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Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district – Palestine

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ABSTRACT

Solid waste management (SWM) is one of the most challenging issues faced by developing countries that suffer from serious pollution problems caused by the generation of large waste quantities. This paper presents the case study of SWM in the Nablus district – Palestine. Surveys for household residents' and SWM program operators, field investigations, on-site waste measurements and characterizations were conducted. Per capita waste generation rates varied between different localities although trends were similar. Overall, the majority of waste was organic (65.1% by weight), suggesting a strong resource recovery potential in terms of animal feed or compost. Recyclable waste (plastic, paper and card) made up 16.7% by weight the waste composition suggesting an incentive to introduce source separation. Household attitudes complemented the waste characterization study, revealing the main problems faced. SWM operators quoted on the current status, highlighting problems with disposing in unsanitary landfills, ineffective solid waste fees system, increasing solid waste quantities and lacking equipment and experienced personnel. To enhance sustainable SWM, public awareness, funding, expertise, equipment and facilities and other provisions currently lacking or inappropriate must be provided.

1. Introduction

Rapidly growing populations, rapid economic growth and rise in community living standards have accelerated the generation rate of municipal solid waste (MSW) causing its management to be a major worldwide challenge (Seo et al., 2004). Particularly in urban cities of developing countries, MSW management (MSWM) is a highly neglected area (Zhen-shan et al., 2009; Batool and Ch, 2009; Chung and Carlos Lo, 2008; Imam et al., 2008; Berkun et al., 2005; Metin et al., 2003; Ahmeda and Alib, 2004). The awareness that improper handling of MSW leads to contamination of water, soil and atmosphere and is a major impact on public health has caused developing nations to address this issue with increasing urgency (Batool and Ch, 2009; Sharholy et al., 2008). In particular, the collection of MSW has been identified as a major problem since in many areas municipal authorities are either unable or unwilling to provide waste collection services to all residents in their jurisdiction. On average, up to 50% of residents lack collection services in urban areas of low and middle income countries (Parizeau et al., 2006). There are limited opportunities for the development of a sustainable SWM systems as government budgets are limited and more than often, collection is overlooked; only the proper disposal of solid waste is perceived as representing a cost (McBean et al., 2005).

Aside from being a technical issue, MSWM is also strongly influenced by political, legal, socio-cultural, environmental, economic factors and available resources. These factors have interrelationships that are usually complex in waste management systems (Abu Qdais, 2007; Kum et al., 2005). All these issues need to be addressed to reach a sustainable MSWM solution. It is usually not the environmental legislation itself that is at the heart of the problem; some developing countries have more refined legislation than developed countries. Rather, it is the lack of enforcement and/or the availability of viable alternatives (Fourie, 2006).

The current paper examines one case study of a developing country dealing with serious pollution problems due to the ineffective management of the large solid waste generated; the city of Nablus in Palestine. The aim of this paper was to estimate the quantity of waste produced that requires collection and the different waste constituents, to assess the level of services, to analyze the current practices of SWM, to evaluate the citizens'

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satisfaction with the level of service provided and to propose an environmentally sound and economically feasible integrated management system for dealing with solid waste. Information was obtained via a thorough investigation of local attitudes and waste management behaviors by means of a survey for household residents' and SWM program operators and a waste characterization study in the Nablus district.

2. Current situation in the Nablus district

There are 72 localities in the Nablus district and a total population of approx. 336,380 inhabitants in 2006 (projection based on figures from Palestinian Central Bureau of Statistics (PCBS), 1999). Joint Councils for Services, Planning and Development (JCSPD) were formed to create a stronger institutional framework in Nablus, reduce waste management costs, support sustainable development of communities, improve environmental and health conditions and raise the quality and efficiency of services in rural areas (Ministry of Local Government, 2004). One important improvement was the allocation of collection services to most localities and improvement of the existing ones. Moreover, major obstacles to proper MSWM such as, lack of reliable data and research, shortage of trained manpower, inadequate legal and regulatory cover, poor institutional and administrative arrangements, shortage of equipment, financial and technical difficulties and a serious shortage of competent private operators were improved.

Regarding solid waste treatment and reuse, the Environmental Quality Authority (EQA) of Palestine suggested that separation and composting of organic waste, incineration, separation and recycling of certain waste streams were considered alternatives that depend on the effectiveness of the proposed collection and landfill measures. The characterization of solid waste streams and the estimation of solid waste generation rates are critical data required to propose any sustainable management system and to find the most appropriate and viable alternative solutions to MSWM. It is one of the greatest challenges that organizations face today; how to diversify the treatment options, increase the reliability of infrastructure systems, and leverage the redistribution of waste streams among incineration, composting, recycling, and other facilities to their competitive advantage region-wide. Although the main constituents of domestic solid waste are similar worldwide, the generated quantity, the density and the proportion of constituents vary widely, even within a country according to the level of economic development, geographic location, weather and social conditions (Sufian and Bala, 2007).

3. Methodology

3.1. Household survey

The target population of the study area consisted of approx. 56,092 households located in Nablus district in 2006 (projection from PCBS, 1999). A survey was designed and administered to a sample of 1068 households to give a 95% confidence level with a confidence interval of 3% in the study area. A simple and structured questionnaire was prepared and pre-tested. The questionnaire aimed to collect information about residents' socio-economic characteristics, attitudes towards waste, waste management behaviors (disposal and waste separation), how much they are able to afford for collection services and their problems faced with the current management system. Due to anticipated variances of waste behaviors and incomes influenced by the type of locality, the surveys were conducted in households in villages (50.1%), refugee camps (9.3%) and Nablus city (40.6%), where the percentages are representative of the proportionate population of people in the three localities.

The surveys took place as follows; after a random start at each location, every third house within the stratum was approached for inclusion in the sample. If there was no answer at the selected household, this was substituted with the next household. A door-to-door interview, conducted from June to August 2006, targeted questions to the head of the household or the spouse. In cases where neither were present, either the oldest child or a relative (over 15 years) were interviewed. Descriptive statistics such as means and ranges was computed by the use of the Statistical Package for Social Science (SPSS version 11) computer program.

3.2. Solid waste management program operators' survey

A second questionnaire was designed that targeted solid waste program operators. The MSW referred to in this study includes residential and commercial waste collected by the Palestinian municipalities. In a few areas, municipalities also collect industrial waste. Construction and demolition (C&D) waste is generally not collected by the municipalities, this is the responsibility of the West Bank citizens'.

The questionnaire aimed to obtain information on the locality type, MSW quantities collected, collection service availability, collection equipment and vehicles, collection fees, methods of collecting the fees, final disposal methods, location/type of dumping sites and other relevant issues. Face-to-face interviews were held with personnel in charge of MSW management in the city, village or refugee camp councils. In the larger cities, this refers to the head of the Health and Environment Department and in the smaller areas, the head of the city or village council. Field observations related to MSW and its management in all the localities were also conducted alongside the interviews from July to September 2006.

3.3. Waste characterization study

Due to the heterogeneous nature of solid waste, determination of the composition is not an easy task. For this reason, more generalized field procedures based on common sense and random sampling techniques have evolved for determining composition (Tchobanoglous et al., 1993). In the literature, there is no specific method used for specifying the number of samples for solid waste characterization. According to the methodology recommended for solid waste characterization by Sharma and McBean (2007), thirty samples are adequate. Based on this, thirty samples chosen to represent the whole district were analyzed in July 2006; 14 samples were obtained from a site managing waste from Nablus city and refugee camps, 8 samples from a site managing the Western localities (Beit Imrin) and 8 samples from a site managing the Eastern localities (Beita). The number of samples obtained from each site is representative of the respective populations in each area. An explanatory sampling locations' can be seen in Fig. 1.

The World Health Organization (WHO) method for sampling solid waste and qualitatively and quantitatively analyzing the samples followed (WHO, 1988). A tank filled with solid waste, capacity 0.5 m^3, was shaken three times without applying any additional force. Random sampling was used in selecting the solid waste sample. The tank contents were then disposed of on screening equipment (1.5×3) m with a (10×10) mm mesh surface size, specifically designed and fabricated for dealing with the heterogeneity of the solid waste. The waste not passing through the mesh surface was then manually separated. The "potential use" categorization was used to sort the waste rather than the traditional material-based categorization as this method was preferable for examining the feasibility of waste separation for composting and recycling (Bernache-Perez et al., 2001; Fehr et al., 2000; Ojeda-Benitez et al., 2003). Based on this method, each sample was sorted into the following

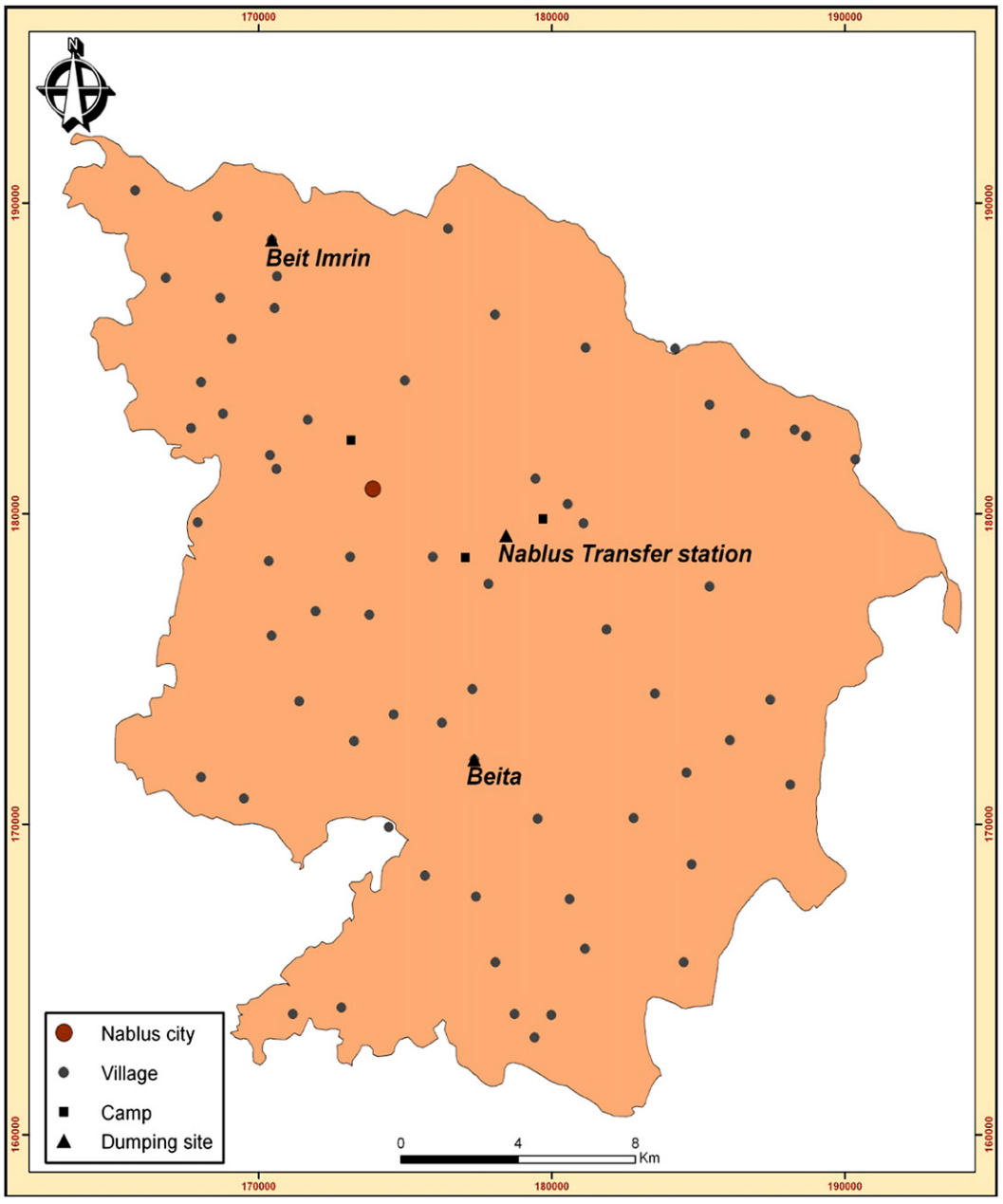

Fig. 1. Sampling locations within Nablus district.

main components: (1) Organic and food waste (compostable), (2) Plastics, (3) Paper and cardboard, (4) Glass, (5) Metals, (6) Textiles, (7) Other waste (leather, wood, ashes, etc.) and (8) Waste less than 10 mm size (passing through the mesh). Photographs showing the separation of waste into the eight categories and waste screening can be seen in the Supplementary file – Figs. 1 and 2.

Eight dustbins, each with capacity 80 L, were used for the separation of the solid waste components into the different categories. A scale was used to weigh the dustbins at the different sampling locations. The percentage and density of the solid waste components, the total sample weight and the density of the whole sample were computed (the latter was found by dividing the total sample weight by the total volume, 0.5 m^3). From the potential recyclable waste, the plastics category had the greatest diversity of materials that included: grocery bags, bottles and netting among others. Plastic waste is occasionally purchased by the local recycling depot; a buy back center where people bring their source separated plastics for resale. However, since the quantity is very low, this was not considered in the waste characterization study.

Data from the different sampling locations were compared using single factor analysis of variance (ANOVA). The F critical values were calculated using an alpha value equal to 0.05 and time steps as the replicate. These computations were performed using the data analysis tool in Microsoft Excel 2000.

4. Results and discussion

4.1. Household survey

Out of the 1068 households interviewed, most were single family residence (71.8%). The average family size was 6.5 persons; 4–6 members having the largest percentage (37.9%) and over ten

members having the lowest percentage (11.9%). Most of the respondents lived in villages (52.1%) and the city (41.2%); only 6.7% lived in refugee camps. Regarding income, most households received a monthly income of 376–750 USD (37.7%) and only 11% received over 1250 USD. Fig. 3 in the supplementary file summarizes the results obtained from the household survey concerning the socio-economic status.

Most of the households stated that for a waste management service they would be able to afford only 1.5–3 USD (34.2%) and 4.5–6 USD (39.1%) per month, whilst only 11.9% would be able to afford 10.5–12 USD. Concerning the maximum distance they would be prepared to walk from their household to the container for waste disposal, 10–20 m was stated by just over half of the respondents. There was a general positive attitude towards promoting sustainable solid waste management, with 64% of respondents stating they would be willing to volunteer in a public awareness campaign. Furthermore, the majority of respondents expressed willingness to separate their solid waste into five main components; paper, glass, metal, plastics and organic compostable waste (45.4% and 15.4% if a small monetary payment was offered). The main reasons for the remaining 39.1% not willing to participate were lack of time, afraid of diseases and dislike to handling waste. Regarding waste disposal behaviors, 29% of respondents, located mainly in villages, either use food waste (a major proportion of household solid waste) for compost or for feeding animals, whilst almost all the remaining respondents dispose of food waste in the regular garbage. The fact that just over a quarter of households in the Nablus district already collect food waste implies that recovery is practicable. This data is listed in Table 1 in the supplementary file.

A statistically significant relationship was found between the locality type and the person in charge of disposing off household solid waste (P-value = 0.000). The percentage of respondents' stating the father was responsible for disposing waste was 14.2% and for the mother was 9.8%. In each locality type, the percentage in the city, village and refugee camps was 20.3%, 8.8% and 17.2%, respectively for the father and 3.9%, 15.1% and 7.1%, respectively for the mother. Interestingly, 40.6% of respondents stated it was children who were mainly in charge of disposing household solid waste. In each locality type, the percentage in the city, village and refugee camps was 41.9%, 39.0% and 46.5%, respectively.

There are 1601 containers in the Nablus city municipality serving 144,981 persons (population in 2006) – whose capacities range from 1 m^3 (91% of containers) to 30 m^3 (0.3% of containers). In most towns and villages (total population: 323,074) a small container, approx. 0.05 m^3, is placed in front of the house. Only eleven villages are an exception to this that have some containers ranging from 0.09 to 1 m^3. In the refugee camps (total population: 24,909), the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) are responsible for collecting household waste, stored in 10 m^3 containers that belong to Nablus city municipality. When questioned about problems faced regarding the nearest container for solid waste, the most common were odor (49%), presence of insects and rodents (47%) and the dirtiness of the container (46%). Other problems highlighted were lack of a container on the household street or the long distance to a container (51%), infrequent emptying of container (28%) and sound disturbance when emptying the container (21%).

4.2. Service provider

Table 1 summarizes the distribution of localities according to the solid waste service provider. There is no collection system in 19 out of the 72 localities in Nablus district; this represents 26% of the localities and 2.6% of the total population of Nablus district. According to the residents of these localities and from field observations, the absence of solid waste collection has been the cause of serious health and environmental problems, such as the spread of open dumps that support large populations of rats, flies and cockroaches that frequently invade nearby dwellings in addition to odor problems.

The solid waste department of the Nablus city municipality is responsible for the solid waste collection in the city – the population of which is 42% of the total served population (of the Nablus district). The most common equipment used for waste collection in Nablus city is carts wheel, of which 90 are in working order. Additionally, there are 8 compacting trucks, 7 transporting trucks, a tractor and a compressor of solid waste. However, most of the vehicles and equipment are in need of replacement.

Within the borders of the refugee camps (which represent 11% of the total served population), the UNRWA is responsible for transporting the solid waste to the nearest container outside the camps; it is then the responsibility of the city municipality to transfer it to the dumping site. The UNRWA use hand carts driven by labors in collecting waste from houses. There are 40 carts and labors in total and 3 foremen (one for each of the 3 refugee camps).

For the surrounding villages, the service provider differs from one locality to another. They are either included within the city collection system or have their own collection system where the service provider is the village or town council, the joint service council committee or a private contractor. The contractor usually has his own tractor and is assisted by one of his relatives to reduce the service cost. In some cases, a towns acts as the private contractor for nearby villages. The village and town communities usually adopt a door-to-door collection combined with truck transport. 25 localities (representing 27% of the served population) use compacting trucks, 22 localities (representing 20% of the served population) use tractors, one village is served by an ordinary truck and the remaining five localities (representing 53% of the population served) are served by the Nablus city municipality. Use of the compacting trucks and tractors for collection and transportation are very practical, especially for localities with low resources, and allows villages to manage well. However, problems arise when the compacting truck requires maintenance as there are no spare tractors available.

Concerning staff, a serious issue is how the overall management is handled as there are no persons with the proper academic training and professional experience required for SWM in the Nablus district. Furthermore, additional staff is needed to cover the services. However, due to economic difficulties, especially in the villages, this can not be supported. Currently, in the Nablus city municipality there are 240 members of staff (1 manager, 1 health inspector, 15 drivers, 27 foremen and 196 cleaners). There is a general need to strengthen donor funds for solid waste as this is the main source of funding for purchasing collection vehicles or containers. Additionally, more focus should be placed on treatment, operation and maintenance costs and separate collection and disposal schemes for hazardous waste (not currently available) should be established.

Table 1
Distribution of localities according to the solid waste service provider.

Service Provider	Number of localities	Population	Population percentage that have solid waste collection service (%)
Local council	8	44,797	14
Contractor	27	69,250	21
Joint Service Council	13	39,137	12
Nablus City	2	134,503	42
UNRWA	3	35,387	11
Total	53	323,074	100

4.3. Solid waste fees system

SWM services are one of the most expensive due to political conditions and lack of proper funds and infrastructure. The costs of SWM are considerably higher in the city rather than the villages, since the higher city population entails more employees, equipment and operation costs. Moreover, in villages, sharing of trucks, tractors and compactor is a common occurrence that reduces costs. The annual cost of solid waste collection and disposal for the Nablus city municipality for the year 2005 is shown in Table 2. The per capita annual expenditure for SWM was 19.7 USD during the same year. Employees' salaries consume most of the budget, reaching approx. 60% of expenditures. Based on the estimate that the total solid waste quantity was 51,160 tons in 2005, the cost of collection and disposal of each ton is approx. 53 USD. The fee collection for the Nablus city municipality was 466,273 USD in 2005; this represents only 17% of the total expenditure costs. Despite the assigned fees for waste collection and transportation, most people are unable to pay resulting in the revenue collected contributing to less than 20% of the money needed to run the services (UNEP, 2003). 100% fee collection is rarely achieved in the Nablus district. The collection rate of MSW fees from Nablus city residents has been at a record low during the past five years, ranging from 30 to 60% (i.e. 40–70% of the residents did not pay their annual MSW fees), the main reason being the deteriorating economic situation. Consequently, this has reflected negatively on the level of services offered (Al-Khatib et al., 2007).

Table 3 summarizes the monthly fee paid in the different localities. In Nablus city, the annual fee for solid waste is approx. 17 USD for residential houses. The refugee camps have no fee since the UNRWA is responsible for collecting the solid waste. In villages the fees differ between the localities, ranging from approx. 15–45 USD per year. The method for collecting the fees also differs; the fee may be included in the electricity bill (in 35 localities representing 35% of the Nablus district population), the water bill (in 2 localities representing 2% of the population), in both the electricity and water bill (in 2 localities representing 2% of the population), or collected separately (in 11 localities, including the city, representing 50% of the population). Including the solid waste fee in the electricity bill may have an advantage in achieving a better collection percentage and decreasing accountant effort and cost. Another variant is the frequency of collecting the fees; Nablus city and two villages collect the fee annually whilst all the other localities collect it on monthly basis.

Table 2
Annual cost of solid waste collection and disposal for Nablus city*.

Item	Sub Item	Annual Cost (USD)
Direct Operating Costs	Transfer and disposal of solid waste	776,026
	Fees for use of scales to weigh solid waste	4435
	Health employees' salaries	1,624,176
	Cleaning materials and supplies	2280
Direct Administration Costs	Administrative costs (health sector)	67,713
Indirect Costs	Indirect operating costs (expenditure on insurance, licensing, maintenance and fuel for Nablus city municipality vehicles)	27,410
	Indirect administrative costs (administrative and salaries expenditure of the accounting, head, mechanical and transport sections)	232,373
	Total	**2,734,413**

*(Source: Nablus City Municipality, 2006).

Table 3
Monthly solid waste service fee for the different served Nablus district localities.

Monthly fee (USD)	Number of localities	Population of localities	Population percentage that have solid waste collection service (%)
0	3	35,387	11
1.25	6	24,750	8
1.50	5	24,271	8
1.75	4	9047	3
2.00	10	22,814	7
2.25	2	9048	3
2.50	17	42,502	13
2.75	1	7931	2
3.00	1	1658	1
3.25	1	3915	1
3.75	1	7248	2
16.96 - annual fee	2	134,503	42
Total	53	323,074	100

Household and commercial waste service fees vary between developing countries and cities, as shown in Table 4. Certain cities collect fees based on the amount of waste generated whilst others only charge a flat rate per month or year. By contrast, some cities do not collect any fees at all; they completely subsidize solid waste services through general funds. Even when waste fees or taxes are imposed by the local government, waste managers often complain that fees are inadequate to cover the costs of waste services, the fee collection system is inefficient or unsupervised and subject to illegal practices.

4.4. Disposal system

Waste disposal is another waste management functional element that has major shortcomings in the localities. The waste produced from the city, refugee camps and some villages is disposed of in an open dump used as a transfer station, approx. 6 km from the city center. This site is an open area of about 3000 m^2 where the waste is stored from two to seven days before being transferred to the final disposal site. The waste is not separated

Table 4
Solid waste management fees for various developing cities and countries.[a]

City, Country	Household and commercial fees
Ulaanbaatar, Mongolia	0.15–0.25 USD/apartment/month. 0.50–0.85 USD/peri-urban household/month Two main hotels each pay 8.10 USD and 18.77 USD/month/occupant (average 30 occupants)
Hanoi, Vietnam	0.55 USD/person/year
Dhaka, Bangladesh	Less than 0.63 USD/person/year, residents pay a Conservancy Tax for solid waste management
Vientiane, Lao	12–216 USD/household/year 360–960 USD/non-governmental commercial organization/year
Chennai (Madras), India	Residents and businesses do not pay any direct waste fees, pay only property tax. Some households pay NGOs about 15–20 Rs/month for primary collection services.
Delhi, India	Proposed system where homeowner has to pay a fixed amount of 15–20 Rs/month for collection services.
Beijing, China	3–7.20 USD/household/year
Shanghai, China	Residents do not pay any direct waste fees.
Hong Kong	Private and commercial establishments do not pay any direct waste fees.
Jakarta, Indonesia	1.80–9.60 USD/household/year
Denpasar, Indonesia	6 USD/household/year
Yangon, Myanmar	Waste disposal tax is paid.
Thailand	Public Health Act (1992) empowers local authorities to set up solid waste collection fees for households, commercial enterprises, markets and industry according to fees announced in the Act.

[a] Reference: Urban Development Sector Unit, East Asia and Pacific Region (1999).

prior to dumping, resulting in a variety of waste from residential, commercial, industrial (small-scale manufacturing, trades and crafts), institutional, and agricultural (animal farm wastes, plant nurseries, olive mills) sources. Furthermore, due to lack of restrictions, dead animals and biohazardous materials from hospitals are also disposed at this site, resulting in a considerable proportion of hazardous and unregulated waste. There are no systems to prevent air and groundwater pollution and waste is sometimes burnt in open air. The waste eventually ends up in an open unsanitary site. The cost of the solid waste disposal costs the city municipality a considerable amount of its income; approx. 15.50 USD per ton. In times of political unrest, due to road closures, the solid waste has to be transferred to another nearby area.

The remaining villages either have a space where they dispose their solid waste (this space is sometimes rented) or they dispose of it randomly (the truck driver illegally dumps the waste in a random location). Table 5 lists the dumping sites ownership types for the localities within Nablus district. There are a total of 34 dumping sites in the Nablus district (including the city transfer station), often shared between localities. None of the dumping sites are sanitary; they are not covered and open pit burning and open pit dumping near and away from generation points occur often. Odors, rodents, flies and vectors are common and scavenging is practiced unsafely in some dumping sites, sometimes by children. The EQA, in recognition to the numerous SWM problems, have prioritized to prevent the operation of random dumpsites that are a greater threat to groundwater and public health and to find suitable landfill sites and develop regional sanitary landfills (Abu Thaher, 2005). The licensing of landfills is made difficult due to environmental and political barriers that limit the choices for disposal alternatives, since the land environmentally suitable and available for landfill construction is under Israeli control that requires a permit (Musleh, 2002; Arafat et al., 2006).

4.5. Solid waste generation

Table 6 shows the annual generation of solid wastes in Nablus city (including three villages and three refugee camps) for the years 2002–2005. The average daily generation rate of solid waste ranges between 0.68 and 1.02 kg person^{-1} day^{-1}, with a mean value of 0.82 kg person^{-1} day^{-1}. In rural areas, towns and villages, the generation rate ranges from 0.4 to 0.6 kg person^{-1} day^{-1} (United Nations Environment Program, 2003) and for refugee camps, an overall average of 0.52 kg person^{-1} day^{-1} (Al-Khatib et al., 2007). These results are in agreement with global trends for developing countries, which also indicate an increase in MSW generation rate with improving economical conditions (Vesilind et al., 2002). Higher living standards and economic activities in Nablus city compared to the villages and refugee areas explain the higher MSW generation rates, the smallest being in the refugee camps. Common practice in villages that reduce the MSW disposed of in landfill is feeding a fraction of the waste to farm animals. This trend is MSW is also seen in other developing countries (Parizeau et al., 2006). In Nablus city, the waste generation per capita quantities are higher than those found in a number of other urban waste generation studies, for example such as 0.33 kg in Gabarone, Botswana (Bolaane and Ali, 2004); 0.51 kg in Guadalajara, Mexico (Bernache-Perez et al., 2001); 0.63 kg in Morelia, Mexico (Maldonado, 2006); and lower than 1.76 kg in Abu Dhabi City, UAE (Abu Qdais et al., 1997). All the above studies used door-to-door collection methods for assessing residential waste generation per capita. However, it was not specified whether commercial wastes from home businesses were also present in the residential waste stream.

Table 5
Nablus district localities' dumping sites according to the type of ownership.

Ownership type	No of dumping sites	Number of localities	Population of localities	Population percentage
Random sites	7	7	18,304	6%
Rented	6	9	21,680	7%
Governmental land	5	6	15,787	5%
Council owned	14	23	87,568	27%
Private (owned by a citizen without any rental value)	1	1	4030	1%
Nablus city	1	7	175,705	54%
Total	34	53	323,074	100%

Table 6
Annual solid waste generated in Nablus city.

Year	Quantity[a] (tons/year)	Population[b]	Mean generation rate (kg/cap/day)
2002	42,153	154,649	0.75
2003	59,284	159,753	1.02
2004	40,716	164,864	0.68
2005	51,160	169,975	0.82

[a] (Source: Nablus City Municipality, 2006).
[b] (Source: PCBS, 1999).

4.6. Solid waste composition

The composition of solid waste is an important issue in waste management. It affects the density of the waste, the proposed methodology of disposal and is necessary for examining reuse, reduction and recycle of waste. The composition of each MSW component determined by the sampling program on a weight and volume basis is shown in Table 7 and Table 2 (Table 2 is found in the Supplementary file), respectively. The figures shown in the tables are averages of all the samples taken and are not weighted in any way. Using the ANOVA technique, differences in waste composition between the sampling locations were not found to be statistically significant, on both a weight and volume basis, confirming the similarity in the waste variation across different areas. The principal components on a weight basis are compostable organics (garden and food waste; 65.1%), paper and card (9.1%) and plastic (7.6%). On a volume basis, the principal components are compostable organics (36.2%), plastic (22.6%) and paper and card (19.2%). These results form the first ever practical survey of the composition of the entire MSW stream carried out in the Nablus district. In summary, MSW in Nablus district has an average recyclable and compostable content of 87.5%, where recyclable waste could include: plastic, paper and card, metal and glass. This provides a significant potential for waste recovery. Food waste as animal feed in already practiced to some extent, mainly in villages and towns in the Nablus district. Other advantageous alternatives include compost or energy recovery via anaerobic digestion that would reduce landfill waste and possibly collection and transportation costs. Source separation of waste to achieve this, through use of different waste containers, is promising given that 60.9% of residents were willing to separate their waste (see Table 1 in the supplementary file).

Other techniques in the literature involved using the standard computer package GenStat for applying the ANOVA technique to find statistically significant associations between the waste produced per household in Wales and variables such as location, season, etc (Burnley et al., 2007). This study found a maximum recyclable and compostable content of 65% and contained 62% biodegradable material. In Mexico, Gómez et al. (2009) found organic waste constituted approx. 45% of all generated MSW and used the ANOVA technique to show that there was no significant difference between the three socio-economic levels.

Bulk densities of solid wastes from the different localities in Nablus district were determined as described in the methodology. Table 7

Table 7
Composition of MSW components (weight basis).

Waste	Sampling location									Overall composition in the district		
	Beit Imrin (western locality)			Beita (eastern locality)			Nablus city					
	av (kg)	s.d.	%	av (kg)	s.d.	%	av (kg)	s.d.	%	av (kg)	s.d.	%
Plastic	6.7	2.4	5.2	9.9	3.4	8.6	11.0	4.9	9.4	9.2	2.2	7.6
Metal	2.5	1.7	2.0	3.7	2.5	3.2	4.1	2.0	3.5	3.4	0.8	2.8
Glass	3.8	2.3	2.9	3.4	1.4	3.0	3.4	2.3	2.9	3.6	0.2	2.9
Paper & Card	6.4	1.9	4.9	12.4	2.6	10.8	14.3	6.9	12.2	11.0	4.2	9.1
Organic	95.3	7.9	73.4	72.1	11.7	62.6	68.3	18.6	58.3	78.6	14.6	65.1
Textile	3.9	2.6	3.0	3.1	2.0	2.7	4.2	2.7	3.6	3.7	0.6	3.1
Other	5.8	3.5	4.5	6.6	3.2	5.7	7.2	3.7	6.1	6.5	0.7	5.4
<10 mm	5.4	3.4	4.1	4.1	3.2	3.5	4.6	2.9	3.9	4.7	0.7	3.9
Overall density (kg/m^3)	295			230			234			240		

shows the bulk density determination results. The high densities of the waste are attributable to high moisture-containing waste such as food leftovers and fruit peelings. The average bulk density of waste is 240 kg m^{-3} with a range of 184–295 kg m^{-3} for the Nablus district. The figure compares well with bulk density data given in literature; for example, 250 kg m^{-3} in Nigeria, Thailand and Indonesia, 300–500 kg m^{-3} for some developing countries (Arab Republic of Egypt, 1992) and 390 kg m^{-3} in Tanzania (Mbuligwe, 2002).

5. Conclusions

Studies carried out in the Nablus district highlighted the current situation of the SWM systems from the point of view of citizens and SWM program operators. Furthermore, the first MSW characterization study was conducted that analyzed the quantity of the different MSW components produced.

Most of the localities (corresponding to 97.4% of the total population of the Nablus district) have a solid waste collection system. Variations in the SWM system are reflected in the collection equipment used, collection frequency, solid waste fees and method of collecting solid waste fees. Examination of additional aspects of solid waste management at the case study revealed other weaknesses. These include funding constraints, weak enforcement of laws governing MSW collection, disposal and revenue collection and low priority given to SWM. Technical issues include a lack of comprehensive waste management plans for the institutions; lack of expertise, and lack of appropriate equipment and facilities. Moreover, a recommendation that the solid waste collection system for each municipality should include C&D waste should be put forward.

The average MSW in the Nablus district has an average recyclable and compostable content of 85% and contains 65% biodegradable organic material. However, reduction of SWM disposed of is landfill is highly dependent on source separation of waste, currently not practiced. To enhance the sustainability of SWM, public awareness, funding, expertise, equipment and facilities as well as other provisions that are currently lacking or inappropriate must be provided. Furthermore, since the envisaged SWM practices call for some behavioral changes, there is a need for community participation on related issues.

Appendix. Supplementary information

Supplementary information associated with this article can be found in online version at doi:10.1016/j.jenvman.2010.01.003.

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