Environ Monit Assess (2021) 193: 732
https://doi.org/10.1007/s10661-021-09522-z

Prospects of sustainable waste management in developing countries: A case study from Jordan

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Received: 23 December 2020 / Accepted: 5 October 2021 / Published online: 18 October 2021
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Abstract This study examined the key challenges obstructing the sustainable development in the waste management sector in Jordan. A questionnaire was designed and conveyed to stakeholders to collect their perspectives on the key challenges and the waste management data parameters. It was concluded that the most critical challenges are the lack of strict laws and legislation, inefficient management, insufficient financial capacity, the lack of strict laws and regulations, and the lack of public awareness and contribution. Nonetheless, waste management challenges in Jordan could be clustered under three dimensions: limited private sector involvement, weak institutional capacities, and poor community engagement. The inadequacy of waste management data in Jordan was tackled through the design of a simple and innovative databank system, and in accordance with recommendations inferred from the questionnaire. The databank system was developed in a way to guarantee the smooth and sustainable data monitoring and storage, and to allow users to generate daily, monthly, or annual progress reports in a simple manner.

Keywords Waste management · Sustainable development · Waste management databank · Waste management challenges · Factor analysis

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Introduction

The sustainable development goals (SDGs), which were recently adopted by all United Nations (UN) members, present a blueprint to rectify the shortcomings of the classic economic growth and ensure the well-being of the environment, society, and ecosystems (Abu Hajar et al., 2020; Henderson, 2007; Luukkanen et al., 2019). Many countries have integrated the SDGs into their economic growth strategies and action plans in pursuance of transitioning different economic sectors into greener pathways. For instance, the renewable energy sector is a fast-growing industry in many countries with established targets for renewable share in the energy mix (Abu Hajar et al., 2020; Gasparatos et al., 2017). Likewise, other sectors such as transportation, agriculture, water supply, waste management, and tourism have seen greening actions to varying extents.

The waste management sector is commonly embodied in sustainable development action plans considering

its high greenhouse gas (GHG) emission potential. In spite of the plausible advances in waste management, the predominant practices do not bring the true harmony between the economic, environmental, and social dimensions of sustainability (Bong et al., 2017; Dedinec et al., 2015). Waste management is more intricate in developing countries owing to the rapid population growth, improving living standards, and the change in consumption patterns (Rodić & Wilson, 2017; Zohoori & Ghani, 2017). Moreover, waste composition has a strong influence on waste management and recycling programs in developing countries. Thorough characterization and composition analysis of solid waste is critical for evaluating the recycling potential and the overall waste management systems (Ezeah et al., 2013). There are substantial differences in waste composition between developing and developed countries. As a result, management practices and techniques adopted from developed countries may not be as effective in developing countries (Marshall & Farahbakhsh, 2013). For instance, organics are the predominant fraction in the domestic solid waste in developing countries, which may negatively affect the feasibility of recycling and recovery of other waste categories (Saidan et al., 2017). Solid waste in developing countries is usually collected and disposed of in arbitrary open and unsanitary sites with considerably lower recycling rates compared to developed nations. Recycling is generally carried out by the informal sector, which is in fact the backbone of waste management in many developing countries. For example, the informal recycling group "Zabaleen" in Egypt has grown to be one of the world's largest and most efficient waste scavenging groups whose contribution to the Egyptian waste management sector cannot go unnoticed (Fahmi & Sutton, 2010). However, the informal recycling groups are always vulnerable to the privatization of waste management services or the prohibition of informal scavenging (Gharaibeh et al., 2011; Khatib, 2011; Troschinetz & Mihelcic, 2009). The informal sector is often creative and flexible enough to respond instinctively to market needs and demand; however, seasonal variations can have a pronounced impact on the quantity and quality of salvaged materials (Ezeah et al., 2013). The informal recycling sector in Jordan has witnessed several shifts and changes over recent years due to economic and political factors. For example, glass recycling discontinued after the Jordanian-Syrian border closure. Plastic recycling has been adversely affected by the fluctuations in oil prices over the past decade (Abu Hajar et al., 2020; Mahasneh, 2020). Plastic recycling is often troublesome for informal recyclers due to its light weight and bulkiness (McLean, 2000).

The sustainable development of the waste management sector is frequently hampered by the mediocre technical capacity of the governmental entities in charge of waste management, weak financing and fee structure, unsystematic waste collection and disposal activities, limited private sector involvement, insufficient infrastructure, obsolete vehicles and equipment, lack of public awareness and contribution, and the absence of reliable data and information (Abu Hajar et al., 2020; Mian et al., 2017; Rodić & Wilson, 2017; Zohoori & Ghani, 2017). The transition from the existing models to new service models may encounter resistance by officials and workers in the public sector, especially if small-scale enterprises are involved in the day-to-day operations. An even more crucial issue for the true sustainability of waste management is the effective legislative framework and decisive enforcement mechanisms. Open waste disposal and burning among other issues are banned by law in the vast majority of the countries; yet these are still practiced in many developing countries owing to the fragile law enforcement mechanisms (Rodić & Wilson, 2017; Zohoori & Ghani, 2017).

Jordan is a developing country in the Middle East surrounded by countries with vulnerable political stability. The rise of the Arab Spring sent waves of refugees to Jordan, and the latest wave of refugees from Syria has placed enormous socioeconomic pressure on the country. Jordan suffers from severe water scarcity, and its indigenous energy sources are only limited to oil shale. The country's economic growth is substantially dependent on imported fossil fuels which goes against the principles of a sustainable and resilient growth, because of the potential energy insecurities induced by geopolitical factors. From an environmental standpoint, Jordan's net GHG emissions in 2006 were 29,000 Gg CO_2-eq, and this figure is projected to double by 2030 under the prevalent scenario (Abu-Hamateh & Al-Shawabkeh, 2008; Abu Hajar et al., 2019; MoEnv, 2014, 2017). Accordingly, the Government of Jordan (GoJ) has recently launched a green growth agenda aiming to gradually shift the Jordanian economy to an inclusive and environmentally sustainable one which maintains a conceivable balance between the economic, environmental, and

social aspects of development. The priority sectors with high green growth potential in Jordan are energy, water, agriculture, transport, waste, and tourism (GoJ, 2015; MoEnv, 2017).

In Jordan, the waste management sector has evolved remarkably, but there is still room for further improvement. The municipalities and joint service councils (JSCs) are responsible for waste collection and disposal in Jordan with minimal private sector involvement. Roughly half of the country's waste is disposed in a sanitary landfill near the capital Amman, while the other half is disposed in open disposal sites which lack the proper sanitary measures. Recycling, which is mostly undertaken by informal recyclers and scavengers, accounts for less than 10% of the overall waste quantities (MoEnv, 2014; SweepNet, 2014). The waste management scheme in Jordan does not satisfy all sustainability dimensions. According to MoEnv (2014), the 2006 GHG emissions of the waste sector in Jordan were estimated at 3.05 million tons CO_2-eq (nearly 10.6% of the country's net emissions). The other key contributors to Jordan's GHG emissions are the energy sector with nearly 20.9 million tons CO_2-eq, the industrial sector with 2.55 million tons CO_2-eq, agriculture with 1.32 million tons CO_2-eq, and land use and forestry with 0.866 million ton CO_2-eq (MoEnv., 2014). Abu Hajar et al. (2020) demonstrated that GHG emissions associated with waste management are likely to increase proportionally to the quantities managed. Further environmental concerns involve the incidental or manmade fires at the dumpsites; the potential air, soil, and groundwater contamination; health and occupational risks; and the unsanitary conditions in the vicinity of disposal sites. From a social perspective, the rate of employment in the waste management sector is relatively low, because the practices employed are not labor-intensive. In terms of economics, waste management services are subsidized by the municipalities' budgets taking into account the low-cost recovery rates (30–60%) (Abu Hajar et al., 2020; SweepNet, 2014).

Identifying the dimensions of challenges obstructing sustainable development is always of key importance to policy and decision-makers. This is particularly accurate for the holistic and sustainable waste management because financial interventions in this sector repeatedly target infrastructure rehabilitation and the construction of new facilities while concepts such as public awareness and contribution, human and institutional capacities, and the legislative framework are often overlooked (Abu Hajar et al., 2020). The lack of up-to-date and reliable data on the waste quantities and flows is one of the most critical barriers to sustainable waste management and planning (Scarlat et al., 2015). Zohoori and Ghani (2017) reported that waste management data in developing countries is often marginal, incomplete, and scattered at different organizations. Currently, waste management data and information in Jordan is available at the Ministry of Environment, Local Municipalities, Department of Statistics, and relevant non-governmental organizations (NGOs).

In this study, the primary objectives were to explore the challenges and obstacles to sustainable development within the waste management sector in Jordan, and to develop a reliable multi-institutional waste management databank system in Jordan to assist policy- and decision-makers in shaping a sustainable pathway for this sector. The waste management challenges and factors were investigated through stakeholder consultation. The target stakeholders are waste management experts and professionals affiliated with the local and national government (e.g., municipalities, ministries of environment and agriculture), NGOs, the private sector, and academic and research institutions. A questionnaire was designed and conveyed to the stakeholders, and the responses were analyzed to draw conclusions and recommendations on different waste management aspects in the Jordanian context. Amidst the sustainable waste management hurdles in developing countries is the marginal, incomplete, and scattered data. The insufficient and disorganized data issue was approached in this study by proposing a design for waste management databank system which ensures the sustainability of data monitoring and the availability of data to officials, researchers, NGOs, and entrepreneurs. The proposed databank system will function as a platform to collect and store the data in one place and disseminate it in an interpretable format to interested stakeholders. This system will comprise the essential components in a user-friendly interface to enable interested stakeholders to store and analyze data, delineate cost and revenue structure, conduct the necessary statistical analysis, compare different scenarios using multi-criteria analysis, and produce useful and informative

reports. To the authors' best knowledge, this is the first study to holistically appraise the key challenges and factors hindering the sustainable development of the waste management sector in Jordan, and to provide an innovative approach for a feasible and sustainable data management in developing countries. This paper is organized as follows: data and methods are presented in "Data and methods", the analysis of the waste management challenges in Jordan is presented in "Challenges and barriers to the sustainability of waste management in Jordan", the characterization of the databank parameters and monitoring frequency is portrayed in "Waste management databank parameters", the design of the databank system is illustrated in "Design of a solid waste management databank system", and the key conclusions are outlined in "Conclusions".

Data and methods

One of the main objectives of this study was to determine the factors influencing the waste management sector in Jordan and the challenges which obstruct the sustainable development within this sector. These challenges are often chronic and interconnected. A questionnaire was created and conveyed to waste management experts and professionals accustomed to the waste management sector in Jordan. The questionnaire was created to cover two dimensions: solid waste management challenges and waste management databank parameters. The variables (questions) were selected based on their theoretical and practical relevance to the waste management sector in Jordan. The first part of the questionnaire tackled the challenges facing waste management in Jordan. A review of several relevant literature studies was conducted aiming to identify waste management challenges in developing countries. It was found that waste management in developing countries is often hampered by the lack of modern solutions and technology, insufficient stakeholder engagement and community involvement, inadequate financing, lack of private sector involvement, insufficient capacity building, weak legislative framework and enforcement mechanism, and the overlapping responsibilities and lack of coordination between different governmental organization (Elagroudy et al., 2016; Ezeah & Roberts, 2012; Fahmi & Sutton, 2010; Gidarakos et al., 2006; Guerrero et al., 2013; Manowong, 2012; Marshall & Farahbakhsh, 2013; Nzeadibe & Anyadike, 2012; Sukholthaman & Shirhada, 2015). These challenges might be entirely or partly relevant to the Jordanian waste management sector; therefore, semi-structured interviews were conducted with waste management officials from local municipalities in Jordan. Eleven challenges/concerns identified based on the interviews and the literature review were listed as questions in the first part of the questionnaire, and the significance or relevance of each challenge to the Jordanian waste management sector was assessed using a 5-point Likert scale, where the respondents were asked to rate each potential challenge on a scale of 1 (least significant) to 5 (most significant). The responses were analyzed using IBM's Statistical Package for Social Sciences (SPSS). The principal component analysis (PCA) was conducted to reduce the 11 questions to a smaller set of underlying factors (latent variables). Oblique rotation was initially used, but the underlying factors were found to be uncorrelated (Bartlett's χ^2 was not significant at 95% confidence level) which contradicts the assumption of correlated factors for the oblique rotation. Thus, the orthogonal rotation was used instead, and several measures for the adequacy of the sample size and the reliability of the data for factor analysis were investigated (Field, 2009; Guerrero et al., 2013). The responses were also categorized based on the score as low (1–2.33), moderate (2.34–3.66), and high (3.67–5).

The second part of the questionnaire was devoted to the waste management databank system. The questions covered different waste management parameters which were selected based on the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) waste data collection forms which were provided to several municipalities in Jordan. These forms contained an exhaustive list of techno-economic parameters including but not limited to waste quantitative and qualitative data, collection services and logistics, disposal practices, and economic data. Nevertheless, the frequent monitoring of all parameters is unrealistic and costly within the Jordanian context. Hence, it was imperative to identify the desired data collection frequency for each parameter from the experts' perspective.

The questionnaire was pre-tested by four experts to validate its content and the clarity of the questions. Afterward, the questionnaire was converted to

an online electronic questionnaire and was sent to 40 waste management experts who were either Jordan-based or have prior experience in the waste management sector in Jordan. Out of the 40 experts reached, 27 responses were received and analyzed, 64% of which were from Jordan, 32% from Germany (due to the partnerships between the GIZ and the Jordanian municipalities), and 4% from other countries. Nearly 56% of the respondents were from academia, 4% from the public sector, 19% from the private sector, and 21% from NGOs. Most of the respondents have 10–20 years of experience in the waste management field.

The databank parameters section of the questionnaire included 13 questions focused on the key parameters and components of a databank system. The respondents answered each question (data parameter) by selecting the suitable monitoring frequency (daily, weekly, monthly, seasonally, and annually). This is a fundamental step in the databank system design, because data collection and management can become rather expensive with many parameters being monitored all too often. The responses were analyzed to group the parameters based on the recommended monitoring frequency.

The databank system was then designed to provide a reliable and integrated system to acquire, process, store, and report waste management data. The databank system was built based on the findings and recommendations inferred from the questionnaire analysis and using Microsoft Excel. Macros were coded into the worksheets using the Microsoft Visual Basic module for data storage, processing, and reports generation. The system was designed such that parameters with the same monitoring frequency are enlisted in one worksheet. The user has the option to print out an automated report based on a specific day, month, or year. The worksheets were also programmed such that the data stored in the worksheet of a time unit (e.g., daily) will be carried over to the worksheets of larger time units (e.g., monthly or annual) and will be displayed as monthly or annual totals.

Results and discussion

Challenges and barriers to the sustainability of waste management in Jordan

In order to highlight the dimensions of challenges facing the sustainable development within the Jordanian waste management sector, 11 questions were listed in the questionnaire to assess the significance and seriousness of each challenge from the stakeholders' perspectives. The descriptive statistics for the 11 questions (mean and standard deviation) are displayed in Table 1. It can be deduced that the most significant barriers to the sustainability of the waste management sector in Jordan are the lack of strict laws and legislation, the inefficient management, and the insufficient financial capacity. These 3 challenges received an average score of 4 or higher. Several literature studies indicated that waste management in developing countries is highly inefficient which explains the excessively high budget allocated for waste management despite the simple and non-labor-intensive practices. In Jordan, the quantity of waste collected and

Table 1 Descriptive statistical analysis of the challenges facing the waste management sector in Jordan ($n = 27$)

Challenge	Mean	Std. Dev	Category
Insufficient financial capacity	4.15	1.03	High
Weak legislation and enforcement mechanisms	4.11	0.89	High
Management inefficiency	4.07	0.68	High
Lack of public awareness and contribution	3.85	1.1	High
Absence of recycling industries	3.67	1.27	High
Insufficient technical capacity	3.63	0.88	Moderate
Illegal or uncontrolled waste disposal	3.59	1.15	Moderate
Lack of PPP	3.56	1.12	Moderate
Lack of incentives	3.48	0.94	Moderate
Deficiency in waste collection equipment	2.85	1.06	Moderate
Deficiency in waste collection staff	2.56	1.12	Moderate

disposed of in 2017 was 3.6 million tons and the corresponding expenses nearly reached US$540 million (Alrai Newspaper, 2017). The equivalent per ton cost is US$150, which is considerably high with respect to developing countries, where the average cost per ton of waste rarely goes beyond US$ 100 (Abu Hajar et al., 2020; Elagroudy et al., 2016). The waste management fees in Jordan are typically charged to the residents' electricity bills, but the cost recovery ranges from 30 to 60% with the difference being subsidized by the municipalities' budgets (SweepNet, 2014). Hence, it is obvious that the two challenges (inefficient management and insufficient financial capacity) are tied up. The other key challenge is the lack of strict laws and regulations which can be blamed on the numerous environmental laws and regulations in Jordan resulting in conflicting and overlapping responsibilities among the different stakeholders. The need for a distinct waste management legislation was recently recognized by the Ministry of Environment (MoEnv) officials, and a draft waste management law was in fact endorsed by the Jordanian Parliament in January, 2020. The proposed law will presumably place the waste management sector on a sustainable pathway and will promote the engagement of the private sector by stimulating sustainable practices such as recycling, reuse, and recovery (Jordan Times, 2021).

The lack of public awareness and contribution was amidst the key challenges with a mean score of 3.85. Public awareness is a critical component of recycling programs based on household separation, and this is why such programs launch awareness campaigns to educate the citizens on the different aspects of waste segregation at source (Guerrero et al., 2013; Troschinetz & Mihelcic, 2009). Several studies reported that there is often a lack of awareness on waste segregation and recycling principles among the civil society and even key stakeholders in developing countries (Ezeah & Roberts, 2012; Le et al., 2018). Awareness campaigns and training programs address this challenge to a certain extent, because even if the citizens are well-informed on the proper waste segregation protocols, the success of recycling from the source programs depends equally on the residents' cooperation and sense of commitment. Therefore, some researchers believe that such programs will only thrive if people were compelled to sort their household waste by virtue of law, and fines can be levied for failure to comply with the correct procedures (Ezeah & Roberts, 2012; Le et al., 2018).

It can also be concluded from Table 1 that other challenges such as the lack of incentives, absence of recycling industries, insufficient technical capacity, lack of PPP, and the illegal or uncontrolled waste disposal practices are of moderate to high significance from the experts' viewpoint. These are in part connected to the previous challenges (public awareness, legislation, management inefficiency, and financial capacity), which perhaps explains the slightly lower significance rating as shown in Table 1. For instance, the lack of incentives, the absence of recycling industries, the lack of PPP, and the illegal or uncontrolled waste disposal practices can all be attributed to the weak legislation and enforcement mechanisms in Jordan. As stated earlier, the proposed waste management law in Jordan is anticipated to alleviate these challenges by promoting the private sector involvement in waste management projects, reducing the number of disposal sites in Jordan while gradually abandoning the old-fashioned open disposal, and stimulating sustainable waste management practices at different scales. The private sector has been previously involved in waste recycling and recovery projects in Jordan; however, many of those projects did not progress as intended due to contractual and legal disputes, technical difficulties, and financial struggles (Abu Hajar et al., 2020; SweepNet, 2014).

In the subject of insufficient technical capacity, a reasonable development has been witnessed over the past two decades as a consequence of embracing international best practices, although there is still room for improvement. For example, Al-Ghabawi landfill, the largest and only sanitary landfill in Jordan, was established in 2003 to the east of the capital Amman to replace the closed Russaifa dumpsite. Nearly 50% of Jordan's solid waste is disposed of in this landfill, which was designed according to the desired standards for environmental protection and pollution mitigation by means of daily and intermediate soil covers, leachate and gas collection systems, and landfill lining (Abu Hajar et al., 2020). New sanitary cells were constructed recently at other existing disposal sites such as the new 50,000 m^2 sanitary cell et al.-Akaider (the second largest disposal site located near the Jordanian northern borders). Moreover, Jordan has received technical and financial support from international organizations in multiple sectors

including waste management, to help mitigate the consequences of the refuge wave on the host communities since 2012 (Albtoosh, 2018). These interventions pursue the technical, institutional, and financial development of the municipalities and will unquestionably deal with most of the aforementioned challenges, but their scope should be expanded to cover municipalities from different regions to ensure that the waste management sector is growing sustainably and proportionally. It is noteworthy to point out that pilot recycling projects based on household sorting have been recently launched in selected neighborhoods in the capital Amman to explore the scalability to the entire city. Waste management policy approaches, such as product stewardship and extended producer responsibility, are attractive solutions to partially or fully shift the responsibilities from governments and taxpayers to producers and consumers. These approaches place a greater responsibility on the producer and consumer and result in considerable savings in the municipal waste management budget (Jacobs & Subramanian, 2012; Quartey et al., 2015). Stewardship and extended producer responsibility programs can be implemented through different schemes such as voluntary and mandatory take-back programs, material use bans, mandated recycling, and disposal bans (Quartey et al., 2015; Wagner, 2009).

The deficiency in waste collection staff and equipment is the least significant challenge as portrayed in Table 1. There are more than 1,000 collection vehicles and nearly 15,000 workers in the waste management sector in Jordan (DOS, 2018; SweepNet, 2014). Opposite to labor deficiency, Abu Hajar et al. (2020) demonstrated that the employment rate in this sector is extremely high considering the simple and non-labor-intensive practices. This is in fact one of the reasons behind the exceedingly high cost and inefficiency of waste management in Jordan. Nonetheless, the inflated employment in this sector is an excellent opportunity to embrace more sustainable practices like recycling and recovery, remanufacturing, composting, and anaerobic digestion, which are far more attractive than the prevailing land disposal methods bearing in mind the economic, environmental, and social dimensions.

The questionnaire responses were analyzed further by considering the employment of the respondents. Since approximately half the respondents were from the academic sector, the mean scores for each question were compared between the academic and non-academic (government, NGOs, private sector) groups using the non-parametric Mann–Whitney test. The null hypothesis for this test is that the mean scores of the two groups are not statistically different at 95% confidence level. It was found that the mean scores for the two groups were significantly different only for the deficiency in waste collection equipment question. Respondents from the academic sector consider this a more serious issue (mean score = 3.27) compared to those from the non-academic sectors (mean score = 2.33). The discrepancy can possibly be explained by the fact that many of the non-academic respondents were involved in projects and interventions which aimed at improving the technical and financial capacities of selected Jordanian municipalities such as the purchase of new vehicles and equipment and the maintenance of existing ones.

To further understand the relationship between the challenges and the underlying factors, PCA was performed on the 11 questions using orthogonal rotation. Although the sample size was 27, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.544 which is higher than the recommended value of 0.5 for an adequate sample size for factor analysis (Field, 2009). The Bartlett's test of sphericity had a significant χ^2 value of 87.56 ($p = 0.003$) meaning that the correlation matrix between the variables is significantly different from an identity matrix, which suggests that the factor analysis is adequate to extract clusters of interrelated variables. Moreover, the correlation matrix determinant was 0.017 which is considerably greater than the recommended cut-off value of 0.00001 for multicollinearity or singularity, and this was also confirmed by scanning the correlation matrix where no correlation coefficients higher than 0.7 were encountered. Four factors were initially extracted from the 11 questions which explained 70.1% of the total variance. Those factors were selected based on a cut-off eigenvalue of 1.00 according to Kaiser's recommendation (Field, 2009). The questions loading onto the factors are displayed in Table 2, where questions with loading below 0.4 were suppressed.

Factor 1 can be associated with the limited private sector involvement in the Jordanian waste management sector. The "Lack of PPP" and "Absence of recycling industries" questions load highly onto this factor while the "Inefficient financial capacity" and "Weak

Table 2 Factors extracted using the PCA and questions (challenges) loading onto each factor

Challenge	Factor 1	Factor 2	Factor 3	Factor 4
Lack of PPP	0.834			
Absence of recycling industries	0.798			
Insufficient financial capacity	0.692	0.577		
Weak legislation and enforcement mechanisms	0.524			−0.458
Management inefficiency		0.815		
Insufficient technical capacity		0.787		
Deficiency in waste collection equipment		0.538		0.427
Lack of public awareness and contribution			0.822	
Lack of incentives			0.821	
Deficiency in waste collection staff				0.862
Illegal or uncontrolled waste disposal				0.532

legislation and enforcement mechanism" have lower loadings onto Factor 1. Hence, it can be presumed that the limited private sector involvement in the Jordanian waste management sector can be mainly attributed to the weak legislative framework and the insufficient financial capacity. Factor 2 can be linked to the institutional capacities; because the questions which load highly onto this factor are the "Insufficient technical capacity" and "Management inefficiency." The "Insufficient financial capacity" and "Deficiency in waste collection equipment" load moderately onto Factor 2. The lower loading of the collection equipment deficiency can be understood given the lower significance of this challenge as explained earlier. On the other hand, the insufficient financial capacity is highly correlated with many other questions, which explains why it was incorporated into factors 1 and 2 with moderate loadings. Factor 3 clearly addresses the public awareness and the questions which load onto this factor are the "Lack of public awareness and contribution" and "Lack of incentives". These two variables are indeed critical to the success of waste recycling schemes, and it has been proven that properly designed incentive programs are not capital-intensive solutions, yet adopting such programs significantly improves the waste separation efficiency (Struk, 2017). Finally, the questions loading onto Factor 4 are related to the legislation, equipment, staff, and disposal. The "Deficiency in waste collection staff" and "Deficiency in waste collection equipment" have been identified as the least significant challenges as shown in Table 1. Although the weak legislation has been shown to correspond to several challenges, it appears to be inversely correlated to the other challenges which load onto Factor 4. Additionally, it does not appear that the questions loading onto Factor 4 reflect a single factor or dimension of waste management.

Cronbach's alpha was used to assess the reliability of the extracted factors in reflecting the construct they are intended to measure. The recommended cut-off alpha for a reliable scale is 0.7 (Field, 2009). It was found that factors 1, 2, 3 have alpha values above 0.7 whereas the alpha value for Factor 4 was 0.385, which reveals that Factor 4 is an unreliable scale. This can be explained by the weak connection between the variables loading onto this factor. The method used to retain factors (based on Kaiser's recommendation of a cut-off eigenvalue of 1.0) could also explain the unreliability of Factor 4, for which the eigenvalue was just above 1.0 (1.035). In summary, the challenges facing the sustainable development of the waste management sector in Jordan can be clustered under three main dimensions: limited private sector involvement, weak institutional capacities, and poor community engagement. Several literature studies addressed the main challenges and barriers to waste management in developing countries. Sukholthaman and Shirhada (2015) identified three broad categories of challenges facing the waste management sector in Thailand, namely, infrastructure, absence of practical and enforceable policies and laws, and weak employment of modern technology in the sector. According to Manowong (2012), factors controlling the effective management of construction waste in Thailand include the availability of clear management procedures for collection, separation, transportation, and disposal; an enforcement mechanism of regulations and policies; stakeholders' engagement; economic incentives to promote

the participation of different stakeholders in waste management and recycling; and healthcare and health insurance plans to mitigate the risks on those involved in waste management activities. Nzeadibe and Anyadike (2012) revealed that ineffective waste collection and disposal in Aba, Nigeria, is triggered by inadequate funding, lack of staff motivation, poor road network, high population density, weak law enforcement, and high illiteracy levels. Ezeah and Roberts (2012) categorized the waste management barriers in Abuja, Nigeria, under four general groups: operational (e.g., training, poor working conditions, insufficient and obsolete equipment), socio-economic (e.g., low level of public education, public negative attitude, funding constraints), natural and physical (e.g., unplanned city aspects, availability of dumping grounds), and institutional and regulatory barriers (e.g., lack of clear strategies, weak legal framework). The effective waste management necessitates defining clear roles and responsibilities of governmental organizations in order to avoid overlapping responsibilities and controversies (Marshall & Farahbakhsh, 2013; Sukholthaman & Shirhada, 2015).

Waste management databank parameters

Data availability and organization are inevitable for an integrated and sustainable waste management system. It is essential that a waste management databank system encompasses several dimensions of data including but not limited to environmental, physical, economic, financial, social, and institutional aspects. Each dimension may incorporate one or more parameters (indicators) which can be used to analyze the progress and simplify the complexities for better future planning (Weitz et al., 1999; Wilson et al., 2015). However, data collection and management can become quite cumbersome and infeasible if too many parameters are being monitored too often; therefore, it is comparative to establish a balance between the number of parameters and the monitoring frequency. Instead of rating the parameters using the 5-point Likert scale, the significance of each parameter was assessed based on the desired monitoring frequency. Thirteen questions covering different categories of waste management parameters were included in the questionnaire, and the experts responded to those questions by selecting the recommended monitoring frequency for each category (or parameter). The responses were analyzed and expressed as percentages for each monitoring frequency as presented in Table 3.

Based on the results displayed in Table 3, the only two parameters which shall be monitored on a daily basis are the waste quantity and vehicle load with 51.9% and 44.4% of the responses, respectively. These two parameters are actually connected because the aggregation of the vehicle's load presumably yields the total quantity of waste managed; however, the vehicle's load has implications on other aspects such as the operating and maintenance of the vehicles. According to the findings in Table 3, none of the waste management parameters is recommended

Table 3 Responses (%) to the monitoring frequencies for different waste management data categories/parameters

Data category/ parameter	Monitoring frequency				
	Daily	Weekly	Monthly	Seasonally	Annually
Waste quantity	51.9	14.8	18.5	7.4	7.4
Container no. and capacity	0	25.9	29.6	29.6	14.8
Waste composition	3.7	3.7	14.8	48.1	29.6
Sources of waste	11.1	7.4	29.6	18.5	33.3
Other waste categories	7.4	11.1	25.9	18.5	37.0
Waste destination	14.8	7.4	22.2	18.5	37.0
Route distance and duration	22.2	3.7	44.4	18.5	11.1
Vehicles load	44.4	14.8	14.8	18.5	7.4
Collection staff	7.4	7.4	37.0	14.8	33.3
Vehicles/equipment O&M cost	3.7	7.4	37.0	22.2	29.6
Landfill staff	3.7	7.4	37.0	14.8	37.0
Landfill financial	3.7	0.0	37.0	11.1	48.1
Associated facilities	3.7	7.4	25.9	25.9	37.0

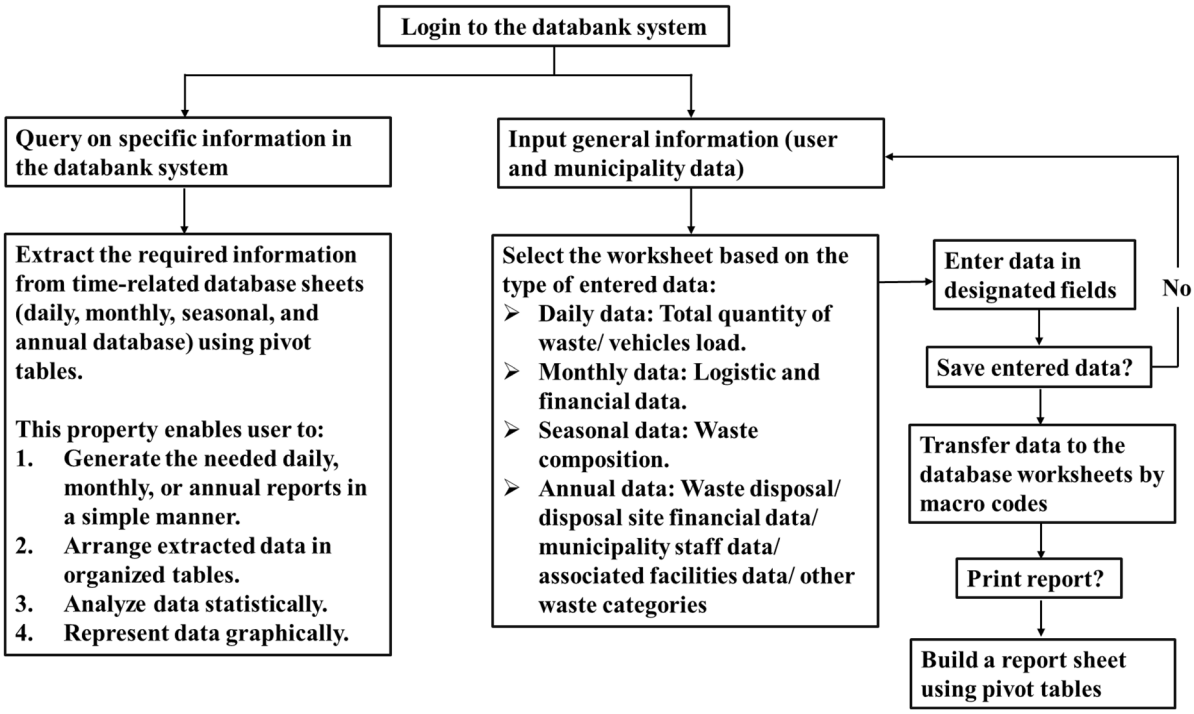


Fig. 1 Data entry scheme for the databank users

to be monitored on a weekly basis; even though the response to "weekly" was relatively high (25.9%) for the container no. and capacity, a higher percentage was observed for monthly or seasonal monitoring. It can also be perceived from Table 3 that several parameters fall under the monthly frequency including the route distance and duration, collection staff, vehicles/equipment O&M cost, landfill staff, and container no. and capacity. The monthly parameters are those associated with the logistic and financial aspects of waste management. The only parameter which is recommended to be monitored on a seasonal basis is the waste composition, and this is in agreement with many studies which indicated that the waste composition is highly influenced by the season (Gidarakos et al., 2006; Gómez et al., 2009). Lastly, the annual waste parameters are those related to the waste destination; landfill/disposal site financial data, staff, and associated facilities; sources of waste; and other waste categories.

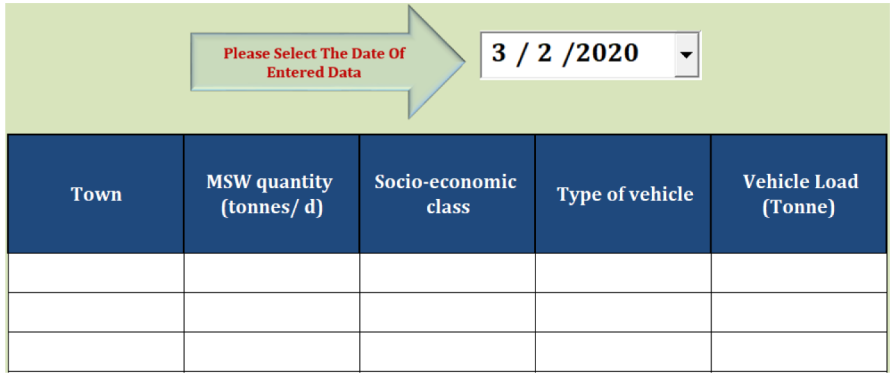
In brief, clustering the waste management data categories and parameters based on the monitoring frequency under daily, monthly, seasonal, and annual groups is anticipated to ensure the sustainability and adequacy of data management in this sector. The findings and recommendations from this section will be the basis for the design of a databank system as presented in "Design of a solid waste management databank system".

Design of a solid waste management databank system

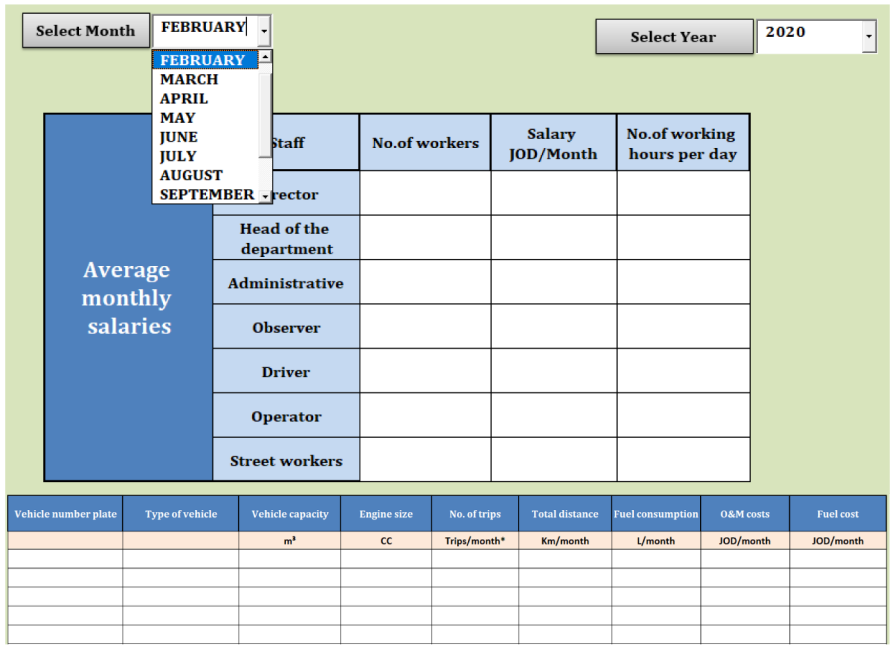
The waste management databank system was developed taking into account the simplicity, robustness, and effectiveness for a long-term usage software. The databank is intended to be used primarily by field operators (data entry) and management personnel (assessment and decision-making). The developed databank system is a Microsoft Excel–based file which is composed of different input and output worksheets. The databank program user interface is designed to be direct, simple, and straightforward for field operators while providing descriptive statistical analysis, correlations, and projections for decision-makers. The program can also provide graphical presentation using histograms and change with time profiles. A general scheme for the software usage is illustrated in Fig. 1.

After running the program, the user is introduced to a customized graphical user interface. The

Fig. 2 Data parameters in the databank system: **a** daily, **b** monthly, **c** annual



(a)



(b)

Disposal Method	Quantity		Number of workers	Total salaries		Total revenue	
Open dumpsite		Tonne /year			JOD		JOD
Sanitary landfill		Tonne /year			JOD		JOD
composting plant		Tonne /year			JOD		JOD
Anaerobic digestion plant		Tonne /year			JOD		JOD
Recycling Center		Tonne /year			JOD		JOD
Incineration plant		Tonne /year			JOD		JOD

(c)

Town	Total quantity of solid waste (tonne/day)
High income area	
Al-Balawnh	10
Low income area	
Alrawaha	10
Altwal-Aljanobi	10
Market area	
Deir-Alla	10
Refugee area	
Altwal-Alshamali	10
Qazmah	10
Total	**60**

(a)

Staff	Average of No.of workers	Salaries (JOD/month)
Deir-Alla		
Administrative	3	1519
Operator	1	300
Director	1	439
Driver	14	5496
Head of department		0
Observer	15	5261
Street workers	78	24859
Grand Total		**37874**

(b)

Material	Quantity of solid waste (tonne/year)	% of grand total
Glass	**653.56**	**2%**
Dry	325.794	
Wet	327.768	
Hazardous Waste	**653.56**	**2%**
Dry	325.794	
Wet	327.768	
Mixed paper	**3,921.37**	**12%**
Dry	1954.764	
Wet	1966.608	
Mixed plastics	**4,248.15**	**13%**
Dry	2117.661	
Wet	2130.492	
Organics	**16,665.83**	**51%**
Dry	8307.747	
Wet	8358.084	
Other	**3,594.59**	**11%**
Dry	1791.867	
Wet	1802.724	
Textiles	**1,633.91**	**5%**
Dry	814.485	
Wet	819.42	
Wood	**653.56**	**2%**
Dry	325.794	
Wet	327.768	
Grand Total	**32,025**	

(c)

Fig. 3 Examples of output reports: **a** daily, **b** monthly, **c** annual

user will be first prompted to fill identity and contact information, district, and data entry type (daily, monthly, seasonal, or annual). Then, the user has the choice of entering data, extracting data using query, or extracting data using report generator. In the data entry, the user can choose daily, monthly, seasonal, and annual data. In the daily data worksheet, the user will enter the daily waste quantity and vehicle load as shown in Fig. 2a. The rows in the entry table enable the user to optionally break down the daily data based on towns or districts. The selected input parameters were grouped under different blocks (worksheets) based on the recommended monitoring frequency as explained earlier in Table 3. The user can then switch to the monthly datasheet to input parameters as illustrated in Fig. 2b. As indicated earlier, the waste composition is the only seasonal parameter which is expected to be carried out in wet and dry seasons. The waste composition data will be inserted as a percentage for each waste category, and the average waste composition (wet and dry) will be computed and used to estimate the annual quantities of the different waste categories which will be displayed in the annual worksheet. Finally, annual data parameters such as those shown in Fig. 2c can be entered in the annual worksheet. Each data entry page includes a "print" button which enables the user to generate an automatic PDF report with descriptive and graphical summaries of the waste management data. For example, printing the March monthly data will produce a report which incorporates all the monthly parameters entered for March along with the compilation of the daily data for the same month (e.g., the monthly waste quantity will be the summation of the daily waste quantities over the 31 days of March). Similarly, the annual report will encompass the annual parameters as well as the compilation of the monthly parameters within the same year. Examples of daily, monthly, and annual output reports are presented in Fig. 3.

Conclusions

This study examined the key challenges and barriers obstructing the sustainable development of the waste management sector in Jordan. The study also aimed to address the lack and inadequacy of waste management data in Jordan through the design of a simple and innovative waste management databank system. It was determined that the key challenges which hinder the waste management sustainable development can be grouped under three main dimensions: limited private sector involvement, weak institutional capacities, and poor community engagement. The most significant and serious challenges according to the respondents were the lack of strict laws and legislation, the inefficient management, the insufficient financial capacity, and the lack of public awareness and contribution. The weak legislative framework and enforcement mechanisms have been shown to influence the other challenges in Jordan; thus, a robust waste management law will be a game changer in the Jordanian waste management sector.

A databank system was developed to facilitate the waste management data monitoring and storage in Jordan. A multitude of parameters was incorporated in this databank, and the monitoring frequency for each parameter was specified based on the recommendations of the waste management experts. The design of this databank system enables the users to input data and generate the needed daily, monthly, or annual reports in a simple manner. The findings and recommendations of this study will provide valuable guidelines for policy- and decision-makers to holistically appraise the development of the waste management sector in Jordan. This is because the interventions in this sector often target infrastructure construction and rehabilitation while ignoring other key waste management challenges and barriers.

Funding This research was funded by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) within the Waste to (Positive) Energy project (Wt(P)E): Universities Cooperation with Jordanian Universities in frame of Supporting Refugees Hosting Communities in Sector of Waste Management.

Availability of data and material The data that support the findings of this research are available on request from the corresponding author.

Code availability The databank Excel file (which contains all macros) is available on request from the corresponding author.

Declarations

Competing interests The authors declare no competing interests.

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