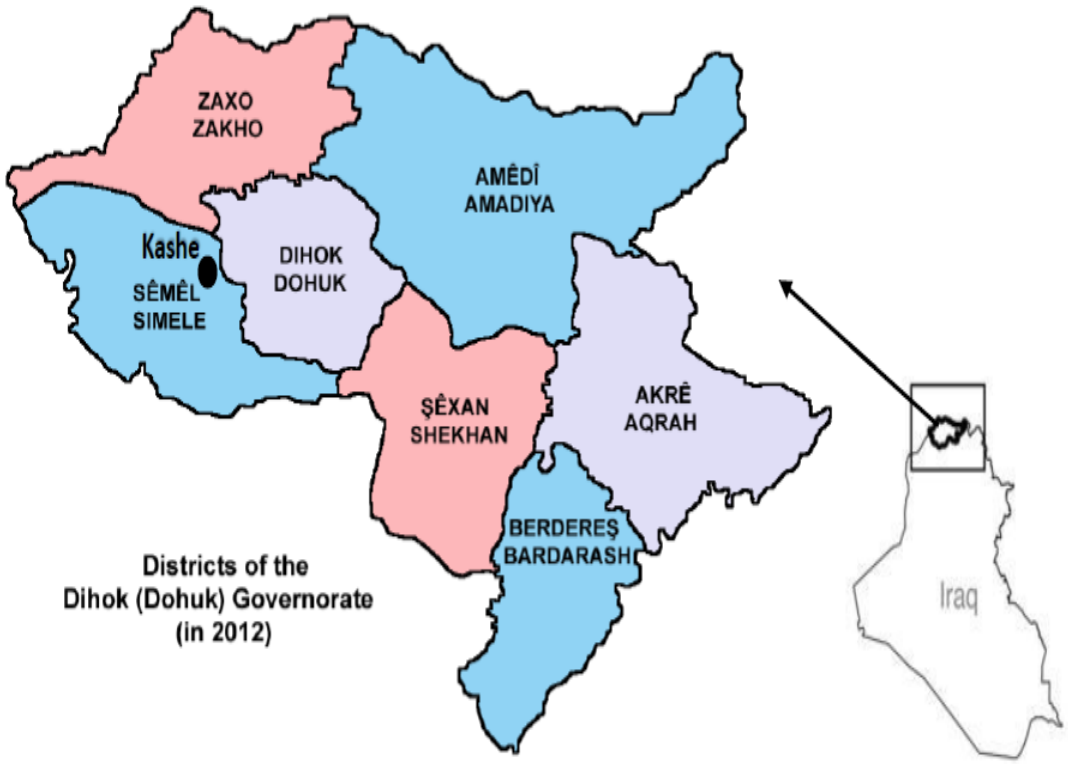

Figure 1: Location of Kwashe MRF, Source: edited by Author, 2019

According to the Kwashe MRF manager, MRF belongs to Duhok province in the Kwashe area; it was decided, with the help of an Egyptian company and UNICEF, to build MRF in the Kwashe area. In 2010, the provincial government began to build with one line of sorting and one damping line with an open space for burial. In 2011, the plant started working and processing waste with a capacity of 200-250 tons per day. In 2014, the government built a second factory line, sanitary landfill, and wastewater tank.

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Figure 2: Kwashe MRF area, Source: Duhok municipality, 2019

The Kwashe waste area consists of MRF/sorting plant with two factories line for waste sorting, one open dumping area for unsorted waste, sanitary landfill, wastewater tank, and one wastewater treatment planta supporter of ACTED organization built.

Today, the sorting plant receives 450 to 500 tons/day of MSWfrom Duhok district and Summel districtin addition to a number of IDPs and refugee camps. The sorting capacity for each factory line is 250 tons per day, but due to the financial crisis. Continuously 40% of receiving MSW (150-200 tons of MSW per day remains unsorted) according to the manager of Kwashe's MRF. The sorting factories are sorting all the MSW;thus, all the sorted/recycled items will be sold to some companies by the auction process, and even the organic material which is treated to be composted. The percentage of dry and wet waste (see table 1).

Table 1: Amount of waste received in sorting plant, Source: Kwashe MRF, 2019

Amount of waste per day (tons) received	Sorting capacity (ton per day)	Organic materials (%)	Non-organic materials (%)
500-550	300-350	60%	40%

1. Introduction

Waste or garbage has been with humans since early dawn; only their definitions have changed. Nowadays, to prevent pollution, save our planet and clean it, humanity starts developinga new system to get rid of waste which is MSW.This system began to clean the cities and manage their pollution rate, collecting waste house by house or in collection center. There was no residents' involvement, so people throw away their garbage without thinking where this goes or how it has been dissolved when they do with using the materials. (Barles, 2014)

To dispose of MSW in developed countries, they start separating their garbage into two categories, each of them according to their capacity. The importing thinks for a developed country is how waste can be reused and sort for the benefit of their areas. The main reason for sorting is to separate recyclable materials from non-recyclable materials is reusing. Sorting (MSW) ensures that it can be processed to recoverthe material, sort hazardous material separately from other types of MSW, and minimize MSW and provide a reduction in landfill space for final disposal. MSW can be sorted into two categories to sort at the source: dry waste and wet waste. Waste separation means separating waste and in the best interest of our health and environment. Dry waste includes plastic, cans, wood and related products, metals and glass, and paper cartons. Wet wastes usually refer to organic waste traditionally generated by eating foods, and it's heavy due to moisture. Waste can also be sorted into a civil entertainment site.

Technically, the MSW can be separated in two ways. The first one is to collect waste and separated by hand/manually or by machine/technically by the MRF, which requires a large investment for processing. There is a high risk of pollutants for workers during manual sorting. Second, it can be separated at the source and then collect and send it to the MRF, which requires more bins and engaging the people, mainly depends on behavioral aspects at the family level. People must pay for municipal services (waste collection and treatment) in developed countries; payments are determined locally and vary from city to city. People/Consumersare obligated by law to sort the waste at the source.

There are many models to know how people interact with waste collection in the motivation-ability-opportunity-behavior model; it's clear how behavior such as waste separation can be formed at the source. The intention is the direct precedents of behavior, but nothing will happen without ability and opportunity. Motivating the actor is the first element in the model. Motivation alone can promote intent, but the motivated person must be able to perform the behavior. Therefore, the concept of ability, which includes knowledge of habit and mission, was added to the model as a supervisor of intent and a determinant of behavior. The second parameter that leads to the intention of the actual conduct is the opportunity. Situation factors such as access to collection facilities and the design of an appropriate source separation system are examples of this model's options. (Ölander & Thøgersen, 1995).

In Duhok city, the collection system of gathering the garbage is to collect the garbage from houses and then being sorted by the MRF, doing this sort in the MRF has many adverse effects; for example, the capacity of the MRF in Kwashe are overload, more than 40 percentages of receiving MSW can't be sorted according to Kwashe MRF Manager, and it is disposed of in open dumping because of the limited capacity. Another adverse effect is using too many labor force workers to sort the garbage manually, which means the process is not cost-effective. The sorting method might affect their health, and it will be a reason for current new diseases. The separation of (MSW) at a source is needed because it will help the MRF be more efficient.

In the Duhok region, which is located in Kurdistan, the increase of population, growth of economic activities i.e.,such as industrialization, urbanization, and raising the living standards and the migration of refugees and IDPs, are resulting in a huge increase in the amount of MSW. Not just in the city but also the whole Duhok governorate, and there is only one MRF located in "Kwashe" and all of the MSW are sent to this facility to be separated. Then the organic wastes are composted, and non-organic wastes are recycled. The capacity of MRF is limited and cannot handle the total quantity generated where they can only separate 40% of the MSW, according to Kwashe MRF manager,2019. The rest is getting rid of by open dumping. Failure to address a proper process of sorting is expected to lead to numerous social and environmental contaminations.

The concept of solid waste management has been more conflict because of human development spatially in the industrial development era. The health problem plus the city locks and clean the streets human invent solid waste management. MSW is all the garbage that has been collected in the city from settlement and commercial areas and roads. In other words, all the garbage that has been thrown away by the public that the government will collect. The MSW includes hazardous waste, which has to be taking care of it carefully; People can be included in MSW collecting by separating garbage at their house or public are, which has to benefit for the public to bee including in helping the community and the environment (Bilitewski et al., 1997).

Waste sorting is a garbage collection and management system which is separated into different elements. Residence separates waste materials into different elements because it benefits their health and the environment. If the mixed waste stays at home for a long time, it will go bad and become a good atmosphere for bacteria and fungi or parasites, not to mention the bad smell. (Barles, 2005).

Waste generation is inevitable, and the materials this waste carries affect human health and the environment. One of the important waste management methods is the separation of wet and dry waste so that the dry waste can be recycled and wet waste can be converted into fertilizer. And that can reduce waste that reaches landfills and takes up space. Air and water pollution rates are greatly reduced also, and it is easy to apply different processes such as fertilizing, recycling, and burning. Family-level waste management begins first; there must be two bins for garbage disposal at home, one for dry waste and the other for wet waste. Items such as aluminum foil, tetra packages, glass, paper, plastic, metals, etc., fall into the dry waste category.

In contrast, kitchen waste such as stale foods, fruits, and vegetables is exposed to wet waste. Waste management disposes of surrounding waste and reduces the intensity of greenhouse gases such as methane and carbon monoxide from the accumulated waste. The depth of existing landfills will also be curbed, reducing all toxic substances to the environment. The number of fossil fuels will also be reduced in this way, resulting in cleaner and more environments. (Barles, 2005)

The United States is gaining popularity in separate recycling of household waste, recyclables, and yard waste. Separation of the source is mandated in some communities, while it is voluntary in others. Most towns have recycling bins for residents to be filled with recyclables and put on collection day next to garbage containers. Source-separated garden waste, like tree trimmings, is placed primarily in plastic bags or packed when it is vast. Residents also bring this waste separated at source to collection points and selling reusable buy-back programs in places wherever curbside recycling of reusable and garden waste isn't accessible. Citizen involvement is essential to the success of source-separated recycling programs. Incentives are sometimes introduced to raise participation, for example, reduced waste gathering fees for recyclers. (Dokin, 2019)

A source separation system can minimize the unwanted effects of incinerators or landfills. Household batteries and chemical products of households, for example, can increase leachate from landfill contamination, incinerator air pollution, and ash from incinerators. Furthermore, some potentially non-combustible waste, such as glass, may decrease incinerator output. Reducing the volume of residual ash from incineration is another incentive for waste disposal. The reusable and particular waste can be separated without separation systems from the waste stream. Separating waste after disposal is more convenient and cost-effective for many societies. In these systems, at transfer stations or MRF, reusable and particular waste is separated mechanically or manually. It may take more labor and higher energy costs to separate recyclables in this manner. Still, it is more beneficial for people because no additional effort is required outside standard waste disposal procedures. Waste separation at source can only be one aspect of an extensive public program for recycling. In addition, elements of more systematic approaches for waste management. The Environmental Protection Agency (EPA) urges communities to establish minimal landfill use strategies and eliminate incineration risks and inefficiencies to reduce the impact of waste disposal on the environment. Reduction of the sources and recycling methods are known to be the most environmentally friendly forms for waste management. (Dokin, 2019)

When there is a requirement for extremely good products or mechanistic separation is complex and expensive, source separation is significant. Organic waste (including food waste and garden waste), for example, makes valuable items such as muck and sawdust. Organic waste that's source separated occurs in a product that is high in quality and value. In contrast, the non-chemical that are polluted by some other waste streams, like plastic or glass, make a product with a quality that's not as high as other products. Its applications are more limited and can even be transferred to landfills.

Waste residual mostly point out to materials remaining after sorting plant or separation at the source, and that otherwise will be transferred to landfill. By enhancing the quality of the gathered products by increasing recovery rates, the amount of residual waste to landfills can be minimized.

Separation of waste at the source plays a significant part in changing behavior. Neither households nor companies separating waste before disposal can increase their knowledge of waste materials and recycling processes. This can affect consumer decisions by encouraging waste prevention and product selection that present preferable recycling chances (Geisler, 2014).

Separate recycled products from the origin are typical of higher quality and can be purchased at a higher price than items obtained as a single stream. There is also less risk for recyclable waste (for example, not tipping over fluids on paper and not combining broken pieces of glass with other items). Separate recycling outlets also do not rely so heavily on expensive processing equipment or manual labor.

This research's main objective is to minimize the amount of MSW that's been sent to the sorting plant by separating the MSW at the source into two categories (Dry & Wet). The wet waste will be sent directly to composting, and only the dry wastes will be sent to the sorting plant and then to the recycling factory; this way of sorting can operate more efficiently. It will improve both the quality of dry waste and the capacity of a sorting plant.

2. Materials and Methods

The methodology builds up with two methods, measurements and interviews. In the first question, "How to source separation can expand the capacity of the recovery facility, " the data collection methods that will be used are interview and measurement. The types of data that will be used are qualitative and quantitative. The purpose and justification of the question are to find out the amount of wet and dry waste, how much waste gets rid of, and that's lead to finding out the source separation efficiency in MRF.

In the second question, "How the source separation process enhances the quality of recyclable waste, " the data collection method that will be used is an interview, the type of data that will be used is qualitative. The purpose

and justification of the question are to know the quality of existing recyclable waste and how the separation at the source affects/raises the recyclable products' quality.

2.1 Justification Case study

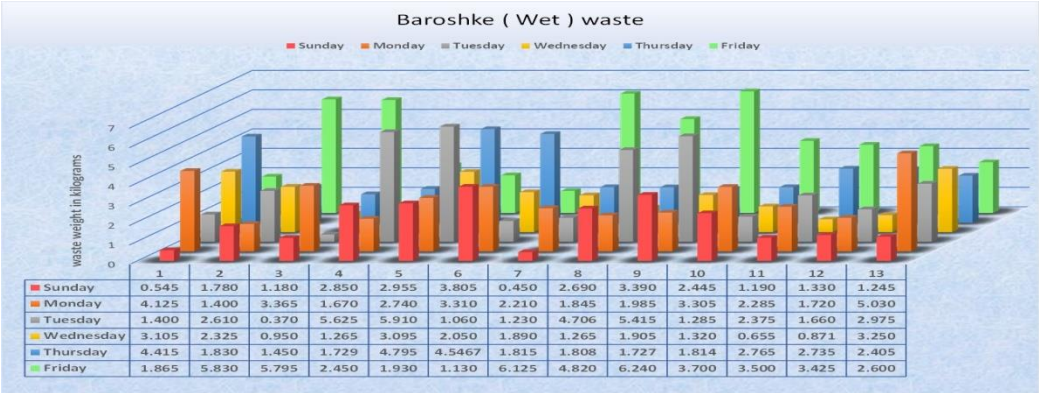
For maximum accuracy, two sites have been chosen for the research's case studies, which were "Gre-sor" neighborhood and "Beroshke" neighborhood, to observe and compare both of them as they differ in many aspects, including the economic and demographic characteristics. Economic factors, socio-demographic factors, and seasonal factors were studied to reach the research aim.

According to the stratified sampling method, the samples of both districts divided the population into two sub-groups (high income and low income). Then the samples were chosen proportionally inside the neighborhood according to our category, which is income level. (Y, S, M 2013).

3. Results and Discussion

In this section, the data we collected about MSW in both case studies (Baroshke and Gre-sor), each for about a week will be presented.

3.1 Baroshke wet waste:

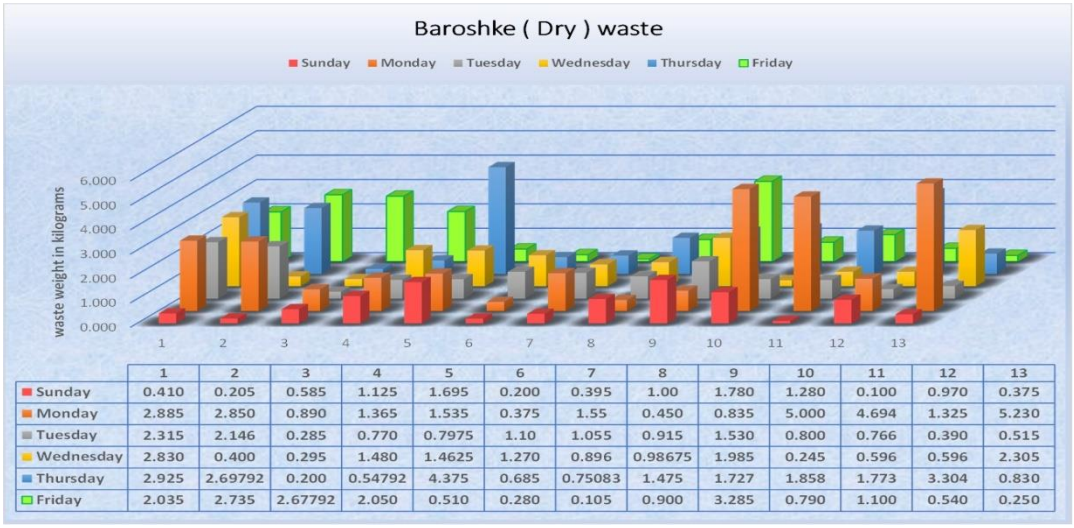


	1	2	3	4	5	6	7	8	9	10	11	12	13
Sunday	0.545	1.780	1.180	2.850	2.955	3.805	0.450	2.690	3.390	2.445	1.190	1.330	1.245
Monday	4.125	1.400	3.365	1.670	2.740	3.310	2.210	1.845	1.985	3.305	2.285	1.720	5.030
Tuesday	1.400	2.610	0.370	5.625	5.910	1.060	1.230	4.706	5.415	1.285	2.375	1.660	2.975
Wednesday	3.105	2.325	0.950	1.265	3.095	2.050	1.890	1.265	1.905	1.320	0.655	0.871	3.250
Thursday	4.415	1.830	1.450	1.729	4.795	4.5467	1.815	1.808	1.727	1.814	2.765	2.735	2.405
Friday	1.865	5.830	5.795	2.450	1.930	1.130	6.125	4.820	6.240	3.700	3.500	3.425	2.600

Figure 3: Quantity of wet waste generation, Baroske

The average family size in Baroshke neighborhood is approximately seven persons, and the weight of wet waste varied with each day. Wet waste a day averaged 2.624 kg per household. If we look closely, we can see that Friday has the highest average of 3.801 kg because on Friday, in most of the houses, all the family members were home, and the low-waste houses were out for different reasons.

3.2 Baroshke dry waste:

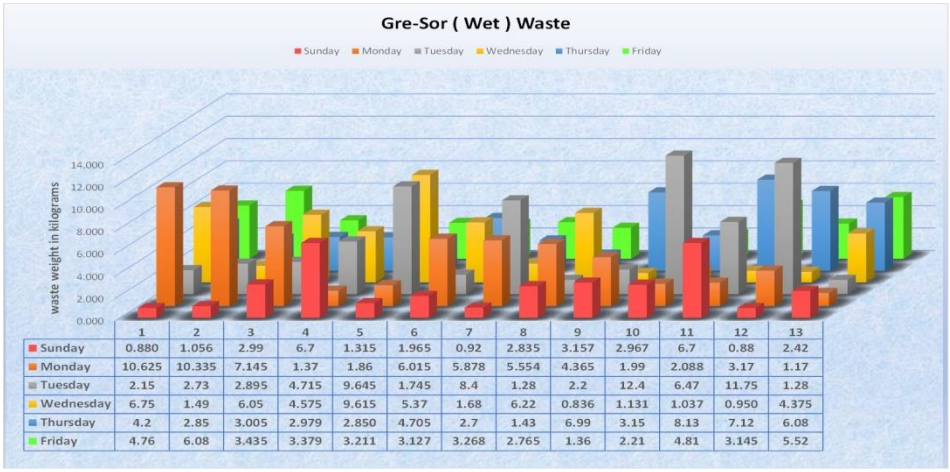


	1	2	3	4	5	6	7	8	9	10	11	12	13
Sunday	0.410	0.205	0.585	1.125	1.695	0.200	0.395	1.00	1.780	1.280	0.100	0.970	0.375
Monday	2.885	2.850	0.890	1.365	1.535	0.375	1.55	0.450	0.835	5.000	4.694	1.325	5.230
Tuesday	2.315	2.146	0.285	0.770	0.7975	1.10	1.055	0.915	1.530	0.800	0.766	0.390	0.515
Wednesday	2.830	0.400	0.295	1.480	1.4625	1.270	0.896	0.98675	1.985	0.245	0.596	0.596	2.305
Thursday	2.925	2.69792	0.200	0.54792	4.375	0.685	0.75083	1.475	1.727	1.858	1.773	3.304	0.830
Friday	2.035	2.735	2.67792	2.050	0.510	0.280	0.105	0.900	3.285	0.790	1.100	0.540	0.250

Figure 4: Quantity of dry waste generation, Baroske

If we consider the family size, the amount of waste was small and reasonable for the dry waste in Baroshke neighborhood. The average daily was 1.388 kg per household, which means that each person produced approximately 0.198 kg of dry waste per day. Each house in the week created different quantities of dry waste on many other grounds every day. There was no particular day for the maximum amount of dry waste.

3.3 Gre-sor wet waste:



	1	2	3	4	5	6	7	8	9	10	11	12	13
Sunday	0.880	1.056	2.99	6.7	1.315	1.965	0.92	2.835	3.157	2.967	6.7	0.88	2.42
Monday	10.625	10.335	7.145	1.37	1.86	6.015	5.878	5.554	4.365	1.99	2.088	3.17	1.17
Tuesday	2.15	2.73	2.895	4.715	9.645	1.745	8.4	1.28	2.2	12.4	6.47	11.75	1.28
Wednesday	6.75	1.49	6.05	4.575	9.615	5.37	1.68	6.22	0.836	1.131	1.037	0.950	4.375
Thursday	4.2	2.85	3.005	2.979	2.850	4.705	2.7	1.43	6.99	3.15	8.13	7.12	6.08
Friday	4.76	6.08	3.435	3.379	3.211	3.127	3.268	2.765	1.36	2.21	4.81	3.145	5.52

Figure 5: Quantity of wet waste generation, Gre-sor

The average family size in the Gre-sor neighborhood is approximately six persons, and if we look at the chart, we can see that there is a significant amount of wet waste. The average amount of wet waste produced per day in a week was 4.069 kg, which means that each individual produced 0.678 kg in a day. The amount of wet waste in this neighborhood on Friday was small by 3.621 kg compared to the other days of the week, and this is because they left their homes on that day for varying reasons.

3.4 Gre-sor dry waste:

	1	2	3	4	5	6	7	8	9	10	11	12	13
Monday	1.28	1.482	3.705	1.735	1.23	1.765	1.750	2.332	1.585	8.73	2.66	2.692	3.045
Tuesday	1.8	2.845	5.605	2.085	0.93	2.36	6.02	3.06	1.855	1.99	2.75	2.656	1.62
Wednesday	3	0.665	11.545	0.97	2.42	1.445	5.8	1.36	1.427	1.326	1.216	2.165	0.215
Thursday	1.35	0.945	1.1	0.65	0.735	0.740	1.665	0.8	5	1.85	1.87	2.055	0.725
Friday	2.89	9.595	1.57	0.485	2.41	2.387	2.253	2.13	0.785	0.775	1.468	1.346	9.095

Figure 6: Quantity of dry waste generation, Gre-sor

The dry waste produced in Gre-sor neighborhood was less than the wet waste, with an average of 2.388 kg per day during a week. But some houses nearly reached 10 kg a few days!

3.5 Comparison between both case studies:

3.5.1 Weighting outcomes for MSW of 13 households at "Baroshke" site:

Day	Total weight of MSW (kg)	Weight of wet wastes (kg))	Weight of wet wastes in percentage	the average amount of wet waste per day	Weight of dry wastes (kg)	Weight of dry wastes in percentage	the average amount of dry waste per day
Sunday	**35.975**	**25.855**	**(71.8%)**	**1.989**	**10.12**	**(28.2%)**	**0.778**
Monday	**63.974**	**34.99**	**(54.69%)**	**2.692**	**28.984**	**(45.31%)**	**2.230**
Tuesday	**50.005**	**36.621**	**(73.2%)**	**2.817**	**13.384**	**(26.8%)**	**1.030**
Wednesday	**39.293**	**23.946**	**(60.9%)**	**1.842**	**15.347**	**(39.1%)**	**1.181**
Thursday	**56.981**	**33.833**	**(59.37%)**	**2.603**	**23.148**	**(40.63%)**	**1.781**
Friday	**66.667**	**49.41**	**(74.1%)**	**3.801**	**17.257**	**(25.9%)**	**1.328**

Table 2: Waste weighing details, Baroske

- Wet wastes: 65.67 %
- Dry waste: 34.33 %

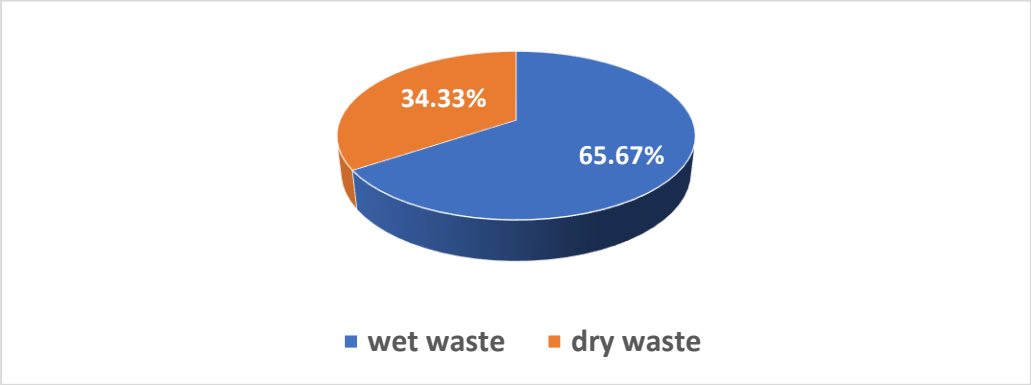


Figure 7: Dry and Wet percentages, Baroske

3.5.2 Weighting outcomes for MSW of 13 households at "Gre-sor" site:

Table 3: Waste weighing details, Gre-sor

Day	Total weight of MSW (kg)	Weight of wet wastes (kg))	Weight of wet wastes in percentage	the average amount of wet waste per day	Weight of dry wastes (kg)	Weight of dry wastes in percentage	the average amount of dry waste per day
Sunday	**61.239**	**34.785**	**56.8%**	**2.676**	**26.454**	**43.2%**	**2.035**
Monday	**95.554**	**61.564**	**64.4%**	**4.736**	**33.990**	**35.6%**	**2.615**
Tuesday	**103.836**	**67.660**	**65.16%**	**5.205**	**36.176**	**34.84%**	**2.737**
Wednesday	**83.628**	**50.079**	**59.88%**	**3.852**	**33.549**	**40.12%**	**2.581**
Thursday	**75.673**	**56.189**	**74.25%**	**4.322**	**19.484**	**25.75%**	**1.499**
Friday	**84.609**	**47.071**	**55.63%**	**3.621**	**37.539**	**44.37%**	**2.861**

- Wet waste: 62.68%
- Dry waste: 37.31%

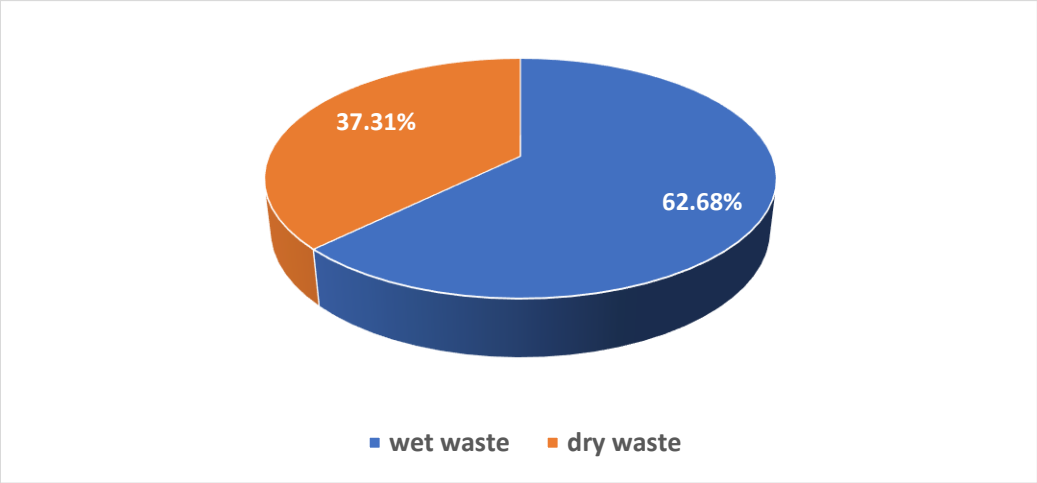


Figure 8: Dry and Wet percentages, Gre-sor

After collecting these results, we can say that families with a rich socioeconomic status, such as Gre-sor neighborhood families, generate more waste than those of lower socioeconomic families like the Baroshke neighborhood. Many wealthy people consume more than lower-income people, which contributes to a higher rate of waste generation. Therefore, we can claim that people's economy and lifestyle create a positive correlation between the family's income and the amount of waste generated.

As for the MSW composition, after measuring the waste weight of 26 households per week, the proportion of wet waste was much higher than the dry waste in both case studies because of the habit of eating fresh food and cooking too much for each member of the family. In Baroshke and Gre-sor the percentages of the waste components are closely related. The amount of wet waste ranges from 62 to 66 percent, and dry waste ranges from 34 to 38 percent.

Kwashe MRF consists of two factories that can sort 250 tons each line of wastes in 8 hours of work, which is 500 tons' wastes in 8 hours, but it has been reduced to 400 tons recently because of the poor economic situation.They receive a daily amount of 500-550 tons of wastes from (Duhok, Summel, and Domis) but only 350 tons are sorted. As they stated, 35% of these wastes are wet wastes, and the other 65% are mixed.The main element that contaminates the recyclable materials is a chemical called Cadmium, and it can be found in Batteries, Dying materials. etc.

And sorting the MSW at the source can increase the MRF's efficiency. It can also improve the recyclable materials' quality (According to the MRF manager in Kwashe).

4. Conclusion

This study provides evidence that household socioeconomic status plays a more significant role in waste generation than demographics. Also, that wet waste is generated daily more than dry waste. Still, households with different income levels and different family sizes can be an essential part of the waste management system with source separation.

As per the data collected from both neighborhoods, the average rate of wet waste is between 62 to 65 percent, while the percentage of dry waste is about 35 to 38 percent; these data suggest that source separation of MSW can increase the efficiency of Kwashe MRF by 62 to 65 percent.

Waste separation at source would make Kwashe MRF more effective, as more than half of the MSW was organic waste, which means the wet/organic waste can be converted tocomposting without needing to be sent to MRF.

The waste separation allows more efficient disposal with less environmental Impact when materials are disposed of, better treatment, and more important. Landfills will last longer and will not need additional land that can be used for other land use purposes. Separated waste increases the quality of waste, which can be sold at a higher price when the dry waste is not contaminated.

As the engineer from Kwashe MRF said, the recyclable materials can be contaminated by many other materials and mainly by a chemical called Cadmium; by separating the wastes at the source, the quality of these recyclables can increase, and this will increase the price in which the recyclables are sold for. Additionally, better recycling means that the usage of raw materials will be decreased if the quality of the recyclables is good enough.

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