

Household-level determinants of residential solid waste generation rates: a study from Nablus-Palestine

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Abstract In this work, we elucidate the relation of various household-level socioeconomic and demographic attributes with the residential per capita solid waste generation rate in the Nablus district of Palestine. The data collection phase entailed an extensive survey of 992 dwellings, thus probing and quantifying key socioeconomic and demographic indicators of each household. Meticulous estimation of the amount of waste generated by each household was conducted at the waste generation point. Relevant statistical tests (ANOVA and Pearson tests) were performed to identify the significant relationships between the socioeconomic/demographic variables and the residential per capita solid waste generation rate, as well as amongst the variables themselves. Statistical analysis of the data revealed that the waste generation rate decreased as the family's income decreased, as parents tended to spend more time at home, as the number of individuals living in the household increased, and as the household tended to purchase its grocery needs in just the needed quantities. Age of dwelling residents was also significant. By showing how these variables affect the waste generated per capita, an argument was made to support their consideration when

designing future waste management systems, not only for Nablus, but also for many other cities with similar profiles.

Keywords Municipal solid waste · Waste generation · Income · Residential waste

Introduction

Solid waste generation (SWG) rate is an integral element of municipal solid waste (MSW) management. It is inevitable that any integrated waste management plan should start with accurate estimates of present and future amounts of waste generated, as well as of waste characteristics [1]. The short-term prediction of future MSW generation rates can facilitate better planning with respect to collection schemes, personnel staffing, waste transportation (routing), and short-term disposal needs [2]. On the other hand, accurate long-term forecasting of waste generation is essential for the selection of appropriate technologies for recycling, treatment, and disposal of MSW and for future planning of landfill sites [3].

Dependence of SWG on various parameters

While the need for accurate projections for future MSW generation rates is unquestionable, achieving the desired prediction accuracy for generation trends in dynamic and/or fast-growing regions can be quite challenging. Thus, there is always room for new and reliable projection tools for MSW generation. One common approach in literature entails correlating MSW generation rates with an array of macro-scale economic and demographic indicators, such as gross domestic product (GDP) [4, 5]. The accumulated literature on this subject suggests that these indicators are

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region- and culture-dependent [6, 7]. Thus, while some trends are universal (such as the correlation between income and quantities of solid waste generated), others may be less obvious. It is worth mentioning here that different studies have arrived at different -and sometimes contradicting- conclusions on the relevance of some indicators to the per capita SWG. The authors stipulate three reasons behind this observation. First, most studies attempted to correlate MSW, which includes commercial, residential, and institutional waste, to indicators which are characteristics of only one source of the waste generated, that is residential waste. Second, in many studies, the per capita waste generation rates were either loosely estimated or roughly calculated based on landfills' daily inflow, thus making it difficult to accurately correlate the calculated per capita SWG values with indicator values obtained for a specific residential area, and to account for waste diversion at the source. Third, studies conducted in different parts of the world sometimes resulted in different conclusions.

Aim of this study and its novelty

Residential waste constitutes a significant stream of MSW in developing countries. In Palestine, the fraction is about 88 % [8]. Thus, by focusing on the generation rates for residential waste, a significant portion of the total MSW can be predicted. This research aims to build on this by identifying the significant socioeconomic and demographic determinants (indicators) that affect the per capita residential SWG rate. This study, however, probes the determinants at the micro-level; that is at the point source of waste generation. This makes the significance of these determinants more readily verifiable. This is different from most previous studies which tend to correlate waste generation rates with macro-level indicators (e.g., GDP) [9]. In our study, by obtaining accurate house-to-house residential per capita SWG rate estimates, those estimates were directly correlated to the economical and demographic characteristics of the households where the waste originated. Moreover, some of the indicators studied in this work, such as the time parents spend at home, are hardly explored in MSW generation literature. A search by the authors for relevant literature on residential solid waste yielded very few results on the relevant influencing indicators, particularly for Palestine. Additionally, not only was this study conducted using a sample much larger than those encountered in other similar studies, it was also conducted in a region (the Middle East) where extremely few studies have been conducted on determinants of residential waste generation, despite being a region with growing waste management challenges.

Methodology

This study was carried out in Nablus district, located in the northern part of the West Bank-Palestinian Territories. The population of Nablus district was about 315,800 inhabitants in the last census of 2007 [10], and it has a population density of approximately 700 people/km² [11]. Nablus is one of the largest Palestinian cities [12]. Therefore, a study carried out in Nablus may be considered as a good representation of Palestine in general. In Nablus, the waste is collected on a daily basis. With regards to recycling, as of 2009, recycling operations had not been institutionalized in Nablus [13]. Thus, recycling at the household level is not very well known nor is it widely practiced in Nablus. Recently, the Nablus Municipality conducted the preliminary environmental impact assessment process for a new recycling plant which they are planning to construct in the city's western region [14].

Sampling population

To study the effects of socioeconomic factors (determinants) on the per-capita residential waste generation rate, a large sample of Nablus district residents was surveyed. The sample size was 992 dwellings (apartments and houses), occupied by residents from a wide spectrum of socioeconomic status (SES). The total number of residents in the surveyed dwellings was 5278 persons. This sample size is substantially greater than that of other related studies [15, 16] and is a statistically significant proportion of the population of the district under consideration. The sampling guide published by Magnani (1997) was used to estimate the sample size. A multi-stage sampling procedure was utilized in the selection of the study population [17]. The dwellings were first stratified according to the SES (low, lower-middle, upper middle and high SES). The stratification criteria were based on the general status of the housing unit and the type of residence. From each stratum, a predetermined number of households were randomly selected to be surveyed [18].

Data collection

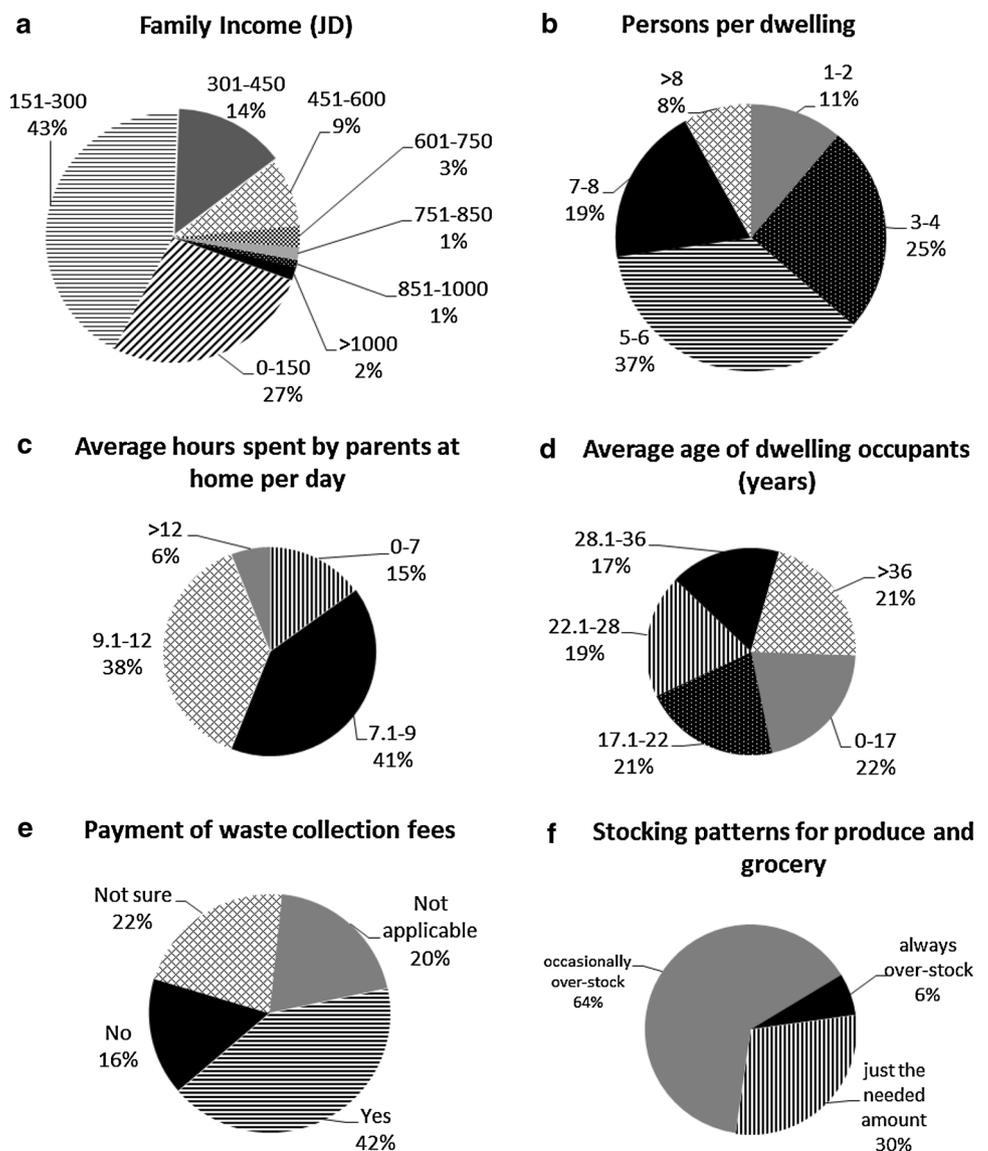
The main tool used in data collection was a structured questionnaire specifically designed for this study. The questionnaire and the pre-testing thereof were carried out in the local language, Arabic. The pre-testing was done on a small -but representative- group of the respondents to determine the questionnaire's effectiveness in terms of format, wording and order. The dependent variable in the questionnaire was the estimated residential per capita SWG rate of a dwelling, on volumetric basis. To calculate the residential per capita SWG rate, the surveyors carried with

them a set of all the standard-sized plastic bags available in the Palestinian market and commonly used by residents for trash collection. As the Palestinian market for these bags is limited, there were only 7 types of trash bags in this set. The standard fill-volume of each of these bags was determined beforehand. When the homemakers of the surveyed residences were interviewed, they were shown the bags and asked to identify the type(s) they use and state (to the best of their knowledge) the frequency at which they dispose of a trash-filled bag of each of the types they used. Additionally, the interviewees were asked to give their best estimate of how full the bags usually were (as a percentage) when they were disposed. The interviewer recorded the answers on the survey sheet of the respective household and later calculated the volumetric residential per capita SWG rate for each household, based on the provided

information. The calculation of the residential per capita SWG rate was done by dividing the calculated volumetric daily waste amount of the dwelling by the number of individuals living in that dwelling, also provided by the interviewee.

Six independent variables were included in the survey. These represent the socioeconomic and demographic characteristics of the household residents. The variables were selected based on the authors' review of relevant literature on macro-scale indicators (e.g., GDP), from which the authors speculated on the potential relevant micro-scale indicators. This does not preclude the consideration of other indicator variables in future studies. The variables considered here are: (1) average household monthly income, in Jordanian Dinar (JD, 1 JD = \$1.4 USD), (2) number of residents in the dwelling, (3) average

Fig. 1 Distribution of independent variables among the sample population



age of dwelling residents (this was calculated by averaging the ages of all residents as provided by the interviewee), (4) commitment to paying municipal solid waste fees (this was probed via the following question: “Did you pay your municipal SW fees last year?”, Answer: Y/N/NA), (5) stocking pattern for grocery and produce. For this question, three options were provided: “we buy just the needed amounts”, “we occasionally over-stock”, and “we always over-stock”, and (6) hours spent at home per day by both parents. Finally, the survey also included a question on the percentage of waste reused or recycled internally within the dwelling itself. The purpose of including this question was to measure the diversion of generated waste from disposal, whether through reusing in-house or external recycling. It was not meant to study recycling per se. Both reused and recycled waste quantities were therefore lumped under one category for the purpose of this study and this was explained to the respondents during the interviews. It was found that the waste generation and disposal rates were almost equal since diversion, via recycle or reuse, was found to be negligible.

Data analysis

Analysis of data was performed using the Statistical Package for Social Sciences (SPSS) software, version 12.0. The appropriate statistical test of significance (Analysis of Variance, ANOVA) was performed using a level of significance

of $P < 0.05$. Where possible (i.e., for correlations between two numeric variables), correlation analysis was also performed using Pearson's correlation coefficient.

The main limitation of this study is the possible bias in self-reported data, both on the volumes of waste generated and the independent socioeconomic and demographic variables. In consideration of this, the researchers attempted to enhance the accuracy by allowing sufficient time to administer and explain the questionnaire to the respondents, and by recording the interviewees' responses themselves.

Results and discussion

Socioeconomic and demographic profiles of the sample population

The distribution of the six independent socioeconomic and demographic variables among the sample population is shown in Fig. 1. Figure 1a shows that the income of most of the surveyed households was in the range of 151–300 JD (43 %). These figures are representative of Palestine in general [19]. Nablus in particular is reported to have had an unemployment rate of 16.5 % during 2012 [20], with an even higher rate among refugees residing in the city [21].

Figure 1b shows the sample distribution in terms of the number of persons living in the surveyed dwellings. Most of the dwellings (37 %), housed 5–6 individuals and this is in

Table 1 Correlations between socioeconomic indicators and the per capita residential SWG rate and amongst the indicators themselves

	Residential per capita solid waste generation rate	Average hours spent by parents at home per day	Overstocking of groceries	Payment of solid waste fees	Average age of household residents	Number of residents per household	Family average income
Family average income	$r^* = +0.26$ $P = 0.000$	$r = -0.140$ $P = 0.000$	Correlated (ANOVA) $P = 0.000$	Correlated (ANOVA) $P = 0.000$	$r = -0.141$ $P = 0.000$	$r = + 0.097$ $P = 0.002$	
Number of residents per household	$r = -0.283$ $P = 0.000$	$r = +0.121$ $P = 0.000$	Correlated (ANOVA) $P = 0.000$	Correlated (ANOVA) $P = 0.033$	$r = -0.483$ $P = 0.000$		
Average age of household residents	$r = +0.134$ $P = 0.000$	$r = +0.172$ $P = 0.000$	Uncorrelated (ANOVA) $P = 0.9430$	Correlated (ANOVA) $P = 0.000$			
Payment of solid waste fees	Correlated (ANOVA) $P = 0.000$	Uncorrelated (ANOVA) $P = 0.202$					
Overstocking of groceries	Correlated (ANOVA) $P = 0.015$	Uncorrelated (ANOVA) $P = 0.754$					
Average hours spent by parents at home per day	$r = -0.172$ $P = 0.000$						

* r Pearson product-moment correlation coefficient

Table 2 ANOVA results showing the correlations between some socioeconomic indicators

Correlated parameters	Correlated groups	Sum of squares	Degree of freedom	Mean squares	F value	P value
Payment of solid waste fees						
AND						
Family average income	Between groups	2957391	3	985797.125	17.115	0.000
	Within groups	56905875	988	57597.039		
	Total	59863266	991			
Number of residents per household	Between groups	47.528	3	15.843	2.930	0.033
	Within groups	5342.532	988	5.407		
	Total	5390.060	991			
Average age of household residents	Between groups	4390.724	3	1463.575	7.297	0.000
	Within groups	198161.7	988	200.568		
	Total	202552.4	991			
Residential per capita solid waste generation rate	Between groups	109.046	3	36.349	6.102	0.000
	Within groups	5885.358	988	5.957		
	Total	5994.404	991			
Average hours spent by parents at home per day	Between groups	18.972	3	6.324	1.542	0.202
	Within groups	4052.088	988	4.101		
	Total	4071.060	991			
Overstocking of groceries						
AND						
Family average income	Between groups	5907566	2	2953782.794	54.098	0.000
	Within groups	53891226	987	54601.040		
	Total	59798792	989			
Number of residents per household	Between groups	154.558	2	77.279	14.569	0.000
	Within groups	5235.297	987	5.304		
	Total	5389.855	989			
Average age of household residents	Between groups	24.060	2	12.030	0.059	0.943
	Within groups	202280.1	987	204.944		
	Total	202304.2	989			
Residential per capita solid waste generation rate	Between groups	50.557	2	25.278	4.201	0.015
	Within groups	5938.551	987	6.017		
	Total	5989.108	989			
Average hours spent by parents at home per day	Between groups	2.323	2	1.161	0.282	0.754
	Within groups	4066.841	987	4.12		
	Total	4069.164	989			

agreement with the census reporting an average family size of 5.5 persons in the West Bank in 2007 (Palestinian Central Bureau of Statistics) [22]. Figure 1c shows the distribution of the sample population in terms of the average hours spent by parents at home per day. This value excludes sleep hours. Most of the interviewed parents (79 %) spent between 7.1 and 12 h at home everyday. This high value is mainly due to the high unemployment amongst Palestinians, especially females. In 2005, the percentage of women economically active in the Palestinian territories was reported to be only 9.5 % [23].

Figure 1d shows the distribution of the sample population in terms of the average age of dwelling residents. The distribution reflects roughly an equal distribution amongst

the different categories. Figure 1e shows the distribution of the sample population in terms of whether or not the household pays its annual waste collection fees. In Nablus city, the annual fee for solid waste is approximately 17 USD for residential houses [24]. It is evident that less than half the residents actually paid the fee, mainly because of the deteriorating economic situation.

Solid waste management services in Palestine are quite expensive due to political conditions and a lack of proper funds and infrastructure. The cost of the services are even higher in cities (as opposed to villages) due to the higher population which implies the need for more waste management employees and equipment and thus greater operational

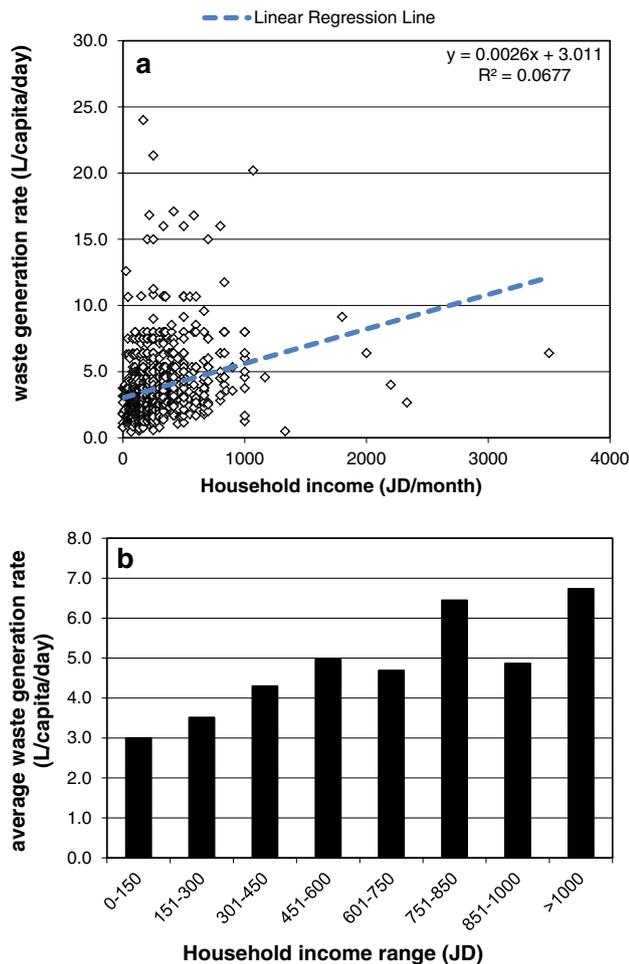


Fig. 2 The variation in the average SWG rate with household income: **a** all data points, **b** stratified averages

costs for the service provider. Moreover, in villages, waste collection vehicles can be shared among several villages, helping in cost reduction [24]. Refugee camps are exempt from waste fees, which explains the “Not Applicable (N/A)” response. The poor collection rate (42 %) is an indication of how a serious fee-based waste management system needs to be more forcefully implemented in Nablus. Finally, Fig. 1f reveals the breakdown of our sample population according to their grocery and produce shopping habits. It can be noticed that a significant number of families occasionally overstock their grocery and produce supplies. This can be expected in light of the perceived savings through wholesale purchases and the relative political instability in the Palestinian territory.

Effects of the socioeconomic and demographic attributes on residential SWG

Table 1 shows a summary of all correlations between the six socioeconomic and demographic variables and the

residential per capita SWG rate. The table also shows the inter-correlations amongst the independent variables themselves. In the cases where the Person correlation coefficient could be calculated, the table also provides that coefficient. Table 1 is complemented by Table 2, which details the key results of the ANOVA tests. It can be seen that all six variables are correlated to the residential per capita SWG rate, making them determinants of it, directly or indirectly. The only exception is the payment of waste collection service fees, which did not have a significant correlation with the residential per capita SWG rate. In addition, a high degree of inter-dependence also exists amongst the variables themselves, as will be elaborated next.

To visualize the relation of the socioeconomic and demographic attributes with the residential per capita SWG rate, the survey data was depicted in two ways. First, the value of the independent variable was plotted for all 992 sample points, with a best-fit linear regression line added. Second, the survey sample of 992 households was stratified into brackets with respect to each of these attributes. The average residential per capita SWG rate of the households within each bracket was calculated and plotted along with the average income of the households within each bracket. Following is a discussion on the observed relevance of each of these attributes.

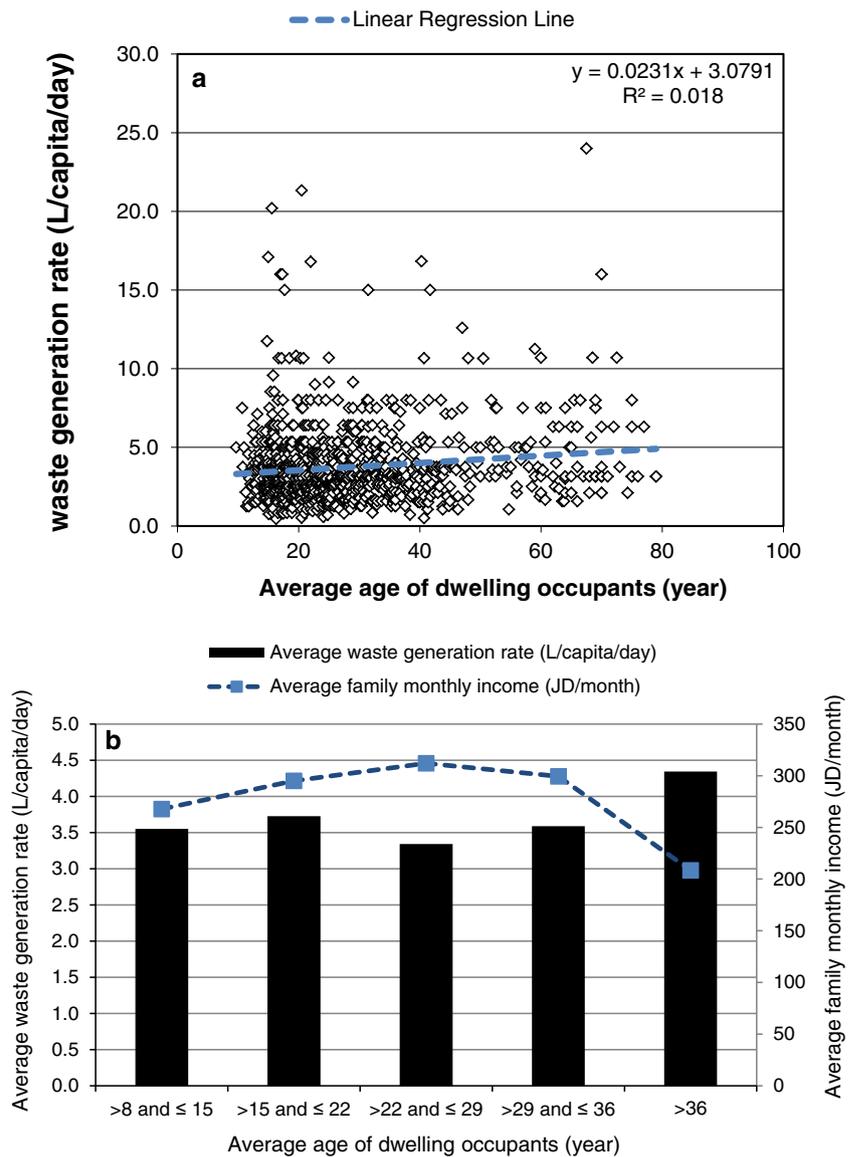
Household income

Financial success affects waste generation by causing more consumer activity on the residential scale [25]. In addition, it may very well be that with higher income, people do not feel the need to be frugal in their management of the resources at their disposal. This leads to greater amounts of waste generated for those who are more affluent. This was noticed in our study for Nablus city (Fig. 2 and Table 1). The findings are similar to those reported by [26] who reported an increase in waste generation with socioeconomic status in Chittagong, Bangladesh both on a per person and per household basis.

Residents' age

When looking at all the sample data points together, one can see a slight upward trend of the residential per capita SWG rate with the average age of household residents (Fig. 3a). However, the stratified averages (Fig. 3b) reveal that households on the extremes of the average ages for their residents produce more waste per capita than the middle range of average age. The solid wastes generated by children consist of items such as diapers, dilapidated toys and old clothes and shoes, as well as food waste. This explains the greater amounts of waste generated in

Fig. 3 The variation in the average SWG rate with the average age of the residents in a sample dwelling: **a** all data points, **b** stratified averages. In **b**, the average age brackets start at 8 years since 9 years was the minimum average age of the households surveyed



households with a lower average age (the first two brackets in Fig. 3b), since such households include young children. In addition, both the elderly and children spend more time at home, which results in more residential waste for the two extreme age categories, as seen in Fig. 3b. The greater waste generation rate among the elderly may also be explained from the perspective that the elderly in Palestine tend to be less aware of ecological issues. Since all of the above is less likely to be the case with respect to middle-aged adults, households with average ages within the range of 22–29 years have the lowest waste generation rates. Figure 3b also shows that the income trend for the age categories is the opposite of that observed between average age and the SWG rate. The extreme average age categories tend to have lower income. This trend supports the

explanation provided in Sect. “Household income”. This inverse relationship between the average income and the average age is corroborated by the negative value of their Pearson correlation coefficient (Table 1).

Time spent at home by parents

Figure 4 shows the trend of how the residential per capita SWG rate decreases as the parents spend more time at home. It also shows that family income follows a similar trend. Interestingly, the variance in the waste generation data also decreases for the higher time brackets (Fig. 4a). On the one hand, the presence of parents in the dwelling for longer periods could lead to more efficient management of household resources, thus reducing the wasted amounts.

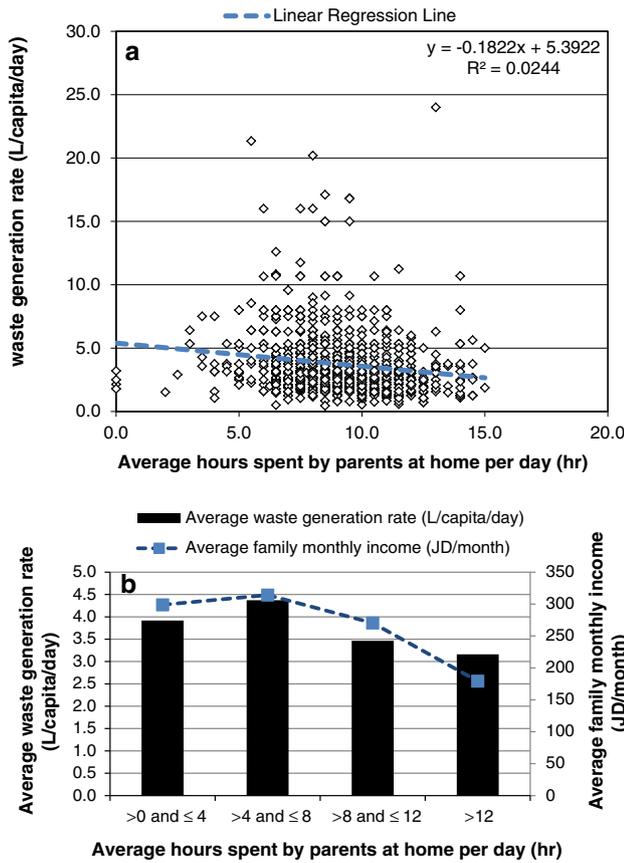


Fig. 4 The variation in the average SWG rate with the average combined hours spent by parents at home per day: **a** all data points, **b** stratified averages

Yet another indirect reason for the trend observed in Fig. 4 could be the fact that unemployment is one reason for longer periods spent at home. Indeed, Table 1 shows an inverse relationship between income and time spent at home by parents in the sample, and similarly there is a direct relationship between the waste generation rate and the average income.

It must be noted that the SWG rate for the 4–8 h range seems to be an exception to the previously explained trend. This may be explained in light of the fact that this age represents middle class parents who have jobs with regular standard hours, allowing them to spend a reasonable amount of time at home with their children, thus contributing more significantly to the generation of household waste. In contrast, the parents in the 0–4 h bracket represent those who are employed in low-paying jobs (as is clear from the trend in income shown in the figure). This leads to a relatively smaller waste generation rate than the 4–8 h range.

All of the above results show that it is important to consider the parameter of time spent at home as a determinant of the residential per capita SWG rate. Interestingly,

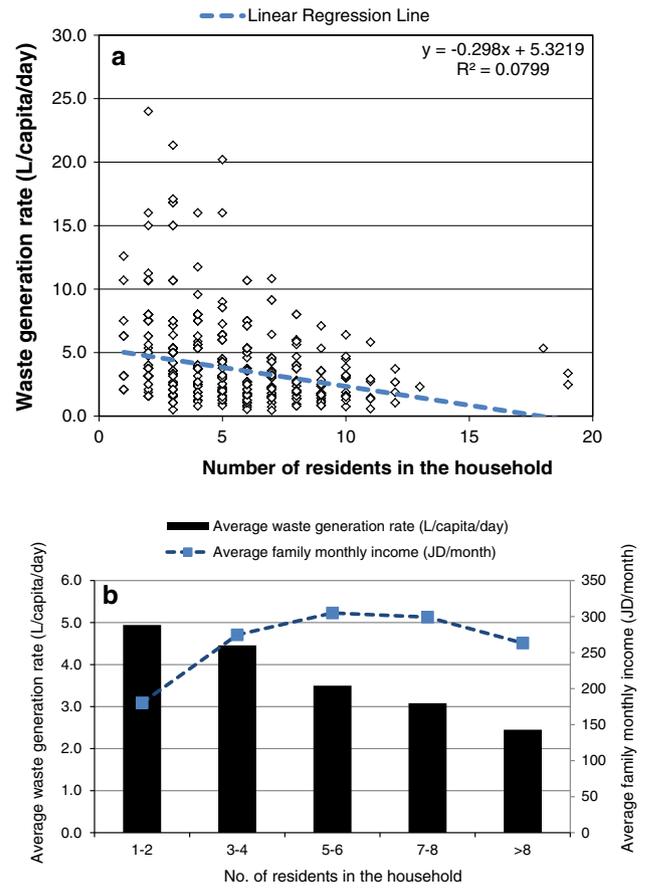


Fig. 5 The variation in the average SWG rate with the number of persons in the sample dwelling: **a** all data points, **b** stratified averages

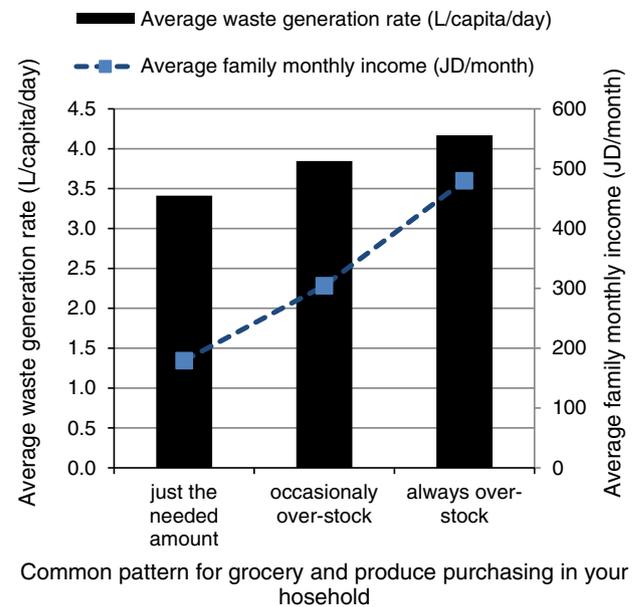


Fig. 6 The variation in the average SWG rate with the common patterns for purchasing grocery and produce in the sample household

time spent at home has been previously suggested to be an important dimension of household waste management from other angles. For instance, in a study by Bennagen et al. [27], they discussed how 53 % of their study respondents failed to segregate their residential waste due to lack of time, and in more than 75 % of the households, the parents were the dominant actors in waste segregation.

Family size

Sometimes people buy product quantities which amount to more than what they actually need. For large families, most of these quantities would be used up. In contrast, in small families, any unplanned increase in the quantities bought (relative to the quantity actually needed) cannot be utilized as easily, and thus may become waste. This leads to the higher residential waste generation rates in smaller families, as shown in Fig. 5 and as proven by the negative Pearson coefficient value in Table 1. Similar observations have been reported in other studies [7, 28, 29]. Another indirect reason for this observation is family income. Poor families in the Middle East region tend to be larger than average [30], which was also detected in our study (Fig. 5 and Table 1). Therefore, the lower residential per capita SWG rates of the larger families may be partially explained by their lower income per capita. However, the households with the lowest number of residents are also found to have the lowest incomes, suggesting that the observed dependency of SWG rates on family size is not completely income related.

Taking into consideration the decline in average household size in the West Bank from 6.1 persons in 1997 to 5.6 in 2011 [31], and assuming that this trend continues, the trend in Fig. 5 suggests that having more households of smaller sizes will lead to even greater future residential per capita SWG rates in the Palestinian cities.

Grocery and produce stocking patterns

A household that is more organized and efficient in managing its resources and monitoring the amounts of products actually needed will tend to utilize everything brought home. This helps significantly reduce the amount of residential waste generated. This can be clearly observed in Fig. 6. People who registered the least residential per capita SWG rates are those who buy just the needed amount. In fact, the effect of overstocking on waste generation can be quite significant. In a study conducted in the UK [32], it was reported that 45 % of food waste in the UK was due to “whole unused or part-consumed produce, probably resulting from factors such as special offers at supermarkets and portion sizes which are too large”. It is clear from Fig. 6 that households with greater incomes have a greater tendency to overstock.

Incorporating socioeconomic and demographic profiles into solid waste management planning

The results presented so far show that a number of socioeconomic and demographic factors act as determinants of the residential per capita SWG rate in Nablus city. Though Palestine is a developing country, similar factors can also be the determinants of waste generated in developed countries, as suggested in other references [33, 34]. In light of these trends, one can expect that an improved economic status will inevitably come at the price of increased waste generation rates. Economic advancement usually leads to smaller families, stronger purchasing power for individuals, shorter periods spent at home by parents (as a result of higher employment rates), and the tendency to over-purchase products. Coupled with the observed poor collection of waste management fees observed in Nablus city, a future economic betterment will leave Palestinian cities like Nablus facing serious challenges to develop and implement effective MSW management programs.

A roadmap that can be envisaged based on the work presented here is to utilize the proven correlations between the various socioeconomic and demographic determinants and the residential per capita SWG rate to predict the future MSW generation outlook. Modeling tools can be employed to quantify the residential waste generation rate in terms of some or all of the socioeconomic and demographic indicators discussed here. They would also allow one to examine if there are any redundant or superfluous variables. Relevant modeling work has actually already been attempted for other regions round the world [35]. Most of the dependent variable considered in this paper are related to income, and therefore modeling methods which have already been used in literature to predict waste generation from income levels can be utilized. The latter can then be used to plan a spectrum of MSW management aspects, including waste collection, recycling schemes, landfill plans, etc. These recycling schemes may be enforced by means such as an advanced disposal fees or a deposit-refund program, as has recently been shown to be the case in a study from Japan [36]. Moreover, this work may also be expanded to see whether such correlation exists between the variables discussed herein and the rate of SWG in other areas of Palestine and in other countries as well. The models which would be developed as a result could be applied on a global scale.

Conclusions

In this study, we explored how the waste generated by the residents of Nablus city in Palestine correlates with an array of socioeconomic and demographic factors. Increased

household income and the tendency to overstock on grocery and produce supplies were found to increase the residential per capita SWG rate, while longer periods spent by parents at home and larger family size both reduce it. Age of dwelling residents is also of significance. Family members at both age extremes (very young and very old) contribute to higher residential per capita SWG rates. A number of interlinked reasons are behind these trends, which were discussed in this paper. On the other hand, no correlation was found between the payment of waste collection service fees and the residential per capita SWG rate, due to the lack of implementation of such fees structure throughout Nablus. Therefore, to improve the waste management situation in Palestine it is imperative that such a policy regarding the fees be applied effectively and that execution of recycling programs become a priority.

This study deals with waste generation at the household level, while considering a large sample of the population. This is of much consequence since the trends observed at the micro level amongst the individual residences that make up a city may be masked at the macro level of a city or a country. In the latter, the trends observed may be due to a variety of variables, and it is only by studying the variables at the micro level that the influence of each variable can be assessed. As citizens are becoming an integral part of cities' solid waste management plans and are demanded to work harder to reduce their waste, such efforts can be more effectively probed and monitored through micro-level studies such as this one.

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