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Evaluating the In-site Sorting of Solid Waste in Selected Educational Institutions – A Pilot Study

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ABSTRACT

This study evaluated the process of in-site sorting of the generated solid waste (SW) in some educational institutions in Ma'an city, Jordan. The study included eight schools and one University. The students and employees of seven schools, as well as the students and employees of the University, had received the awareness campaigns concerning the importance and benefits of in-site sorting of SW. As a control, one school student and employee who had not received awareness campaigns were involved. The institutions were provided with four bins at each collection site (glass and plastic, paper and cardboard, metals, and bread). The content of bins in each institution was collected and sorted manually to evaluate the efficiency of the conducted awareness campaigns on onsite sorting behavior. The mass ratios of many SW components in their designated bins in the reference school (control) were higher than the average ratios in the assigned bins for the same component in all schools. As for the University, the results of the manual sorting showed that all bins included a mix of SW in different ratios; moreover, the proportions of glass and plastic, and metals were lower than the proportions of other components. On the basis of the above mentioned results, it can be concluded that the awareness campaigns did not achieve the stated goals; subsequently, the in-site sorting failed in the schools and the University. Thus, different awareness campaigns should be assessed to identify the best approach positively affect the SW sorting and disposal habits of people.

Keywords: solid waste, awareness campaigns, in-site sorting, educational institutions, manual sorting.

INTRODUCTION

Waste management is a global issue that requires attention to reduce environmental pollution and adverse effects on human health and safety [Reddy, 2011]. Historically, solid waste (SW) management was limited to collection and disposal to protect public health and improve the aesthetics of cities [WBG, 2018]. In the nineteenth century, due to changes in people's lifestyles and the availability of many new products, the quantity of the produced SW increased, and their composition changed dramatically. According to WBG (2018), the world generated about 2.01 billion tons of municipal SW in 2018, and about 33 percent were not properly managed in an environmentally safe manner. The generation rate of SW worldwide differs from 0.11 to 4.54 kg per person per day, with an average of 0.74 kg [Kaza and Bhada-Tata, 2018]. In Jordan, SW management is limited to the collection and disposal to landfill. Recently, more attention has been paid to SW management in Jordan, focusing on recycling, recovery, and reuse. Therefore, researchers have been funded and conducted studies concerning energy and material recovery from

SW in Jordan [Aljbour et al., 2021; Al-Hajaya et al., 2021; Al Nawaiseh et al., 2021]. Jaradat and Al-Khashman (2013) evaluated the potential recovery of materials from municipal SW (MSW) in Jordan, Ma'an; they concluded that municipal SW management is still facing many challenges due to insufficient data concerning its quality and characteristics. Furthermore, the study showed that the per capita daily generation rate of MSW in Ma'an was 0.78 kg. The daily generation rate reached 72.5 tons, with only 65 tons received in the landfill and about 7.5 tons recovered by the informal recycling sector. They also reported that the waste composition was organic (65%), paper and cardboard (15.5%), plastic (11%), metals (3.4%), glass (2.8%), and other fractions (2.3%).

The key elements for integrated SW management are reduction, recycling, reuse and recovery. Sorting and separating SW into their components is the first step toward recycling, reusing, and recovering valuable materials. Central sorting, usually at the material recovery facility (MRF) or landfill, is the dominant practice in most developing countries, including Jordan. However, sorting through mixed waste is hazardous and can pose a severe health threat to workers. It is also not the most efficient method for recovery, due to cross-contamination during the collection and transport process. In-site sorting is considered the best practice to improve the recovery of SW fractions and protect the environment.

Recyclable waste includes plastics, metals, paper, cardboard, and organic waste. In Jordan, less than 10% (5–10%) of the generated SW is recycled due to poor awareness campaigns, the unavailability of the required space, and the lack of market for recovered products. Other factors that limit sorting are the high price of electricity and energy required to complete the process, the limited storage space, and price fluctuations that are not economically feasible [Jaradat and Al-Khashman, 2013].

Conducting awareness campaigns to explain the importance and benefits of SW sorting at the site in terms of environmental and economic aspects, besides providing the required infrastructure, are the main requirements for applying in-situ sorting in developing countries. According to Memon (2010) as well as Hoornweg and Bhada-Tata (2012), the influence of socioeconomic, pro-Environment attitudes and program design on recycling has been established. It should be mentioned that participation in sorting and recycling activities does not tend to occur spontaneously, and the legal mandate may not be sufficient to influence the public to adopt sorting and recycling practices. Therefore, intervention by conducting awareness campaigns is often required [Lee and Paik, 2011].

The SW produced in educational institutions like schools and universities has high proportions of reusable and recyclable components like paper, plastic, and food waste. Furthermore, the literature suggests that young educated people are more environmentally aware [Debrah et al., 2021]. Thus, in-situ separation of SW in these institutions is more likely to succeed. This study aimed to assess the impact of awareness campaigns on the efficiency of in-situ sorting. The campaigns have been held for three years in selected educational institutions (One University and eight schools) in Ma'an city.

MATERIALS AND METHODS

Study area

Ma'an is the largest governorate in Jordan, with an area of 32832 km^2 which constitutes 37% of the total area of Jordan (Department of Statistic, 2018). Its population reached about 171100 at the end of 2018, representing 1.7% of Jordan's population. Ma'an is divided into 14 areas, all serviced by the municipality of Ma'an in terms of SW management (Figure 1).

Educational institutions in Ma'an City

The educational institutions present in Ma'an governorate include (Al Hussein Bin Talal University), 5800 students [Al Hussein Bin Talal University, 2019]; Ma'an Community College, 600 students [Al-Balqa Applied University, 2019]; College of Shoubak, 220 students [Al-Balqa Applied University, 2019]. Ma'an City has 38 public primary and secondary male and female schools with a total of 10365 students.

Solid waste sorting campaigns

For three years, the students and employees of 8 schools and one University (Al Hussein Bin Talal University) received awareness campaigns concerning the importance and benefits of in-situ SW sorting. The campaigns were run by The South Association for Conserving Environment and Community. The association provided the

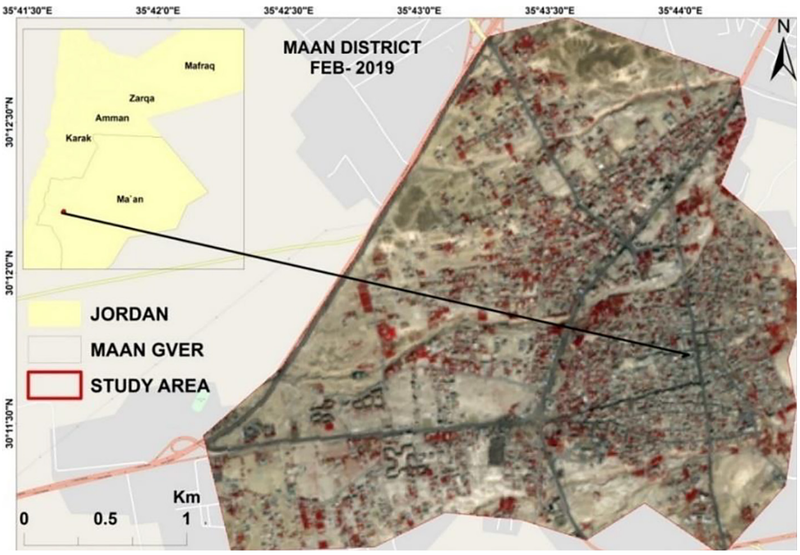

Figure 1. An aerial view of Ma'an (Royal Jordanian Geographical Center, 2019)

targeted institutions with the required containers to facilitate the in-situ sorting of SW. Each collection site had four bins to separate the wastes into four fractions: Paper and cartoon, Glass and plastic, Metals and Bread.

This study included Al Hussein Bin Talal University and eight schools. One school the students of which did not receive awareness campaigns has been used as a reference school to study the efficiency of awareness campaigns (Table 1).

Experimental design

Each collection site has been provided with four-coded bins, one for each waste fraction, as shown in Figure 1. The yellow bin is for paper and cardboard, the orange is for glass and plastic, the blue is for metals, and the green is for bread. The containers are made of solid plastic with a capacity of 240 liters. The containers were located in suitable places in the schools and the university yards (Figure 2).

Waste collection and sorting

The content of similar containers in each school has been collected separately in large cubic cloth bags. After emptying the containers, the collected bags were closed well and transported to the separation hangar. The SW from each school was placed in four separate piles; each consisted of one bin's content. The manual sorting of each pile into four components was conducted by janitors, who were previously trained in the mechanism of SW sorting. General security instructions regarding wearing the apron, gloves, and masks have been followed. The containers containing the same component have been sorted manually into four fractions: Paper and cartoon, Glass and plastic, Metals, and Bread. The total weight of SW produced in each school, the weight of the contents of all containers having the same component in each school, and the weight of each fraction after manual sorting were recorded using a weighing balance with an accuracy of 0.1 kg. The collection frequency of SW has been conducted

Table 1. Schools' names, student numbers, and ages of the studied schools

No.	School Name	Students No.	Students' age (years)	School code
1	Nusseibeh Secondary School	464	5-18	A
2	Ma'an Secondary School for Girls	472	16-18	B
3	Khadijha Bint Khuwailad Elemantary School	550	5-14	C
4	AL-Khalil Bin Ahmed Elementary School for Boys	420	9-15	D
5	Ma'an Comprehensive Secondary School for Girls	211	17-18	E
6	Khaled Bin Al Waleed Elementary School for Boys	375	9-15	F
7	Ma'an Secondary School for Boys	255	13-15	G
8	King Abdullah II of Excellence School	185	13-18	I

Figure 2. Waste collecting and Sorting containers. The yellow bin is for paper and cardboard, the orange is for glass and plastic, the blue is for metals, and the green is for bread

daily from the University and the eight schools using a mini vehicle with a crew of two persons. The collection process started after school time (3:00 pm). After completing the manual sorting processes and weighing all the waste fractions from the eight schools, the waste was filled into plastic bags and disposed of by the municipality crew to the landfill.

RESULTS AND DISCUSSION

The manual sorting of SW from eight schools and Al-Hussein Bin Talal University was conducted, having the total mass of SW produced in each school and the mass and ratio of each separated SW component from each bin. Table 2 shows the results of manual sorting for Ma'an secondary school for girls (B) as an example. The total mass of the produced SW was 183.95 kg. The mass of paper and cardboard produced 51.8 kg, of which 47.1% were found in the bin allocated for paper and cardboard, 43.2% in the bin allocated for glass and plastic, 3.8% metals bin, and 9.9% bread bin.

The total mass of glass and plastic produced was 97.75 kg, of which 70.5% were found in the bin allocated for glass and plastic, while 14.3, 3.5, and 4.4 % were found in the bins allocated for paper and cardboard, metals, and bread, respectively. The total mass of metals produced was 10.25 kg, of which only 13.3% were found in the bin allocated for metals, while 58.9, 23.5, and 4.3% were found in the bins allocated for glass and plastic, paper and cardboard, and bread, respectively. The mass of bread produced was 24.15 kg, of which 78.8% were found in the bin allocated for bread, and 3, 3.4, and 1.4% were found in bins allocated for metals, glass and plastic, and paper and cardboard, respectively.

As a result, in-site sorting in this school was not successful except for bread, likely due to

Table 2. Mass and percentage of SW components of the bins in Ma'an secondary school for girls

Bin	Paper & cardboard		Glass & plastic		Metals		Bread		Total %
	Mass (kg)	%	Mass (kg)	%	Mass (kg)	%	Mass (kg)	%	%
Paper & cardboard	26.9	47.1	24.75	43.2	2.1	3.8	3.35	9.9	100
Glass & plastic	14.3	21.6	46.5	70.5	2.3	3.5	2.9	4.4	100
Metals	9.2	23.5	23.1	58.9	5.2	13.3	1.7	4.3	100
Bread	1.4	6.5	3.4	15.7	0.65	3.0	16.2	78.8	100
Total mass in container (kg)	51.8		97.75		10.25		24.15		
The mass ratio of SW in a container from the total mass generated in all containers	28.16		53.14		5.57		13.13		100

religious/cultural reasons where particular respect for bread is attributed in the Jordanian culture. The results also showed that glass and plastic are the highest percentages, 53% of the SW generated in Ma'an secondary school for girls, followed by paper and cardboard, 28.16%.

The results shown in Table 3 represent the summary of the manual separation of SW in all schools, namely the proportion of SW components in the bins allocated for each component and the average ratio for each component in all schools. The average percentage of paper and cardboard content in the bins allocated for paper and cardboard in all schools was 33.9% with a standard deviation of 7.4, where the maximum ratio of 47.1% was found in the bin of the B school, and the minimum ratio of 24.8% was found in the bin of the D School. These results revealed that the in-site separation of paper and cardboard from SW was inefficient. In the bins allocated for glass and plastic, the average ratio of glass and plastic was 54.5% with a standard deviation of 13.7; the maximum ratio reached 80.6% in the I school while the minimum percentage of 40.7% was found in the E school bin. The separation of glass and plastic is slightly better than that of paper and cardboard but still not satisfactory. As for metals, a low separation efficiency was observed; the average ratio of metals content in the bins allocated for metals was 20.2% with a standard deviation of 9.4, and the maximum percentage was 37.6% in the E school while the minimum was 12.6 in the C school. The high separation efficiency of 78.8, 68.1, and 75.7 % of bread was found in some schools: the G school, E school, and I school, respectively. At the same time, it decreased significantly in other schools. The average ratio is 54%, and the minimum percentage is 17%, which explains the high SD value of 25.4. As seen from the above results, the in-site sorting was not successful. The SW components are found in all bins.

In many cases, the ratio of one component or more exceeded the ratio of the component for which the bin was allocated. An exception is bread separation in some schools; this probably happened, as mentioned before, due to religious/cultural reasons in Jordanian culture. The results also show that glass and plastic form the highest constituent of the SW generated in all schools [Berber et al., 2017; Hamoda and Abu Qudais, 1998].

The results of manual sorting for the reference school where the students and employees did not receive the awareness campaigns on the concept and importance of waste sorting in the C school are highly similar to the results of the schools that received awareness campaigns. Moreover, the proportions of many SW components in their designated bins were higher than the average in the assigned bins for the same component in all schools, indicating that the awareness campaigns conducted did not achieve their goals. Thus, a comprehensive review should be made to overcome the problems that led to the failure of these campaigns and consider them in future campaigns. The results of manual sorting for the SW collected from Al Hussein Bin Talal University are shown in Table 4. For Al-Hussein Bin Talal University, the total mass of paper and cardboard produced 1033.6 kg, of which 59% were found in the bin allocated for paper and cardboard, in the bins allocated for glass and plastic, metals, and bread, the ratio of paper and cardboard reached 19.2, 6.7, and 15.1% respectively. The total mass of glass and plastic produced was 490.4 kg, of which only 18.6% were found in the bin allocated for glass and plastic, while 46.3%, 6.2, and 28.9% were found in the bins allocated for paper and cardboard, metals, and bread, respectively. The total mass of metals produced was 168.1 kg, of which only 7.4% were found in the bin allocated for metals, while 20.5, 37.5, and 34.6% were found in the bins allocated for glass and plastic, paper and cardboard, and bread, respectively. The mass of bread produced was 821.6 kg, of which 54% were found in the bin allocated for bread,

Table 3. The proportion of each component of the manually separated SW in the designated container in different schools

Bin/school	A	B	C	D	E	F	G	I	Average	ST_{DEV}
Paper and cardboard	40.5%	47.1%	37.4%	24.8%	32.5%	27.3%	29.1%	32.5%	33.9%	7.4
Glass and plastic	53.2%	70.5%	49.8%	46.7%	41.7%	48.1%	45.5%	80.6%	54.5%	13.7
Metals	31.9%	13.3%	12.6%	17.1%	37.6%	18.3%	17.6%	13.2	20.2%	9.4
Bread	49.4%	78.8%	30.9%	19.6%	68.1%	17.4%	27.8%	75.7%	46%	25.4

Table 4. Mass and Percentage of SW components of the bins at Al-Hussein Bin Talal University

NS	Paper & Cardboard		Glass & Plastic		Metals		Bread		Total %
	Mass (kg)	%	Mass (kg)	%	Mass (kg)	%	Mass (kg)	%	%
Paper & cardboard	373.9	59.0	121.9	19.2	42.8	6.7	95.65	15.1	100
Glass & plastic	316.5	46.3	127.3	18.6	42.1	6.2	198.4	28.9	100
Metals	228.1	37.5	124.6	20.5	44.8	7.4	210.3	34.6	100
Bread	115.1	19.6	116.6	19.9	38.42	6.5	317.25	54.0	100
Total mass in container (kg)	1033.6		490.4		168.12		821.6		2513.7
The mass ratio of SW in a container from the total mass generated in all containers	41.10		19.50		6.60		32.80		100

and 6.5, 19.9, and 19.6% were found in the bins allocated for metals, glass and plastic, and paper and cardboard, respectively.

The mass of bread produced was 821.6 kg, of which 54% were found in the bin allocated for bread, and 6.5, 19.9, and 19.6% were found in the bins allocated for metals, glass and plastic, and paper and cardboard, respectively. All bins included a mix of SW in different ratios. Moreover, the percentages of glass, plastic, and metals in the bins allocated for them were less than the ratios of other components. The results bove reveal that the in-site sorting at the University did not succeed despite the conducted awareness campaigns [Aldayyat et al., 2019; Ajaradin and Persson, 2014; Ajaradin and Persson, 2011].

The results showed that 42.8% of the generated SW in the schools were glass and plastic, followed by 26.6% paper and cardboard, while bread and metal content reached 17.2% and 13.4%, respectively. At Al Hussein Bin Talal University, the highest percentage was for paper and cardboard 41.10% followed by bread 37.7%, glass, and plastic 19.5% and metal 6.70% (Table 4). The total quantity of the collected SW in the studied institutions during five days was estimated to be 4113.72 kg, of which 426.2 kg of paper and cardboard, 685.45 kg of glass and plastic, 214.55 kg metals, and 273.8 kg of bread. On the basis of the cost of each SW component in the local market, the annual financial return from selling these wastes was estimated to be 42976.12 Jordanian Dinars (JD) per year, 3678.7 JD from paper and cardboard, 23705.5 JD from glass and plastic,1791.4 JD from metals, and 13800.5 JD from bread, where one JD equals to 1.4$) [Ajbour et al., 2021; Kinnaman, 2017; Mrayyan and Moshrik, 2006].

CONCLUSIONS

This study has been conducted on sorting solid waste management in selected educational institutions in Ma'an city, southern Jordan. The applicability of SWM has been extensively examined from technical and social perspectives according to the results. The results showed that school waste is mostly glass and plastic, while university paper and cardboard have the highest proportion with a ratio. The optimal age group to focus on to promote the idea of in-site sorting is 10–18 years. On the basis of the obtained results, it was concluded that they did not have enough knowledge about handling and sorting SW. Finally, the conducted study showed that in-site sorting, whether in schools or the University, was unsuccessful, despite the awareness campaigns directed to the students in these institutions.

This study recommends that awareness campaigns and related waste management issues be a participatory and complementary process between the public and private sectors. More intensive and effective awareness campaigns should be conducted to improve the efficiency of in-site sorting.

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