STRATEGIC ENVIRONMENTAL ASSESSMENT OF INTERVENTION OPPORTUNITIES FOR IMPROVED SOLID WASTE MANAGEMENT IN THE GREATER KHARTOUM CITY, SUDAN

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EXECUTIVE SUMMARY

This study applied the strategic environmental assessment (SEA) approach to evaluate alternative opportunities for improving the current system of solid waste management (SWM) in the Greater Khartoum City (GKC). The study employed sound data collection methods to generate credible information on principle elements of the system. Amount and type of generated waste, collection efficiency, and post-generation processing activities were the three main areas where poor quality or missing data have been identified. The study established that the GKC produces 3,340 tons of solid waste every day, at a rate of 0.42 kg per capita per day, out of which 31.5% is collected and transferred to landfills. Very different estimates of these key parameters have been used by various public and private decision makers to design policy reforms and draw investment plans.

Our surveys indicated that there are significant solid waste segregation and recycling activities taking place throughout the waste supply chain, from generation to disposal at landfills. These activities are performed by informal waste pickers (Nakasha/Barkata), who currently remove 233 tons of recyclables, amounting to 7% of total solid waste supply. It is estimated that the livelihoods of 3,900 people are highly dependent on these activities. The size and economic value of this informal sector is estimated at SDP 12 billion per day. Results of this study showed that about 75% of all plastics is currently removed from the stream of solid waste and recycled mainly for export markets. Some knowledge of recycling of carton and paper materials was gained, but more research is desired on the size and value of these products. One limitation of this study however, is not improving on the current poor information on the state and fate of other recyclables such as used tires, batteries, electronics, and agricultural residues.

Survey results also indicated that only 17% of all medical waste generated within the GKC is currently receiving separation and post-collection treatment. The current policy practice permits some waste collection companies to remove unsegregated medical waste from source (e.g. hospitals), and hence weakens the incentive for source separation. Also, high degree of non-compliance with the requirements of safe discharge of medical waste at designated dumping sites is reported. This poses a serious threat to the health of people engaged in medical waste collection and processing, particularly the large number of informal waste separators (Barkata) found at dumpsites. The study found that very high rates of recycling own waste at premises is currently practiced by most factories, especially within the paper, food, and cartons industries.

Other gaps in existing baseline information needed for application of the SEA framework, relate to the type and levels of likely socioeconomic impacts and environmental risks associated with the alternative intervention strategies of integrated solid waste management (ISWM) under investigation.

Information generated by the study on the size and economic benefits from informal waste processing provided good basis for accounting for potential socioeconomic implications of alternative strategic plans being evaluated. This study also acquired data on potential environmental impacts of alternative ISWM options. The data provided the basis for conducting a SEA of alternative intervention options for improved ISWM in the GKC.

To apply the SEA analytical framework, unexploited opportunities for improving the current system of SWM are defined by 7 scenarios of plausible intervention options were specified. SEA of alternative strategies for ISWM in the GKC generated useful information on the economic, social, and environmental costs and benefits of the evaluated options that are of significant value for improved policy making and strategic ISWM planning. All assessed scenarios gave a mixture of desirable and undesirable outcomes. Generally, considered intervention options suggest positive results in mitigation of the negative environmental externalities and consequent human and ecosystems health risks can be achieved with changes in practices. Environmental quality gains however, are realized at some socioeconomic costs. Increasing collection efficiency and introducing separation of waste at source by out-scaling of currently piloted Door-To-Door (DRTDR) and Fixed-Time-Fixed Place (FTFP) modalities for instance, impose a high cost on employment opportunities and the livelihoods of some of the poorest urban population groups, the Barkata. On the other hand, reuse and recovery (composting, biogas, incineration) interventions offer economic co-benefits in terms of soil nutrients (fertilizers) and energy generation.

A sound composite measure of the net impacts of each of the compared alternatives was necessary for an objective evaluation of the implied trade-offs between these multidimensional choice options. This required measures with a common denominator to use to aggregate the constituent elements of outcomes into one composite measure. This study was able to quantify the economic costs and benefits associated with jobs and recovery of some material and energy contents of solid waste, such as fertilizers from composting and energy from chemical and thermal treatments. The study however, could not measure values of environmental quality impacts, like reduction of pollution and human health risks for lack of needed data. Qualitative indicators of the nature and intensity of such impacts have been alternatively used, which did not allow aggregation of all impact values into a single composite measure. This points to the necessity of investing in scientific research to measure the values of identified impacts, especially on some critical environmental processes and services, as well as on human health, where we currently have the biggest knowledge gap.

Based on the above summary of results, the following conclusions and recommendations are made in this document:

- Pre-generation waste prevention measures, such as use of taxes, incentives and regulation instruments (e.g., banning the use of plastic bags) have not been exploited, and hence present intervention opportunities with high potential for improvement in waste management outcomes.
- Segregation of waste at source using separate bins and DRTDR collection are likely to succeed and need further testing for:
  - Institutional waste (schools, varsity campuses, office & industrial premises, hospitals, etc.)
  - Organized commercial activities (supermarkets, etc.), and possible
  - Households in high income suburbs.
- On the other hand, FTFP collection of unseparated waste may be more suitable for low and middle income neighborhoods.
- Introduction of source separation and collection systems such DRTDR and FTFP is expected to result in major job losses in informal waste separation and recycling activities. This presents a major concern and requires careful examination and planning before introduction, given the current role of informal waste pickers in separation and recycling of solid waste. Examples of options for intervention to mitigate this negative socioeconomic impacts include:
  - Assessment of options for integrating informal waste separators (Barkata) in the intended formal recycling & processing systems;
  - Exploring appropriate business models to organize informal pickers in cooperatives or any other SMEs, supported with access to skills development, concessional credit, modern recycling techniques and equipment, etc.
- Introduction of incentives such as use of rebates (discounts) on waste collection levies, deposit refunds, and other relevant policy measures need to be tested for promotion of waste separation at source.
- Massive public awareness and education campaigns to enhance ownership, willingness, engagement and participation of local community elements and NGO-related "friends of the environment" initiatives are necessary for achieving environmentally sound and inclusive solid waste management systems.
- Exploring opportunities to modernize and raise the efficiency of existing plastic, paper and carton recycling activities have good potential for improved SWM.
- Best ways for exploiting the potential in recycling and reuse of the currently unutilized large share of organic material in solid waste in the GKC calls for urgent attention. Detailed feasibility studies of essential technical efficiency aspects are necessary to investigate key questions on optimal locations for setting up needed separation, composting and energy recovery

facilities, and inform the choice between biogas and composting, among other alternative intervention options.

- Incineration and thermal processing options need good costing and efficiency data, given the current high cost of these technological innovations.
- Appropriate regulations for discharging waste in illegal sites and open public spaces, and fines for not protecting and fencing of private properties that are vacant or under construction and thereby attracting free and easy access for waste dumping are needed.
- Regulating discharge of construction and demolition debris must be enforced.
- Major knowledge and information gaps need to be addressed, including:
  - State of post-generation processing of other recyclables (tires, batteries, electronics, etc.); and
  - Measurement and valuation of environmental impacts.
- Enforcement of regulations and policies for the safe discharge of medical waste, particularly collection, segregation and treatment of toxic and infectious waste to prevent health risks many agents are exposed to along the waste supply chain. Careful assessment of viable alternatives for on- and off-site waste treatment options must be conducted.

1. INTRODUCTION AND MOTIVATION

The state of waste management in the Greater Khartoum City (GKC), Sudan's capital city and largest centre of urban development, has reached crisis levels. Heaps of uncollected or unprocessed waste all over the city became a normal scene, and consequent high air, land and water pollution levels are posing serious threats to human and ecosystem health. Rapid urbanization, massive expansion of informal economic activities and unorganized settlement patterns, coupled with weak environmental governance and poor planning and policy frameworks, are major factors creating this situation (Pantuliano, et al., 2011; Abdalla and Balla, 2013; CEA, 2014).

Recent efforts by the government and initiatives co-sponsored by a number of donor agencies and non-governmental organizations (NGOs) to address the waste problem in the GKC fell short of fully realizing their goals. Failure of these attempts to achieve the desired results is attributed to lack of appropriate strategy to guide integrated waste management and sustainable urban development planning. One major reason behind the poor performance of such interventions is their partial approach to diagnose and treat problems of much bigger and more complex processes involving several stages through which waste is generated and disposed of. Almost all projects implemented in the past and the several proposals currently under consideration for approval by the government of the state and donor agencies were developed to manage only sub-phases of the entire waste generation, disposal, and processing continuum.

The majority of these projects were built on some uncertain assumptions and scenarios about the functioning of other segments of the process, and hence missing opportunities for potential improvements to exploit in other phases of the complete system. For instance, the implemented or proposed intervention measures do not adequately consider existing waste management infrastructure and operational systems in place and how those set the context within which suitability of alternative options for improvement ought to be evaluated (i.e., how waste is currently generated, collected, processed, and disposed of and who is involved in each of these activities and will be affected by proposed interventions). Not accounting for a number of important environmental, economic and social cost and benefit implications for the welfare of affected parties is one common shortcoming of implemented or proposed plans for improved waste management. Also, consistency of considered plans, programs and projects with national and local policy objectives of various sectors of economic activity is usually overlooked. Moreover, large disagreements exist between the baseline information on which key technical assumptions of the proposed interventions are founded. One example is the huge divergence in estimates of the size and composition of generated and collected solid waste in the GKC. Absence or weak analysis of institutional aspects and the roles of different actors in the various stages of waste generation and disposal, and in the governance and management of the proposed interventions at different tiers of policy and decision-making is another important deficiency of most plans and projects.

Policy choices made on basis of such deficient information and partial assessments are highly likely to be misguided leading to suboptimal allocation of resources. More credible baseline information on key structural parameters, and integrated systems' approach to characterization of the functioning of various components of the entire system are critical for decision making at such strategic levels. Strategic environmental assessment (SEA) is the tool considered appropriate for evaluating alternative intervention options for optimal control and management of systems involving environmental processes (Finnveden et al., 2007; Desmond, 2009; Fischer et al., 2011). This study employs the SEA approach and criteria to identify and evaluate alternative intervention strategies for integrated waste management in the GKC.

The following Section 2 specifies the objectives of the study. In Section 3 we provide basic background information on the study area, and assess the current state and gaps in existing knowledge as well as identified needs for more objective identification and comprehensive assessment of strategic intervention options for improved integrated waste management (IWM). The analytical approach of the SEA is presented in Section 4. Section 5 describes sources and methods employed to collect the needed data. Results and findings of the application of the SEA framework to IWM in the GKC are discussed in Section 6, and Section 7 discusses conclusions and recommendations for future research efforts.

2. OBJECTIVES OF THE ASSESSMENT

The main objective of this study is to generate more credible baseline information on key structural features and assess the environmental and socioeconomic merits of alternative strategic courses of action at different stages of the current process of waste generation and disposal. This information is needed to support well informed decision making for integrated waste management in the GKC. The following specific aims are pursued under this main objective:

i. Collect and analyse baseline information on:
   a. Sources and magnitude of the different types of municipal waste generated;
   b. Current collection, storage, and processing activities and infrastructure (e.g. transport facilities and storage/dumping sites in operation) and efficacy of the current system of waste management in terms of the percentage of the different types of waste collected, transported, and processed;
   c. Actors (e.g. public and private agencies, NGOs, waste pickers, etc.) involved in managing current waste collection and processing operations, including number of beneficiaries and magnitude of the economic benefits derived (e.g. by informal local pickers and processors);
   d. Types and significance of environmental damages and risks associated with current operations at different stages of the waste generation and processing system;

ii. Develop a strategic environmental assessment (SEA) framework for evaluating the potential of alternative intervention options for improved waste management in the GKC;

iii. Identify intervention options to improve the efficacy and reduce (enhance) environmental and socioeconomic negative (positive) externalities at different stages of the process;

iv. Apply the developed SEA framework to assess the merits and demerits of the alternative intervention opportunities identified;

v. Use the results of the SEA to derive recommendations to assist policy decision makers with designing the appropriate integrated waste management systems.

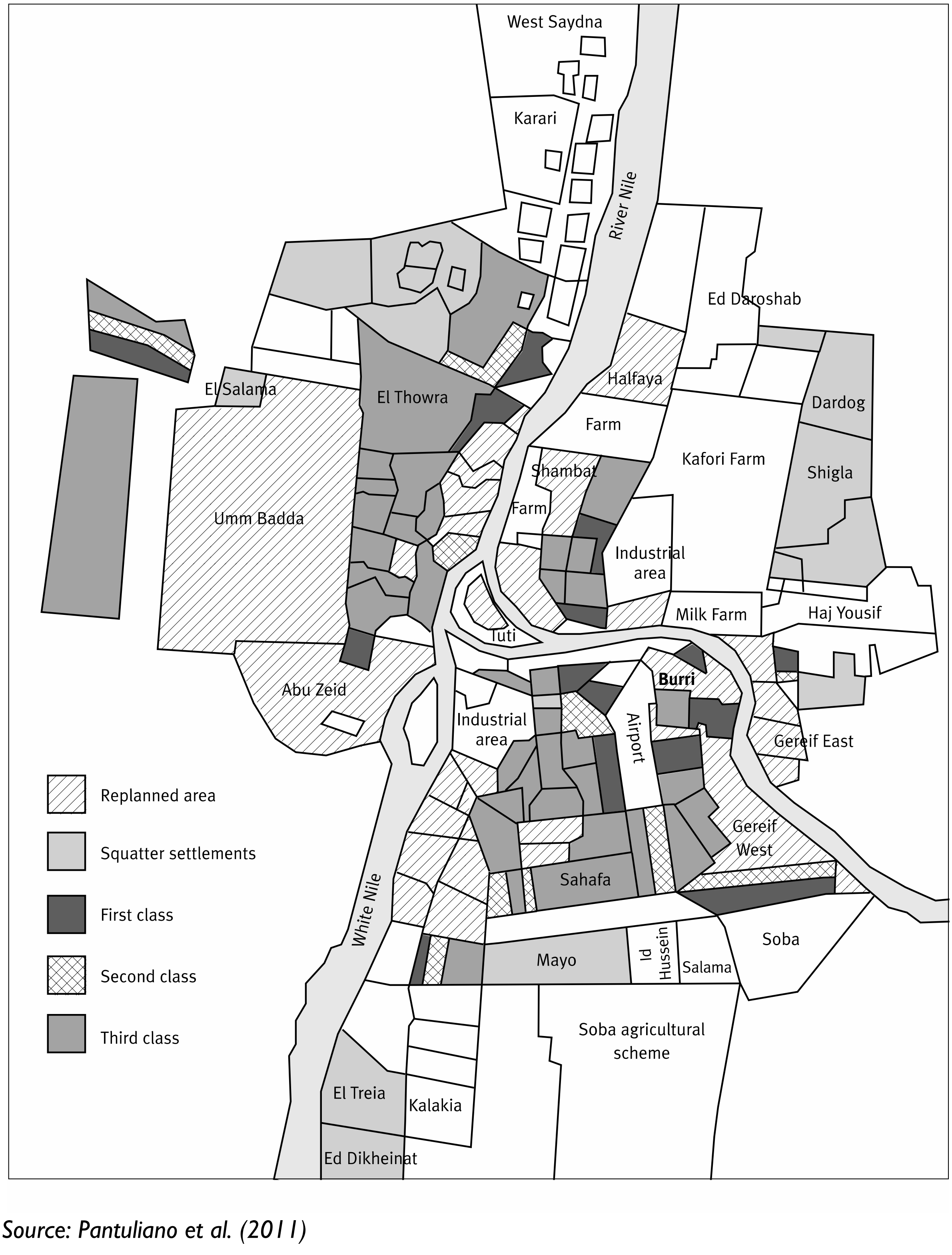
3. STATE OF KNOWLEDGE AND POLICIES OF WASTE MANAGEMENT IN THE GKC

Considerable efforts have recently been made to address the waste management crises in Khartoum State. Based on the knowledge gained and analysis carried by a number of studies, intervention measures to improve the situation were recommended and some of the proposed plans have been tested over the past few years. While there are signs of progress and some improvements have been realized, a number of important gaps remain in the current state of knowledge and understanding of the functional and operational attributes of the waste management sector as a one integrated system. In this section we assess the performance and identify knowledge gaps and shortcomings in current efforts to better manage the process of waste generation and processing in the GKC.

3.1 GKC STUDY AREA

Three cities constitute the GKC, namely Khartoum (south of the Blue Nile and west of the White Nile), Omdurman (west of the White and River Niles) and Khartoum North – Bahri (north of the Blue Nile and west of the River Nile). Residential settlements of the GKC are organised into the three housing areas of First, Second, and Third classes (see Figure 1). In the original city plans, this classification was intended to house residents from different social status groups (Pantuliano et al., 2011). Over time, however, new housing developments deviated significantly from their original building specifications and current residential structures within these areas display diverse social class representations. The GKC continued to receive large numbers of people displaced from their home regions due to severe droughts and armed conflicts in various parts of the country over the past three decades. The displaced populations have been accommodated in several unplanned expansions of the city boundaries, primarily in squatter settlements and internally displaced refugee camps (Pantuliano et al., 2011). The population of the internally displaced in the GKC had reached more than 2 million by 2010 (Pantuliano et al., 2011). The Sudan Central Bureau of Statistics (SCBS) estimates a total population of 8 million people in the GKC by 2020, 13% of which is rural (CEA, 2014; HCEURP, 2016)

Figure 1: Map of Khartoum



Source: Pantuliano et al. (2011)

The GKC is split into seven localities (Karari, Um Bada, Um Dorman, Khartoum North (Bahri) East Nile, Khartoum, and Jebel Awliya) (see Figure 2). Each locality is further subdivided into municipal Administrative Units (AUs), which together comprise a total of 301 AUs managed under local municipal authorities of the Khartoum State Government (KCC, 2020).

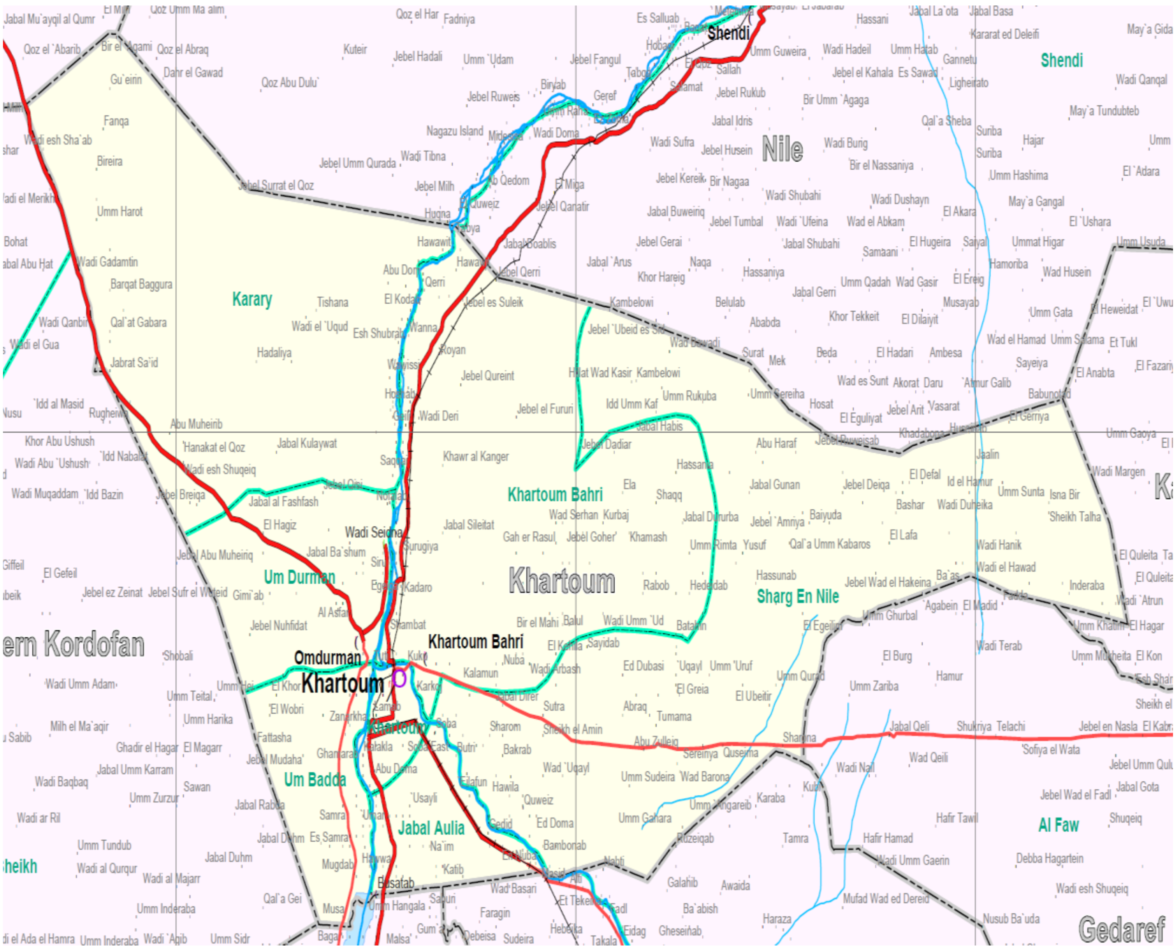


Figure 2: Greater Khartoum City Localities (CEA, 2014)

3.2 WASTE GENERATION, COLLECTION, PROCESSING, AND DISPOSAL IN THE GKC

Research work and management efforts made have not been balanced as only some sectors in select segments of the complete waste system received attention. Being the largest source of the waste problem, municipal solid waste (MSW) was given priority over other types of waste[1]. Although solid waste generated by industrial processing activities is largely managed by municipal authorities as part of the city's MSW, it has received much less attention. Between these two extremes, medical waste is given moderate priority in terms of needing improved management, and requires specialized codes of regulation and policy measures. Handling and disposal of other types and sources of waste, such as construction and electronic waste and agricultural refuse, have been largely ignored.

3.2.1 Household and Commercial Waste

Waste from private homes and commercial service activities (e.g., market centres and shopping places, restaurants and informal street food vendors, schools, etc.) comprise the bulk of MSW. Good baseline information is available from a number of studies using methods of reasonable credibility to estimate quantities of waste generated and collected from these sources. Estimates of amounts of waste generated were derived using a number of primary data collection techniques, including direct field observation and measurement of waste samples, perspectives of surveyed respondents and key informant interviews, as well as institutional records (Abubaker et al., 2014; CEA, 2014; HCEURP 2014 and 2016; Elbaroudi et al., 2015; EWASCO, 2016). As illustrated in Table 1, the average rate of waste generation by households per day per person was estimated to fall in a range between 0.32 kg and 0.78 kg in the GKC. However, the upper bound of 0.78 kg stands out as an outlier compared to estimates of other studies. While these studies seem to agree on estimates of the average quantity of waste generated per person per day from private homes, estimates of waste from commercial sources diverge significantly, by more than 9-fold (Table 1).

The main source of information on rates of waste collection is the Japan International Cooperation Agency (JICA) project, under which Khartoum State Government (KSG) continued receiving assistance on management of MSW since 2010 (HCEURP, 2014). With the assistance

[1] This study did not cover sewage waste and sources of atmospheric pollution and emissions.

of JICA, the Higher Council for the Environment, Urban, and Rural Promotion (HCEURP) developed a Master Plan for MSW management in Khartoum State, the main goal of which is to raise collection of MSW from the current collection rate of 65% (Table 1) to 80% by 2028 (HCEURP, 2016). The JICA's estimate of 65% collection efficiency appears an outlier compared to the 30% rate estimated by other studies (Table 1). Another more recent study reported a collection efficiency rate of 36% for the first half of 2019 (Mohamed, 2019). To be expected, organic matter (mainly food waste) contributes the biggest share of waste from households (66.3%), whereas more paper and plastic are found in waste from commercial sources, particularly schools (CEA, 2014) (Table 2).

All sources appear to suggest that MSW management in the GKC is at the lower end of desired efficiency on the waste management pyramid (Abubaker et al., 2014; CEA, 2014; HCEURP 2014 and 2016; Elbaroudi et al., 2015). This means that collected waste is simply disposed of with little if any processing. Currently, municipal authorities (i.e. KSG organs at localities' level) or contracted private service providers collect unseparated MSW from household and commercial sources, and transport it for final dumping in open landfills through intermediate waste transfer stations. Although no formal separation and recycling activities were reported, informal separation of recyclable waste performed by local scavengers (Nakasha and Barkata) was observed during this study. The large share of about 40% (more than 2000 tons/day) of generated waste that does not reach the final landfills (HCEURP, 2016) is an indication of the possibly substantial size and importance of these informal waste recycling operations. Also, some of this undocumented portion of the MSW is reportedly burned at source or at dumping sites (Abubaker et al., 2014; CEA, 2014; HCEURP, 2014 and 2016; Elbaroudi et al., 2015). Unfortunately, except for a general overview provided in a study by Ahmed (2016), no information is available on the apparently significant role of informal waste pickers in the MSW pyramid, and on what share of the waste is burned in transit to landfills in the GKC. The large magnitude of waste reported unaccounted for in the MSW flow could also be due to either the seemingly high estimate of MSW generation rate compared to other studies (Table 1), or an overestimation of the waste collection efficiency of 65% proposed by HCEURP (2016).

3.2.2 Industrial waste

Manufacturing represents one major constituent of economic activity and an important employer in the GKC. Industrial activity in the city has also witnessed large expansions over the past two decades reaching more than 1400 industrial processing establishments in 2018 (Khartoum State Ministry of Industry, 2014 and 2018). Obviously, the sector's contribution to waste generation is expected to be large and continually growing in significance. Surprisingly however, very limited assessment work and information can be found on the state of industrial waste generation and its management. Industrial waste for instance, is not included in the JICA Master Plan for waste management in the GKC (HCEURP, 2016).

3.2.3 Medical waste

The medical waste sector received more attention and research compared to industrial waste activities. Like domestic solid waste from households, better information is available on waste generation by the medical services sector. Estimates of average rates of waste generation were derived from standard methods of sample surveys and reasonably reliable direct measurement techniques. Large variations remain, however, between sources of these estimates (Table 1).

Lack of adequate data on collection and post-generation processing (i.e., recycling, incineration, etc.) represents another important gap in the baseline data for medical waste management in the GKC. Available studies provided little or no information on rates of collection of medical waste. Most studies indicated that only partial segregation into hazardous and non-hazardous waste is practiced at some hospitals, while most healthcare services facilities in the GKC dispose of all waste as mixed or unseparated (Yousif, 2006; Ahmed et al., 2014; CEA, 2014; Abdalla, 2014; Daifa, 2015; Hassan et al., 2018). Few hospitals are equipped with waste incineration units on site and the vast majority transport their waste for processing off-site (Ahmed et al., 2014; CEA, 2014; Abdalla, 2014; Daifa, 2015; Hassan et al., 2018).

3.2.4 Other waste

Other types of MSW that are largely ignored and calling for more attention and research include, agricultural refuse, construction demolitions, and electronic waste (CEA, 2014; Abbas and Ali, 2015; Mohamed and Mohamed, 2016). Very preliminary crude estimates of quantities and state of management of waste from these sources are found in the CEA (2014) and Abbas and Ali (2015) studies. An overview of the state of management of waste generated by the transport sector, which includes metal scraps, used lead acid batteries, lubricant oil, and tires is provided in the CEA (2014) report.

3.2.5 Hazardous waste

Good information is available on Persistent Organic Pollutants (POPs) that is regularly updated in the National Implementation Plan (NIP) as required under the Stockholm and Basel conventions on toxic and hazardous waste, and ratified by the government of Sudan. Municipal waste features prominently in the NIP as the major source of unintended POP (UPOP). Uncontrolled domestic waste burning is reported to contribute more than 80% of total UPOP in the country (HCENR, 2007).

Except for only a few examples (e.g., sugar and petrol refining and power generation), little information is available on management of hazardous waste from other mining (e.g. gold) and industrial processes (tanneries, textiles, chemicals, steel, etc.), where the common practice seems to be to discharge the waste directly (without treatment) into municipal wastewater networks (HCENR, 2007; CEA 2014).

Some information is available on management of hazardous medical waste from the few attempts made to investigate and address challenges in this sector. Findings of recent assessments of the state of medical waste management in the GKC indicate that progress has been made in separation and proper disposal of hazardous medical waste at a number of hospitals in the GKC (Yousif, 2006; Ahmed et al., 2014; CEA, 2014; Abdalla, 2014; Hassan et al., 2018). Nevertheless, many health services' facilities continue to mix and dispose of all unseparated medical waste with MSW. No data is available on the percentage of hazardous constituents of medical waste separately managed and disposed of. Available information also suggests that currently most of the toxic medical waste is transported to be processed off-site, as on-site waste incineration capacities almost no-existent in the GKC (Ahmed et al., 2014; CEA, 2014; Daifa, 2015; Hassan et al., 2018). Risks to human health from medical waste have risen with the recent spread of the COVID-19 pandemic.

Table 1. Sources and quantities of waste generation in Khartoum State (various sources)

Source of Waste	Total Amount (ton/day)	% collected	Amount per day/unit			Year	Source of the Data
			Unit	Units (000)	Kg/unit		
Domestic-households	1,734	30	People	5,621	0,308	2011	CEA (2014)
	2,360	ND	People	6,600	0.358	2013	Abubaker et al. (2014)
	2,688	30	People	7,385	0.364	2016	EWASCO (2016)
	2,765	ND	People	6,600	0.40	2014	Elbaroudi et al. (2015)
	ND	ND	People	ND	0.45 [a]	2017	Hamdalla, (2017)
	4,890	65	People	6,600	0.778	2013	HCEURP (2014)
	2,647	ND	People	6,600	0.401	2013	Elzaki & Elhassan (2019)
Domestic-commercial (businesses, shops, restaurants, schools, etc.)	84.07[b]	ND	People	5,621	0.015	2011	CEA (2014)
	940	ND	People	6,600	0.142	2013	Abubaker et al. (2014)
Industrial	44	ND	People	4,654	0.01	2004	El Sidig (2004)
	612	ND	People	6,600	0.09	2013	Abubaker et al. (2014)
Medical	94.8	ND	Bed	6,600	14.4	2011	CEA (2014)
	88.0	ND	Bed	ND	ND	2013	Abubaker et al. (2014)
	6.25 [c]	ND	Bed	4,008	1.53	2014	Ahmed et al. (2014)
	ND	ND	Bed	ND	0.87	2013	Saad (2013)
	ND	ND	Bed	ND	0.60 [d]	2016	Elya and Babiker (2016)

ND indicates no data available

[a]This estimate represents the rate of waste generation from households in states other than Khartoum (Hamdalla, 2017)

[b]Schools contributed 27.2 ton/day (32%) of this quantity, at the rate of 0.021 kg/day/student, composed mainly of plastic (42%), paper (39%), and rest is organic waste (CEA, 2014).

[c]It is estimated that about 20% of the waste generated represents hazardous medical waste (Ahmed et al., 2014).

[d]This study was carried in Port Sudan City.

Table 2. Percent Composition of generated waste in Khartoum State (various sources)

Source of Waste	% Plastic	% Paper	% Organic	% Other	Year	Source of the Data
Domestic-households	14.43	11.01	66.32	8.24	2011	CEA (2014)
	10.86	4.61	52.82	31.71 [a]	2016	EWASCO (2016)
	13.03	5.27	49.32	24.33 [a]	2013	Elzaki & Elhassan (2019)
Domestic-commercial (businesses, shops, restaurants, schools, etc.)	21.08[b]	39.16	39.06	0.70	2011	CEA (2014)
Municipal solid waste (household & commercial sources)	10 [c]	20	55	15	2013	Abubaker et al. (2014)
	17.45	20.74	31.44	30.37	2013	Mofadel et al. (2016)
	12.7	11.8	49.5	26.0	2013	HCEURP (2014)
Medical waste	DC [d]	DC	DC	DC	2011	CEA (2014)
Electronic waste	DC [e]	DC	DC	DC	2011	CEA (2014)
	DC [f]	DC	DC	DC	2011	Abbas and Ali (2015)

ND indicates no data available; DC indicates a different classification used

[a]Contains high percentage of soil

[b]Schools generated more plastic (41.5%) and less organic waste (20.5%) but same share of paper waste (CEA, 2014).

[c]Estimates of this study include industrial and medical waste

[d]Medical waste is classified into hazardous and non-hazardous

[e]Ewaste classified in different categories with glass and Aluminium from lamps leading (61%) other materials (e.g. Ferrous, Copper, plastic, etc.) (CEA, 2014). Abbas and Ali (2015) found that fans dominated the composition of Ewaste (10.2%), followed by mobile phones (8.5%), and lamps (8.2%)

3.3 SOCIOECONOMIC AND ENVIRONMENTAL IMPACTS OF WASTE GENERATION AND MANAGEMENT

Negative environmental externalities and public health hazards associated with the current system of MSW management in the GKC, include attracting scavengers; insects, mosquitos and flies to breed; unpleasant odour and aesthetic scenery; water and soil pollution; clogging of drains; health risks and fire hazards from open burning; etc., among many others (Abdalla and Balla, 2013; Abubaker et al., 2014; CEA, 2014; Elbaroudi et al., 2015; HCEURP, 2016; EWASCO, 2016).

Very little effort however, has been made to identify and assess the economic, social, and environmental impacts of current state and operations of managing different waste types in Sudan in general, and the GKC. As part of the national communication under the United Nations Framework Convention on Climate Change (UNFCCC), the Higher Council for the Environment and Natural Resources (HCENR) prepares the country's inventory report on greenhouse gases (GHGs) emissions, a section of which is devoted to emissions from the waste sector. Emissions of only three GHGs: CO_2, CH_4, and N_2O are included in the Third National Communication Report or 3NCR (HCENR, 2020). Derivations of GHGs emissions in the report are, again, based on the same assumptions and values of key parameters of waste generation and collection in the GKC that we have earlier identified as likely outlier estimates of the true value of these parameters. Also, The 3NCR covers only a subset (open dumping, burning, and incineration) of the entire waste supply and processing value chain. This represents the only source of information on environmental impacts of waste management in the country that we could find.

Similarly, information on the contribution of current systems of municipal waste management to UPOP is regularly reported as part of the NIP for POPs (HCENR, 2007). Some limited attempts have been made to report on health hazards associated with managing medical waste (Tairab, 2009; Daifa, 2015) and other waste (electronic and electrical, etc.) (CEA, 2014). We could not find any other work attempting to assess the many social, economic and environmental impacts of the state of waste management in the GKC.

3.4 GOVERNANCE, POLICIES, AND PLANNING FOR IMPROVED WASTE MANAGEMENT

Since the early years of the 20th century, responsibility for managing waste in the GKC rotated between local municipal AUs and the currently named: Khartoum Cleaning Company (KCC). The said authorities continue to share the responsibilities of collecting, transporting and disposal of waste from the 301 AUs constituting the seven localities of the GKC, mainly using own resources but also outsourcing private service providers. Waste is collected regularly from various locations in the city suburbs, commercial and industrial centres and transported for final dumping at the three open landfills (Taiba Elhasanab, Abu Wilaidat, and Hattab) in the three GKC sections of Khartoum, Omdurman, and Bahri, respectively. Collected waste is transferred to final dump sites through intermediate waste collection stations. Up to now, the system of waste management in the GKC can be considered resembling the typical case of "low coverage and irregular collection services, open dumping and burning without air and water pollution control", a practice common to most developing countries (Abubaker, 2014). Consequently, the natural ecosystems and human population in the city continue to bear the burdens of environmental degradation and health hazards caused by such poor systems of waste management.

Performance of the system of waste management has seen some improvements in recent years as a result of efforts by the Khartoum State Government (KSG), particularly with respect to collection and transfer of MSW (HCEURP, 2016). Taking advantage of major financial and technical assistance from the Government of Japan, the KCC and KSG Localities invested in building five new waste transfer stations in Ombadaa, Soba, Karari, AbuSeid, Al Andalos, and Wad Dafeea; and upgrading existing landfills at Hattab in Bahri, Taiba El hasanab in Khartoum, and Abu Wilaidat in Omdurman. Through JICA's assistance the waste collection and transport infrastructure and skills of the KCC and KSG Localities' staff and operational capacities of their mechanical fleet have been greatly enhanced since 2013 (Hamid, 2019; Mohamed, 2019). KCC and Khartoum State Localities operational budgets are financed through revenue from levies on waste collection and management services, which covered only about 50% of total operational expenses in 2019 (Hamid, 2019). This indicates how tight is the financial constraint under which these agencies operate and the significant direct subsidisation needed from the government of the state.

To address the worsening waste management situation, the Governor (Wali) of Khartoum State (KS) issued an order to launch The Khartoum State Cleaning Project (KSCP) in 2001. This was followed by a number of state legislations to regulate waste management, most important of which is the Temporary State Law No. 22 of 2014 instituting integrated waste management (IWM) in KS and establishing the KCC to take full responsibility of waste management in the State (Ahmed and Ahmed, 2015). The KCC developed full strategy and vision for reforming KSCP and implementing IWM. The KSG waste management strategy contained very comprehensive short, medium, and long term goals and implementation plans for instituting detailed specifications of standards for management of waste in all sectors of economic activity (Ahmed and Ahmed, 2015). All the projects proposed in the KSG waste management strategy were incorporated in the HCEURP master plan (HCEURP, 2016). One major weakness in the design of the master plan is the fact that all its very detailed intervention strategies and measures have been derived based on outlier values of key parameters of the system, such as estimates of the quantity of MSW generated (i.e. 0.778 kg per day per capita) and current and possibly inaccurate collection rate of 65%, as identified earlier.

Implementation of the KCC waste management strategy and the master plan is currently underway. The still to be developed and enforced principles and standards for monitoring and evaluation of performance continue to delay instituting clear policies, guidelines, and codes to be observed and complied with at various sectors (Osman, 2010; Ahmed et al., 2014; CEA, 2014; Ahmed, 2019).

4. STRATEGIC ENVIRONMENTAL ASSESSMENT FRAMEWORK FOR INTEGRATED SOLID WASTE MANAGEMENT

Traditional processes associated with generation and disposal of solid waste are linked to several negative environmental externalities. Integrated solid waste management (ISWM) has been promoted as a more environmentally friendly and economically efficient approach to managing solid waste (UNEP, 2009; UN-Habitat, 2009; Herva et al., 2014; Srivastava et al., 2014; Sadef et al., 2016). ISWM is a systems analysis approach, which considers all phases in the waste generation and disposal process as integral components of one system that needs to be jointly managed. In the ISWM model, waste passes through various stages in a long value chain from generation to its final destination, as illustrated in Figure 3. Many agents are involved, employing different institutional arrangements and management techniques at the various phases of the value chain through which solid waste flows (Srivastava et al., 2014; Ikhlayel et al., 2016; Sadef et al., 2016).

The 3Rs of reducing, recycling, and reusing (recovery) of waste define the principles of optimal interventions to achieve an efficient and sustainable system of ISWM (Srivastava et al., 2014; Sadef et al., 2016; Paul et al., 2019). The material balance of ISWM can be traced along the waste supply value chain depicted in Figure 3. Institutional and technological options suitable for application of the 3Rs principle vary depending on the stage at which waste is flowing along its value chain. Optimality of the type and combination of intervention measures along the waste management hierarchy, therefore needs to be evaluated in terms of environmental and socioeconomic desirability.

Different intervention options of the 3Rs suit different phases of the waste management hierarchy. The first R (reducing) for instance, is appropriate at all stages of the value chain, starting from prevention or avoidance at the pre-generation phase. Several regulatory, technological and economic policy measures have been experimentally applied to induce reduction of waste at pre-generation (e.g., regulating production or taxing use of plastics, deposit requirement on bottles and cans, subsidizing alternatives to single use non-degradable carriers, educating and raising awareness of the public, etc.) (Defra, 2010; Staniskis, 2010; Fischer et al., 2011). Quantity of waste can also be reduced during post-generation phases through separation, recycling and reuse. Separation allows diverting different types of waste (i.e. paper, glass, plastics, metal, organic) for recycling and further processing. Reuse and resource recovery are possible at various stages of the flow, particularly at landfills. Examples include composting of organic waste and waste to energy processes (e.g. generation of heat and electricity through biogas combustion, incineration, etc.). Different options in the 3R measures have different environmental and socioeconomic benefits and costs that need to be compared to evaluate their optimality (Watson and Bulkeley, 2005; Staniskis, 2010; Herva et al., 2014; Milutinovic, 2017).

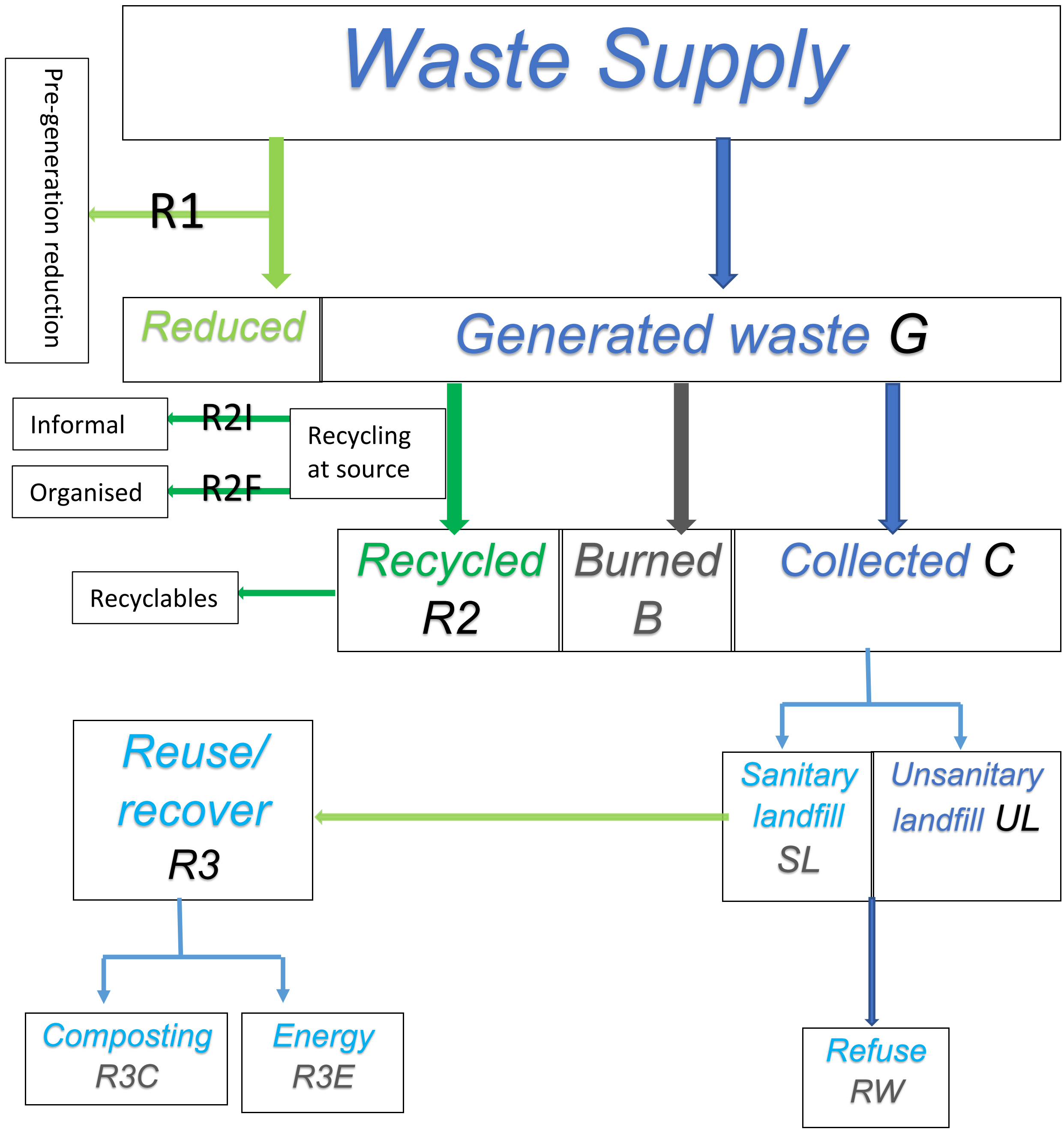


Figure 3. The solid waste supply chain

<u>Material balance:</u>

$G = C+B+R2$; $C = UL+SL = R3+RW$; $R3=R3C+R3E$

Strategic environmental assessment (SEA) is recommended for conducting such evaluations of alternative courses of actions and plans. Unlike the environmental impact assessment (EIA) technique, which is applied at a specific project level, SEA is employed to evaluate alternative strategic options at earlier stages in the planning and decision-making processes (Finnveden et al., 2007). The use of SEA for ISWM has grown after several donor agencies, including the European Union (EU) promoted application of its procedures in planning their development assistance programs (Brooke *et al*., 2004; Nilsson *et al*., 2005; Salhofer *et al*., 2006 and 2007; Chaker et al., 2006; Finnveden et al., 2007; Fischer et al., 2011; Milutinovic et al., 2017).

Many analytical techniques, such as life cycle analysis (LCA), risk assessment, material flow accounting, energy entropy methods, cost-benefit tools, among others, have been used within the SEA procedures to evaluate the environmental and socioeconomic impacts of alternative strategic planning and policy options (Finnveden et al., 2007). Steps of conducting an SEA follow procedures similar to those of EIA studies, starting with a scoping exercise to identify potential environmental risks to be assessed, evaluation of alternative options for management and mitigation of risks, peer review and public consultation, presentation of assessment recommendations and plans for monitoring implementation of an environmental management plan (Fischer et al., 2011).

4.1 ENVIRONMENTAL IMPACTS AND SOCIOECONOMIC COSTS AND BENEFITS ASSOCIATED WITH ISWM

Several negative and positive environmental impacts are associated with waste generation and disposal processes (Fischer et al., 2011; Ikhlayel et al., 2016; Srivastava et al., 2014). SEA is employed to evaluate alternative options considered for minimizing negative and enhancing positive impacts of an ISWM system. In addition to the potential environmental impacts of each of the proposed ISWM plans, implications for key socioeconomic aspects of affected parties are also assessed in the SEA (Chaker et al., 2006; Fischer et al., 2011). Table 3 provides a summary of the major types and nature of environmental and socioeconomic impacts identified in the literature to accompany different states of alternative solid waste management systems.

All phases of the waste management chain of activities have both direct and indirect implications for human health. People living in close proximity to waste dumping sites, or engaged in formal and informal waste collection, transport, and recycling are exposed to many health hazards. Waste dumps provide favourable feeding and breeding environments for all sorts of insects (e.g., flies, mosquitoes, etc.) that cause many diseases like malaria and others. Open burning of waste and air, soil and water pollution from waste are sources of many risks to human health (see Srivastava et al., 2014). Increased concentration of metals and other hazardous materials (e.g., total dissolved solids, total oxygen demand, chloride, sulphate, nitrate, etc.) contaminating soils and surface and ground water have been linked to solid waste disposal (Nagarajan et al., 2012). A number of green house and other gases are emitted from anaerobic decomposition of the organic contents of solid waste in dump sites and landfills (Ikhlayel et al., 2016)[2]. In addition to being the source of 30% of all global methane emissions, landfills also occupy extensive land areas and thereby eliminate other alternative productive land uses (Fischer et al., 2011).

Different systems of waste management at different phases of the waste supply hierarchy are associated with different socioeconomic implications, some of which are beneficial while others are harmful. Recycling and reuse of waste for instance, reduce the amount of terminal waste to be disposed of, as well as eases the need for further exploitation of natural resources (e.g., land use). In addition to easing the demand side pressure, solid waste management provides opportunities for augmenting the supply of natural resources by recovering valuable materials (e.g., fertilizers) and energy (e.g., fuel, heat and electricity) from conversion of organic and inorganic waste. Solid waste management also has the potential to contribute to generation of income and employment opportunities, particularly among the poor and disadvantaged groups, such as the case with informal recyclers (Fahmi and Sutton, 2010; Srivastava et al., 2014; Tedde, 2014; Sadef et al., 2016). At the same time, setting of some waste management infrastructures (e.g. landfills) may come at the expense of displacing human communities or disrupting the health and functional integrity of sensitive ecosystems.

ISWM strategies thus aim to move the system away from the inefficient and environmentally undesirable environmental impacts posed by little or not treatment before disposal of waste to landfills. This can be achieved through increasing the shares of waste in the 3Rs segments of the hierarchy. Accordingly the alternative ISWM options to be evaluated will constitute different plausible combinations of the waste management practices of Table 3.

[2] The share of MSW in total global GHGs emissions (estimated at 2%) is higher than that of air traffic (1.5%) and not far from the 2.5% share of ship and rail transport (Fischer et al., 2011).

Table 3. Environmental and socioeconomic impacts of different solid waste management practices [a]

SWM Practices	Open Burning B	Recycling (Informal) R2I	Recycling (Formal) R2F	Unsanitary Landfills UL	Sanitary Landfills SL	Resource & Energy Recovery (R3)		
						Composting R3C	Biogas R3E	Incineration R3I
Water pollution								
Chloride	L+	L-	L-	H+	L+	L+	L+	L+
BOD	L+	L-	L-	H+	L+	L+	L+	L+
TOC	L+	L-	L-	H+	L+	L+	L+	L+
Sulphate	L+	L-	L-	H+	L+	L+	L+	L+
Nitrate	L+	L-	L-	H+	L+	L+	L+	L+
Suspended solids	L+	L-	L-	H+	L+	L+	L+	L+
Atmospheric pollution								
GHG (CO_2, CH_4, NO_x)	H+	L-	L-	L+	L+	L+	L+	M+
Other Gases (CO, H_2S, HCl)	H+	L-	L-	L+	L+	L+	L+	M+
Soil pollution	L+	L-	L-	M+	L+	L-	L-	L-
Health hazards	M+	L-	L-	M+	L+	L+	L-	L+
Visual & odour beauties	H-	L-	L-	H-	M+	M-	N	N
Land area used for waste	M-	L-	L-	H+	H+	M-	M-	M-
Damage biodiversity & ecosystems health	L+	L-	L-	M+	M+	N	N	N
Displacement of communities	N	N	N	H+	H+	N	N	N
Energy benefits	M-	L-	L-	M-	L-	L+	H+	M+
Fertilizer benefits	M-	N	N	M-	L+	H+	L+	N
Employment benefits	L-	M+	M+	L+	L+	M+	L+	L+
Poverty reduction benefits	L-	H+	L+	N	N	L+	L+	L+
Infrastructure costs	L-	L-	L+	M+	H+	L+	M+	H+

L, M, H, and N refer to low, medium, high, and neutral impacts, respectively.

Signs (+) and (-) indicate impact increasing and impact decreasing effects, respectively

a. Letters B, R2I, R2F, UL, SL, R3C, and R3E refer to the SWM activity indicated in Figure 3.

5. SOURCES AND METHODS OF DATA COLLECTION

Credible baseline information is essential for conducting the intended assessment. As described in Section 4 above, implementing the SEA analytical framework for IWM involves developing and comparing alternative strategic options for improving the current system of waste management with the business as usual scenario. Poor baseline information can misguide identification and specification of intervention opportunities for reforming the current system and in turn weakens the validity and optimality of choices to be made. Data needed to improve the quality of available baseline information are determined on basis of the gaps identified in our analysis of existing knowledge about the system of waste management in the GKC. The following are main gaps identified for the current study to address:

1. Good data on household waste generation is available, but information on collection efficiency (i.e., percentage of waste collected, and accordingly what goes missing in between) needs further interrogation.
2. Available data on waste from commercial centres (markets, restaurants, etc.) suffer some deficiencies, particularly with:
   i. Collection efficiency (how much is collected)
   ii. Some sections not well covered, such as institutional waste (e.g,. business/office complexes including main university campuses and private and public entitites).
3. Information available on quantities of medical waste generated show significant variations between the few sources of these estimates, and data on collection and post-collection treatment activities is poor.
4. Data on industrial waste is largely lacking (both on generation and post-generation).
5. The large gap between quantities of waste generated and volumes reaching dumping sites indicate significant post-generation activities are not accounted for. While most studies seem to suggest that there is basically very little formal recycling, available numbers on the magnitude of waste missing in the flow suggest that informal waste separation and recycling by Nakasha and Barkata handle a significant share of MSW, on which no information exists. This gap was noted by the HCEURP master plan, which recommended undertaking detailed study of the size of this informal activity and scale of domestic and export markets for its products, in terms of number people involved, and types and quantities of recyclables exchanged (HCEURP, 2016). As noted earlier, the only source of

information on these activities is the study by Ahmed (2016), which provided some general overview of selected attributes of informal plastic waste separation and recycling.

6. Open burning of waste by road sides and illegal dumping sites has been reported but no data available on its size and share in generated waste.
7. Limited assessment of environmental and socioeconomic impacts. Apart from available information on GHG emissions, the impacts on many other important aspects of environmental quality and ecosystems' health and their consequences for human health and well-being, have not been investigated. Even GHG emissions have only been measured for the current system of SWM but not for the wide range of alternative ISWM options displayed in Table 3.
8. No information on quantities of other waste (e.g., construction and electronic waste, agricultural refuse, used oils and lubricants and tyres).
9. Existing knowledge about hazardous waste is also very limited.

It is important to note that this study does not intend to cover the types of waste defined in points 8 and 9 above (e.g., electronic, hazardous waste, etc.) Data needed to close above identified gaps were collected from various sources. Secondary data of relevance is compiled from documentary sources (e.g., official statistics from records kept by various agencies, published and unpublished reports/studies, etc.). The study also conducted surveys for primary data collection. Key informants (i.e., officials of federal, state, and local level public and private institutions, researchers, community leaders, etc.) were surveyed individually or in groups. Samples of informal waste collectors have been interviewed on aspects of relevance to the assessment. Some direct field observations and measurements were also carried out. Information was compiled on the current operation of the entire value chain of the system of waste generation, collection, processing and resource recovery. The surveys gathered data on sources, quantities and composition of the various types of waste, how and who handles collection and processing, and the final destiny of remaining waste materials. In addition, data on other socioeconomic attributes of the system have been collected, including governance regimes, waste management policy and regulations, among others. Based on the gap analysis summarised above, we carried the surveys described in subsequent sections to collect data needed to implement the assessment.

5.1 WASTE COLLECTION EFFICIENCY SURVEYS

To complement secondary data on waste collection activities compiled from institutional records of the KCC, we carried surveys at intermediate waste transfer stations and final dumping sites. The purpose of these surveys was to validate official records of the KCC information system monitoring the agency's waste collection operations. Accordingly, these surveys conducted direct recording of amounts of waste arriving at and leaving the three intermediate transfer stations in Khartoum, Omdurman, and Bahri towns, and amounts received at the three landfills at Abo Wilaidaat, Taiba, and Hattab. To account for possible variations in operational circumstances, the surveys have been repeated several times during different days and different weeks at each of the waste transfer and final dumping sites by our field enumerators capturing information independently of the KCC recording system. To correct for biases that could arise from the prolonged Covid-19 lockdown, surveys have been repeated during and after the lockdown (i.e. in normal days). Enumerators spent full days at the sites recording numbers and capacity of vehicles arriving and leaving the surveyed sites as well as the source and destination from and to which the transported waste is designated, and conducting direct visual inspection of carried weights for validation. The data collection instrument used for this purpose is presented in Annex 1.

5.2 MEDICAL WASTE SURVEYS

To fill the gaps identified above, this study attempted to address the observed discrepancies in reported generation rates, and gather information on collection and post-collection treatment of medical waste. No surveys have been carried in hospitals and other health services centres and needed data was compiled from secondary sources. We surveyed entities engaged in collecting and processing medical waste, including federal and state health ministries and municipal authorities, as well as private service providers such as the Saudi-Sudanese Group SEPCO, among others (Ahmed and Idris, 2020).

5.3 INDUSTRIAL ACTIVITIES' SURVEYS

A sampling frame listing industrial establishments in the GKC and their location, together with other attributes (production capacity, ownership, etc.) was obtained from the most recent industrial surveys (KSMI, 2018) and used for selection of the sample for this survey. Based on available budget and time constraints a total sample of 120 industrial processing establishments has been determined, which represents 8% of total number of factories currently in operation in the GKC.

Certainly, quantities and composition of waste generated from these industrial units vary depending on the nature of the industrial process in question and operational capacity of the unit (e.g. total production, number of employees, etc.). We therefore employed the stratified cluster sampling technique to design the sample of units to be included in the survey. Industrial establishments have accordingly been classified into 18 (6 x 3) strata based on type of industry (6 types) and location (3 locations representing the three towns of the GKC). A uniformed sampling fraction of 8% has been applied to select subsamples from each the 18 strata. Because of the fact that many very small industrial establishments have been enumerated in the industrial survey, we have chosen to include only units with at least 25 employees. Units that were not in operation at the time of the survey have also been excluded. Due to the rule of selecting at least one unit from each stratum our final sampling fractions deviated in some cases from the 8% ratio (see Annex 2). A structured questionnaire was designed and pretested for collecting the industrial waste survey data (see Annex 3).

5.4 SURVEY OF INFORMAL WASTE SEPARATION AND RECYCLING ACTIVITIES

Due to the fact that little information is available on activities of this important segment of the waste supply value chain in the GKC, we decided to invest major efforts in improving the current state of knowledge about the size and functional value of these activities. For proper planning of our survey, pilot tours have been carried to locate the whereabouts of these activities. Our pilot tours located major operations and concentration of informal waste separation and recycling activities at waste transfer stations and landfills. We conducted surveys in all these sites. Samples of informal waste separators were randomly selected and interviewed at each of these sites. Data collected from informal pickers' surveys was supplemented by information compiled from key informants, particularly staff of the KCC at dumping sites where these activities are performed. A semi-structured questionnaire (see Annex 4) was used to collect information on the number and socioeconomic attributes of people involved in these activities, types and quantities of recyclables they process, and where and to whom do they sell their goods.

Our pilot surveys also identified many smaller concentrations of activities of informal waste separators in all residential suburbs, as well as at scattered set of random illegal waste dumping sites, market centres, and business and industrial areas. Barkata bring their collections of recyclables from these sites to sell to middle traders at weighing points (shops) spread all over the GKC. These represent the first point of trade in this value chain of informal recycling of solid waste. Information on the types, amounts, and prices of delivered recyclables, and numbers of informal waste separators arriving at these points was acquired from traders in all major recyclables' shops in the three towns of the GKC. Samples of Barkata operating in a selected set of suburbs in the three towns were also interviewed for additional information, particularly on their socioeconomic attributes (Hamdalla, 2020).

Our surveys also covered the second point of trade in this value chain, at which middle traders deliver to plastic shredders, who then sell pieces of more finely shredded plastics in a third stage to plastics factories and exporters for processing. Detailed description of the sample and sites where these surveys have been conducted are given in Hamdalla (2020).

5.5 THE DATA ON ENVIRONMENTAL IMPACTS

Our surveys found very limited information on the many social, economic and environmental impacts of the state of waste management in the GKC. Emissions of only three GHGs, namely CO_2, CH_4, and N_2O are reported in the Third National Communication Report – 3NCR prepared for the UNCCC (HCENR, 2020). As noted earlier estimates of GHGs emissions in the report were are based on the same assumptions and values of key parameters of waste generation and collection in the GKC that we have earlier identified as likely outlier estimates of the true value of these parameters. The 3NCR provided estimates of GHG emissions from open dumping, burning, and incineration, out of the entire waste supply and processing value chain. This confirmed the need for major efforts to close this big gap in available literature.

6. FUNCTIONAL ATTRIBUTES OF THE CURRENT SYSTEM OF SWM IN THE GKC: THE BASELINE

Data collected from the various primary and secondary sources described above were used to estimate the value of key parameters of the system of SWM currently in place in the GKC. We first characterize the state of the current system of SWM in the GKC to represent our updated baseline. Table 4 presents summaries of the main characteristics of the current system, and specifies its key parameters benchmarked against relevant data for similar developing countries' regions. Recycling and processing of solid waste activities, specially the role of informal waste pickers is then assessed.

6.1 SOLID WASTE GENERATION (G) IN THE GKC

Results of our assessment of the data indicate that the GKC currently generates 3,340 tons of solid waste every day, most of which (96%) come from domestic sources (3,200 tons). Households contribute 95% (3,040 ton) of the domestic waste. The remaining solid waste is supplied by industrial (92 tons/day) and medical (48 tons/day) sources. Organic materials constitute 56% of the contents of all solid waste, while plastics and paper contribute 8% and 16%, respectively (Table 4). One must note however, as will be explained later, that more than 90% of solid waste generated by industrial activities is recycled at premises (within own industry) and the remaining little unrecycled portion (92 tons) goes to the general pool of the to be collected solid waste.

6.2 Collection and separation of solid waste in the GKC

At present, only 31.5% of all waste generated (G[3] in Figure 3) in the GKC is collected by respective authorities (e.g., KCC plus a few private collectors). Collected waste is transported to waste transfer stations (CTS in Figure 3), or in some cases, directly taken for final dumping at landfills (see Annex 7 for more details on the flow of collected waste in the GKC). Except for recycling within the industrial sector, there is no organised formal waste separation and recycling at source (RSRF = 0), transfer stations (RTSF = 0), or landfills (RLFF = 0). Informal waste pickers (Nakasha/Barkata) manage to separate and recycle an amount of 109 tons

[3] Note that G here does not include waste recycled at premises within the industrial sector (see Table 5).

(3.3%) per day at source (Table 4), i.e. before collection (RSRI in Figure 3). This reduces the amount of waste to be collected at source to 3,231 tons (G - RSRI = 3,340 – 109 = 3,231).

Only 1,018 tons of this waste (CTS in Figure 3) are collected and moved to transfer stations (see Annex 7 for details), which suggests a low collection rate of 31.5% (1,018 of 3,231 total tons) at source. The significant share of uncollected waste (2,213 tons) is either burned by residents in open roadside fires (BSR in Figure 3) or left to decompose. We could not measure amounts of burned waste but our field observations and information provided by key informants suggest that no less than half of the uncollected waste is burned at the source, and include mainly paper, carton, old cloth, and organic waste.

While no waste separation takes place at transfer stations (i.e. RTSI = RTSF = 0), informal waste collectors continue their unorganised waste separation and recycling activities at landfills (RLFI). All waste moved to transfer stations is delivered to final landfills (CTS = SL+USL = 1,018 tons), out of which the Barkata continue removing another amount of 124 tons (12.2%) before final dumping (RLFI in Figure 3). Open burning of waste also continues at final landfills (BLF). Again, it was difficult to estimate the portions of the remaining waste that are burned at those sites.

Except for as little as 5 tons per day of plastic shredded at the recycling facility built at Abu Wilaidat landfill, no other waste processing and recovery activities (R3C and R3E in Figure 3) are taking place at final or end point landfills. Which means that all remaining waste is dumped as refuse (RW in Figure 3). Three landfills are now operating in the GKC, all of them are considered unsanitary (e.g. has no gas collection or leachate water recovery mechanisms). The described current practice characterises our Status-Co Scenario presented in Table 6.

Table 4. Sources and quantities of waste generation in the GKC compared to relevant regions in the developing world

Source of Waste	Composition (%)			% collected	Amount per day		Source of the Data
	Plastic	Paper	organic		Kg/person	Ton [a]	
Households	13	7	56	45	0.38	3,040	GKC Tables 1&2[b]
	13	**7**	**56**	**45**	**0.38**	**3,040**	***GKC 2020 Status-Co scenario*** [c]
Commercial (including schools, varsities, and business offices)	16	18	48	ND	0.02	180	GKC Tables 1&2[b]
	16	**18**	**44**	**45**	**0.02**	**180**	***GKC 2020 Status-Co scenario*** [c]
Domestic solid waste (households plus commercial)	13	17	48	45	0.40	3,200	GKC Tables 1&2[b]
	12	**16**	**54**	**31.5**	**0.40**	**3,200**	***GKC 2020 Status-Co scenario*** [c]
	9 - 12	6 - 9	65 - 77	40 - 65	0.4 - 0.6	-	East Africa[d]
	4 - 15	6 – 16	42 - 74	48 - 72	0.12 - 1.8	-	Asia[e]
	11 - 16	10 - 16	53 - 68	40 - 95	0.4 – 0.9	-	Middle East and North Africa[f]
Industrial	ND	ND	ND	ND	0.03-0.26	-	Middle East and North Africa[f]
	ND	ND	ND	ND	0.05	400	GKC Tables 1&2[b]
	25	**21**	**24**	**21.9**	**0.01**	**92** [g]	***GKC 2020 Status-Co scenario*** [c]
Medical	ND	ND	ND	ND	0.003-.004	-	Middle East and North Africa[f]
	ND	ND	ND	ND	0.008	60	GKC Tables 1&2[b]
	ND	**ND**	**ND**	**ND**	**0.006**	**48**	***GKC 2020 Status-Co scenario*** [c]
TOTAL (all waste)	12	14	52	45	0.458	3,660	GKC Tables 1&2[b]
	8	***16***	***56***	***31.5***	***O.418***	**3,340**	***GKC 2020 Status-Co scenario*** [c]

ND indicates no data available

[a]Based on a total population of 8 million people in the GKC (CEA, 2014; HCEURP, 2016)

[b]An average of estimates of available literature summarised in Tables 1 and 2

[c]Based on this study surveys

[d]Okot-Okumu (2012)

[e]Hoornweg and Bhada (2012) and Shekdar (2009)

[f]Negm and Shareef (2018) and El Amine et al. (2018)

[g]This represents only 8% of total solid waste generated from industrial processes, and the remining 92% (1000 ton/day) of own waste is recycled at premises

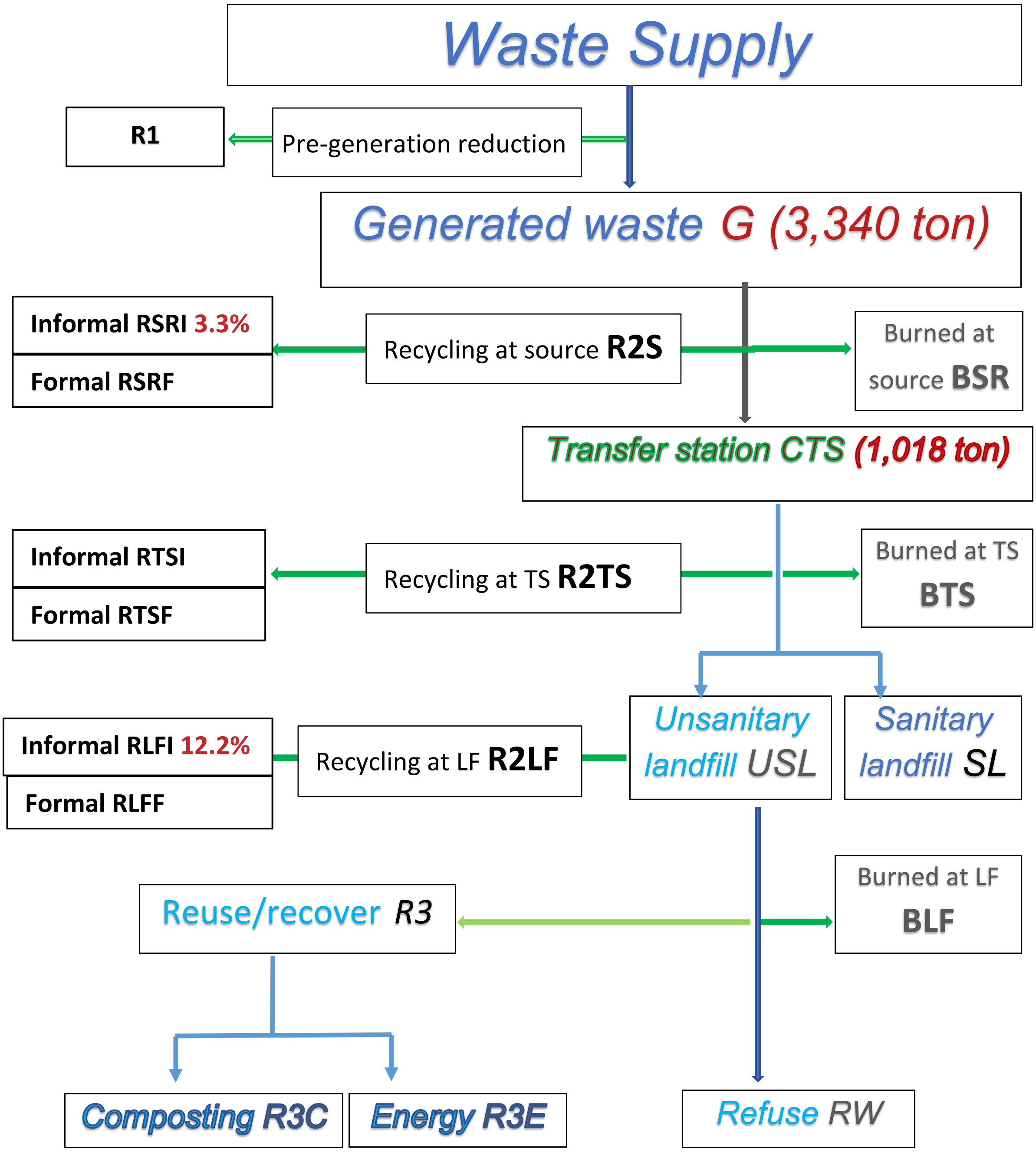


Figure 3. Solid waste flow management options in the GKC

6.3 Waste recycling and processing in the GKC

Our surveys indicate that solid waste segregation and recycling outside industrial premises is at present performed primarily by informal waste pickers (Nakasha/Barkata) and some crew of waste collection companies[4]. Informal waste segregation and recycling activities have been reported to take place throughout the waste supply chain, from generation to disposal at landfills. It is estimated that the livelihoods of 3,900 informal waste recyclers (Barkata) and their families are entirely dependent on these activities (Table 5). The Barkata remove an estimated total of 200.6 tons of plastics, 22.4 tons of metals, 10 tons of carton & paper, and smaller quantities of other recyclables (e.g. cloth, etc.) every day from the waste stream. Our surveys also estimated that among the informal separators are 500 employees of waste collection companies, who engage in waste separation activities (while on the job), collecting 15 tons of plastics per day, to supplement their wages. However, only a small fraction of these products is reused by industrial activities downstream, as the plastic industry rely heavily on imported materials. The bulk of the recycled plastic consists of empty bottles delivered mainly to the export market through a supply chain of middle traders and operators of small waste processing warehouses (i.e., shredders, compressors, etc.), and hence very little beneficiation of this material takes place domestically. This value chain of waste recycling employs 1,600 workers and 800 operators in small plastic shredding and compression units widely spread over the GKC (Table 5).

The significant role of these informal waste separation and recycling activities is evident from the large amount of plastic waste (200.6 tons/day) removed by these agents, which represents 75% of the 267 tons of total plastic waste generated in the GKC (calculated as 8% of all solid waste). Although the percentage of plastics recycled by informal waste separators is relatively high, our direct field observations and assessment of key informants suggest that almost all plastic waste is recycled and very little, if any, is left to decompose or burned at source and dumping sites. This is also confirmed by the fact that the waste separation factory built at the Abu Wilaidat landfill had discontinued due to insufficient arrivals of recyclables and its plastic recycling unit is buying plastic waste from the Barkata. We therefore believe that no less than

[4] This was also observed to be a common practice among waste collection crews as an additional source of income given the poor wages they are receiving from the KCC (HCEURP, 2016). The same practice has been reported by private waste collection companies (e.g., Director of Saudi-Sudanese Group, personal communications).

90%, if not all plastic waste in the GKC is recycled by these unorganized Barkata and associated value chain. The missing portion of plastic waste of 25% could either be due to overestimation of the share of plastics in total waste (8%), or underestimation of amounts of plastics removed by Barkata.

Apart from the high recycling of plastics and some carton and paper waste by informal separators, there seem to be minimal, if any organized processing of solid waste discharged outside premises by residential, commercial, and industrial establishments. This is particularly the case with organic waste. However, in addition to the share of solid waste recycled by informal separators (Barkata), our surveys found significant waste recycling and processing activities at premises within the industrial sector (Alkhalifa and Matter, 2020). Table 6 shows that almost all waste from the carton and paper factories, and 94% and 78% of the waste generated by the food and plastic processing industries are, respectively recycled at premises. We could not collect information on other recyclables that could be of high potential value such as used tyres and electronic waste, among others.

The size and economic value of this informal sector is estimated at about SDP 12 billion per day, employing 6,500 people (Table 5). Although informal waste separators seem to earn a decent income (SDP 461/day) compared to average wages of unskilled workers in this sector (i.e. less than SDP 100/day), it exposes the Barkata to serious health hazards. It is also clear that there is a good potential for even higher economic returns to this activity if better organized, when one considers the much bigger income margins accruing to middle traders and other downstream value addition activities (Table 5). Ways for modernizing and integration of these activities in the formal economic system are therefore worth exploring and seriously considered in policy design as they have a potential to generate significant wellbeing benefits to a large segment of the poorest in the country. In addition to the direct economic, social, and health benefits, these programs will impact positively on the urban environment of the GKC, as the strong evidence from the literature on similar experiences in many developing countries suggests (Wells, 1995, Lardinois, 1996, Iyer, 2001, Scheinberg, 2001, Fahmi and Sutton, 2006, USAID, 2009; Wilson et al., 2009; Nzeadibe and Ajaero, 2009, Parishwad et al., 2016,). Carton and paper materials come second to plastics in terms of the potential value of improvements in their current state and degree of recycling and recovery.

Table 5. Quantity and value of recyclables in the GKC

A. Quantities of Recyclables										
Segment in the value chain	**Agents**	**No. of People**	**Average Quantity of Recyclables (Ton/day)**							**Plastic Kg/capita /day**
			Plastic bags	Plastic liquids	Other plastics	Total plastic	Metal	Carton & paper	Total recy-clables	
1. Waste separation		**3,900**	**16**	**99.8**	**84.8**	**200.6**	**22.4**	**10**	**234**	**54**
Neighbourhoods	Barkata	900	4.5	19.8	19.8	44.1	6.3			49
Market centres	Barkata	800	3.0	13.2	13,2	29,4	4.2	10		49
Dumping sites	Barkata	1,700	8.5	51.8	51.8	112.1	11.9			66
Collection companies	Crew	500	0	15	0	15.0	0			30
2. Processors of recyclables		**2,600**	**0**	**25**	**25**	**100**	**0**	**10**		
Shredding & compression	Workers	1,700								
	Operators	900								
B. Values of recyclables										
1. Waste separators (Barkata)		**3,900**	**Average values of recyclables**							**SDP/capita/day**
Average selling price (SDP/kg)			10	7	10		15	ND		
Total value in SDP 000/day			160	698.6	848	***1,706.6***	336	***ND***		***461.2***
2. Middle traders										
Average selling price (SDP/kg)			20	30	30		25	150		**SDP/capita/day**
Total value in SDP 000/day			320	2,994	2,544	***5,858***	560	1,500	***7,918***	***900***
Value added in SDP 000/day						***4,151***				***1,200***
3. Processors: shredders/compres-sors		**2,600**	**Average values of recyclables**							
Average selling price (SDP/kg)						50				
Total value in SDP day						10,030				
Value added in SDP 000/day						***4,012***				***1,835***
4. GRAND TOTALS		**6,500**				**9,870**	**560**	**1,500**	**11,930**	

Table 6. On site (at premises) separation and recycling of waste within the industrial sector in the GKC

Industrial Sector	Generated Waste			Waste Composition		
	Total waste (ton/day)	Ton waste/ton production	% recycled at premises	% plastic	% carton & paper	% organic
Plastic	14.17	0.16	78	83.5	0.1	11.4
Food	48.07	0.08	94	2.1	3.1	94.2
Carton and Paper	2.16	0.04	100	0.0	100	0.0
Furniture	1.10	0.14	0	0.5	0.5	6.3
Packaging	0.20	0.01	0	0.0	0.0	0.1
Textile	0.04	0.08	0	0.0	25	0.0
Glass	0.20	0.4	0	0.0	0.0	0.0
Total	65.94	0.07	89	19.5	5.6	71.5

Source: This study surveys (Alkhalifa and Matter, 2020)

Two agencies manage the collection and processing of medical waste in the GKC: The Medical and Toxic Waste Administration (MTWA) and the Saudi-Sudanese Group (SSG) Company (SEPCO). The MTWA is a Public Enterprise arm of HCEURP, whereas SSG is a private company. Both companies are licensed by the Khartoum State Department of Health to collect and process medical waste from health services centres. The two companies seem to be competing for contracts with hospitals. While SSG requires separation of hazardous from general waste before collection, MTWA contracts for collection of unseparated waste at a lower fee than that of SSG. This worked in favour of the MTWA contract, leading to a steady drop in the number of hospitals contracted by SSG, as more hospitals switched to the service of MTWA. Currently, 102 hospitals pay for the services of SSG, down from an initial number of more than 400 few years back (Idris and Ahmed, 2020).

The current policy and service charge system is discouraging waste separation at source (i.e. hospitals), and is becoming an important factor behind the problem of discharging hazardous medical waste mixed with general solid waste. This problem is exacerbated by the observed non-compliance of waste transport fleets with the requirement of discharging medical waste at a specific dumping site separate from the general waste dumps. The implication of this practice is increased health risks to which people engaged in medical waste collection and processing are exposed. That is of particular concern for the large number of informal waste separators (Barkata) found at dumpsites, as reported above.

The only medical waste that is currently receiving separation and post-collection treatment is the portion collected by the SSG (8 tons/day), which represents only 17% of all medical waste generated within the GKC. A total of 9 incinerators have been counted in the GKC, seven of which employ thermal burning and the remaining two are steaming facilities (autoclaves). Except for the SSG autoclave the rest of these incinerators are not in operation due to various reasons (Idris and Ahmed, 2020).

7. APPLICATION OF THE SEA FRAMEWORK TO ISWM IN THE GKC

This section presents detailed discussion of the procedure and results of the application of the SEA framework described in Section 5 to evaluating alternative intervention options for improving the efficiency, sustainability, and inclusiveness of the current system of solid waste management in the GKC. Unexploited opportunities for improving the current system of SWM are defined first, based on which scenarios of plausible intervention options are specified. The SEA framework is then used to compare and evaluate the economic, environmental, and social desirability of identified option scenarios for intervention.

7.1 POTENTIAL ALTERNATIVE OPTIONS FOR IMPROVED SWM IN THE GKC

Minimizing waste generation (G), which may include efforts to achieve high recovery of materials and/or energy from the generated waste (i.e., minimal amount of unprocessed waste, specifically waste uncollected from sources plus the residual refuse RW at landfills), are considered the most desirable states in the waste supply chain. Desirable interventions for improved SWM therefore, should aim at moving the waste management system towards smaller G and minimal unprocessed waste residual. Our earlier specifications revealed that the current system of SWM (i.e., STATUSCO Scenario) in the GKC is closer to the bottom of the waste pyramid, e.g., huge portion of the waste uncollected from sources and left to be burned or decompose on roadside (2,611 tons) plus a large refuse RW (894 tons), amounting to 94% of G. Various combinations of the 3R measures depicted in Figure 3 have the potential for enhancing the efficiency and social desirability of the current SWM in the GKC. The following opportunities for improved SWM discussed in the subsections below remain unexploited.

7.1.1 Waste prevention

A number of options for reducing the supply of waste have been successfully tested in many countries. Experiences with policies discouraging the use of nondegradable packaging and carrier materials (e.g., single-use plastic bags), and encouraging use of more environmentally friendly alternatives (e.g., degradable materials and long-lived plastics) demonstrated good potentials (UNDP, 2019). Examples include banning by regulation (Kwori, 2019), or introduction of market-based instruments (e.g., taxes) to disincentivise use of nondegradable single-use materials or subsidies to promote long-lasting alternatives (e.g., bar-coded reusable shopping bags that collect bonus points for each reuse) (UNDP, 2019). Investing in raising public awareness of the importance of proper handling of waste for protection of environmental health is key to influencing positive changes in people's waste generation and management attitudes.

7.1.2 Increased efficiency of waste collection

According to Table 4 only 31.5% of total generated waste is currently collected. This presents an opportunity for improving the efficiency of SWM in the GKC. Available information also suggests that many parts of the GKC are not covered by waste collection services, which provides another opportunity for potential efficiency gains from widening the territory of collection services to reach all areas. Recent efforts by the KCC, with assistance from JICA, to increase the efficiency of waste collection services showed positive results (HCEURP, 2016). Fundamental elements of the KCC (2017-2030) Strategic Plan have been incorporated in a comprehensive Clean Khartoum Master Plan 2 (CKMP2) for 2020-2028 in the GKC. The said CKMP2 focused on improving waste collection efficiency through significant investments in upgrading the waste collection infrastructure (rehabilitation of existing and construction of additional transfer stations and landfills), and enhancing work efficiency (operational capacity, especially technical and managerial skills and acquisition of necessary machinery) (HCEURP, 2016). Two systems of waste collection have been tested by the KCC-JICA project: door-to-door (DRTDR) and fixed time/fixed place (FTFP).

While both systems are currently being tried, a highly unorganised version of the DRTDR system (e.g., collection of waste discharged on streets outside living and working places or dumped in open public sites) dominates waste collection in the GKC. Although the CKMP2 considered the FTFP (collection at fixed time, from fixed communal discharge point at frequency of two days every week) to be more efficient and cost effective than the DRTDR collection, both have advantages and disadvantages when options of managing other phases of the waste supply chain are taken into consideration. The more efficient FTFP system for instance, will most likely exclude the large number of informal waste pickers (Nakasha) currently engaged in segregation and recycling of solid waste at source under the inefficient DRTDR system. This would imply a potentially high social cost. In fact, the FTFP will necessarily seriously limit opportunities for both, informal and organised waste segregation and recycling at source, unless clients will be willing to separate waste at home (i.e., before delivery to segregated communal collection bins). Scenarios that will allow evaluation of these trade-offs will be developed in combination with alternative waste recycling and processing options to be considered in subsequent sections.

7.1.3 Recycling, reuse and recovery of material and energy from waste

The biggest opportunity of all is presented by the fact that solid waste in the GKC currently receives very little processing, except separation and selling of some recyclables (mainly plastic and paper) by informal waste pickers to scrap traders and processors. So many waste processing options have been successfully practiced worldwide. Examples include recovery and recycling of glass, plastic, and paper; reuse of furniture; composting of organic waste; and conversion of waste to energy. Utilization of such waste treatment options requires segregation of waste into recyclables (e.g., glass, plastic, paper, metal, etc.), organic fraction for biological processing (e.g., composting), and other materials for thermal processing (e.g., combustion and gasification) (Subramani and Murugan, 2014).

The CKMP2 contains proposals for initiating solid waste processing activities in the GKC. Proposed projects aim to introduce: (1) waste separation at source, (2) recycling and composting facilities, (3) and incinerators at landfills (HCEURP, 2016). Major research efforts however, need to be undertaken to examine the feasibility of the proposed projects and plan for their implementation (e.g., the CKMP2 recommended recycling studies).

A. Waste separation at source

Many benefits are realized from early separation of recyclable materials from the general waste. Obvious examples include reduction of the volume of waste to be handled and less economic efforts required for cleaning at later stages from contamination by the mix of other waste materials, hence higher market value for recyclables in return. Use of separate bins for segregation and discharge of waste at sources is the proposed instrument for this in the CKMP2. It is not clear however, how this will be operationalised under the promoted two waste collection systems (DRTDR and FTFP). A plan for gradual introduction of separate bins at source after careful pretesting is accordingly proposed in the CKMP.

B. *Recycling and composting facilities*

As noted earlier, at present there are no organized waste treatment and processing activities in the GKC. The main recycling operations are mainly performed by a large number of informal waste pickers (Nakasha) on city streets, at illegal dumping sites in open public spaces, and around formal waste transfer stations and landfills. The CKMP2 proposes establishment of facilities for sorting and recycling of solid waste at new transfer stations in the GKC. Direct competition between the proposed organized waste processing activities and the current role of informal recyclers is inevitable. Moreover, successful phasing in of the planned waste separation at source, is expected to have important implications for the size, type, and location of waste processing facilities to be introduced downstream. Careful assessment of these trade-offs is therefore necessary to conduct, and critical for planning investments in additional waste processing facilities along the waste supply chain. The CKMP2 appropriately recommended undertaking a comprehensive recycling study, that must take into consideration the said trade-offs, particularly options for possible integration of informal waste recyclers in such formal systems of waste treatment.

Like in most developing countries organic matter makes up the bulk (more than 50%) of solid waste in the GKC, which provides another obvious opportunity for extracting significant re-use value. This sizeable potential benefit from proven ways of processing organic waste remains unexploited. The CKMP2 proposes investment in composting of organic waste to extract nutrients for soil enrichment. Alternative treatments of organic waste include the waste-to-energy recovery in the form of biogas fuel. Other benefits from reusing the organic component include reducing the volume of waste to be buried or burned in landfills, and hence lower the pressure on land use and environmental hazards caused by leachate. Choice of the type of treatment and the optimal size and location of such facility cannot be made in isolation from changes taking place upstream the waste supply chain, and hence requires critical assessment of the technical and socioeconomic suitability (USAID, 2009).

C. *Incinerators and recovery of materials and energy at landfills*

Options available for further processing of the large residual refuse at landfills include recovery of energy through thermal treatments and incineration facilities. The environmental and economic benefits from these treatments however, need to be evaluated against potential additional economic costs and environmental externalities associated, particularly with expensive incineration plants.

The CKMP2 contains some plans for upgrading existing landfills that are basically open dump sites not equipped for leachate and methane management and control. Alternative options available for implementing these plans need to also be critically assessed in terms of their economic, social, and environmental costs and benefits as well as optimal timing for the considered interventions. Examples include a stepwise incremental upgrading process starting for instance, with transition from open to controlled dump sites, then move to sanitary landfills. The move to controlled dumps is expected to reduce the visual and health hazards of scattered waste in and around the dump site area caused by informal waste sorting activities. This will, however, impact negatively on activities of informal waste recyclers (e.g., fencing off access for Barkata), who concentrate in and around landfills and hence may require special arrangements. Although initial investment and cost of operating sanitary landfills are high, they surely have much higher social and environmental benefits, in terms of protection against water and soil pollution, and reduction of methane emissions and health risks to waste pickers and landfill workers (USAID, 2009).

7.1.4 Benefits from potential governance reforms

There are opportunities for improving the efficiency and social and environmental desirability of the current system of SWM in the GKC, through some appropriate institutional and governance reforms. For instance, lack of specific by-laws regulating SWM activities, such as waste discharge and dumping by the general public and business entities; informal recycling; role of government, private companies, and community organisations; codes and standards for collection, transfer, and final disposal of waste, and construction of landfills; among others, provide examples of reform areas with significant potential gains.

Compliance with regulations however, requires collaboration from stakeholders (public, private, and communities) involved in generation and processing of waste. This calls for innovative institutional reforms and local governance regimes that promote participation of local stakeholders in decision making and management of waste from generation to final discharge. Interventions with potential to bring about significant improvements in sustainable waste management, such as source separation, payment of levies, and abstention from discharging waste in illegal dump sites, will require collaboration from and change of attitudes of stakeholders. Exploring and testing the suitability and effectiveness of alternative forms of mobilizing support and participation of local stakeholders, such as through community-based waste management, is of high worth and priority. In this regard, one area of institutional reform with high potential for improved SWM, is experimenting with various models for organising activities of informal recyclers in cooperatives or other business enterprises. Serious investment of resources and efforts in means of raising public awareness about sustainable waste management will be critical for promoting needed behavioural changes and compliance with environmental management codes.

7.2 SEA OF SCENARIOS OF PLAUSIBLE INTERVENTION OPTIONS FOR ISWM IN THE GKC

In the remainder of this section, we apply the SEA framework described in Section 5 to evaluate plausible scenarios of alternative ISWM strategies for the GKC. The following scenarios have been developed based on the preceding overview of potential opportunities for improving the efficiency and sustainability of the present system of waste management.

7.2.1 Scenario 1 (STATUSCO)

This is the baseline scenario representing the SWM system currently in place. As shown in Table 7 below, main features characterising this scenario are: A total of 3,340 tons of solid waste is generated every day in the GKC, 31.5% of which is collected and transported through transfer stations to final dumping at open unsanitary landfills. No organised waste separation at source. Only 7% of the waste is recycled by informal pickers (3,900 employed), 46% burned, and remaining 47% left to decompose. Sorting by informal recyclers and open burning takes place at source, transfer stations and landfills.

7.2.2 Scenarios 2 – 8: Source separation, recycling, composting, and energy recovery

We evaluate in these scenarios the plans to phase in source separation under the CKMP2. Different variants of this scenario reflecting different waste processing activities are evaluated. Common to all these scenarios are: (a) collection of all (100%) generated waste, and (b) recycling of all recyclables (plastic, carton, paper, metal, and other), amounting to 24% of generated waste, as shown in Table 4. We also assume that if separation is done at source (i.e. homes, markets, and business premises), segregated waste can be removed directly from the source (i.e., DRTDR collection system) for processing elsewhere, and this eliminates informal recycling. Subsequent processing in this case is assumed to be a formal activity performed by any of the following agencies: the KCC, organised small/medium enterprises (SME) of informal waste recyclers, NGOs and communal cooperatives, private businesses (e.g., plastic, metal, and paper recycling industries).

ii. The first alternative scenario proposes recycling 24% and discharging the remainder (76%). Informal recycling is eliminated, at the expense of losing 3,100 jobs, under source separation, open burning of half (38%) of the unrecycled waste (76%, primarily organic material) continues, and the remaining (38%,) left to decompose in route to and at landfills.
iii. Composting of all organic matter share of generated waste (i.e. the 56% share shown in Table 4), is then introduced in this scenario, leaving only 10% to decompose as RW after burning 10%.
iv. Incineration of the 10% RW (burnable waste) is then added to composting in this scenario, eliminating RW in OLF & open burning remains at 10%
v. This scenario repeats all waste treatment and processing activities of scenarios 4, but replaces composting with biogas production
vi. Scenario 6 repeats Scenario 5 with an institutional arrangement to save employment of Barkata involved in informal separation activities
vii. Scenario 7 recovers energy through thermal treatment instead of incineration
viii. This scenario explores the benefits from discharging residual waste (10% RW) to sanitary landfill (SLF) in this scenario instead of the OLF.

In the remainder of this section, we evaluate the costs and benefits of the above scenarios of alternative strategies for improving the economic efficiency and environmental sustainability of the current system of SWM in the GKC. Quantitative assessment of the merits and disadvantages of each scenario has been attempted where data availability permitted (e.g. jobs, amounts of materials and energy recovered, etc.), and otherwise qualitative evaluations were provided. Above scenarios have been developed introducing interventions in stepwise fashion to evaluate their incremental effects. Obviously, many other alternative scenarios with more possible combinations of intervention options can be evaluated.

Table 7. Plausible scenarios of alternative ISWM intervention options (entries in percentages)

Scenarios	Open burning	Recycling		Com-posting	Energy recov-ery		Incinera-tion	Open landfill	Sanitary landfill
		Informal	Formal		Bio-gas	Ther-mal			
1. STATUSCO	46	7	0	0	0	0	0	47	0
2. Source separation & collection	38	0	24	0	0	0	0	38	0
3. Composting of organic added	10	0	24	56	0	0	0	10	0
4. Composting & incineration of RW	10	0	24	56	0	0	10	0	0
5. Biogas & incineration of RW	10	0	24	0	56	0	10	0	0
8. Biogas & organised informal recycling	10	JOBS	24	0	56	0	10	0	0
9. Biogas & thermal replacing incineration	10	0	24	0	56	10	0	0	0
10. Biogas & RW to sanitary landfills	10	0	24	0	56	0	0	0	10

7.3 RESULTS OF THE SEA

Table 7 compares potential outcomes of the scenarios proposed above to evaluate the environmental and socioeconomic desirability of alternative interventions options. All tested scenarios produce a mixture of desirable and undesirable outcomes. It is clear from Table 7 that all interventions aimed at improving solid waste management mitigate negative environmental externalities and consequent human and ecosystems health risks. These environmental quality gains however, come at some socioeconomic costs. Increasing collection efficiency and introducing separation of waste at source by out-scaling of currently piloted DRTDR and FTFP modalities for instance, impose a high cost on employment opportunities and the livelihoods of some of the poorest urban population groups, the Barkata. On the other hand, reuse and recovery (i.e., composting, biogas, incineration) interventions bring about economic co-benefits in terms of soil nutrients (fertilizers) and energy generation.

Clearly, choice among the considered alternatives involves major trade-offs between their environmental and socioeconomic merits and demerits. Objective evaluation of the implied trade-offs however, requires use of appropriate measures of these outcomes and sound criteria for performing the comparative assessments. The best and easiest criterion for comparing such multidimensional choice options would be to construct a composite measure of the net impacts of each option. This requires measures with a common denominator to use to aggregate the constituent elements of outcomes into one composite measure. Availability of quantitative measures of the various impact outcomes would make this task feasible. This study was able to quantify a subset of potential impacts, particularly economic costs and benefits associated with jobs and recovery of some material and energy contents of solid waste, such as fertilizers from composting and energy from chemical and thermal treatments.

On the other hand, the value of a number of other impacts, especially environmental quality related ones, like reduction of pollution and human health risks, could not be quantified for lack of needed data. Qualitative indicators of the nature and intensity of such impacts have been alternatively used, which cannot be readily added up with quantitative impact measures. This precluded the feasibility of aggregating in one composite index constituents of such multidimensional impact processes. Investing in scientific research to measure the values of identified impacts, especially on some critical environmental processes and services, as well as on human health, where we currently have the biggest knowledge gap, is therefore critical for proper benefit-cost assessments. Assigning values to potential gains in the supply of fertilizers and energy, among other more tangible impacts, is relatively easier than valuing environmental amenities.

To take advantage of the unexploited opportunities of recycling, reuse and recovery, particularly the large share of the unutilized organic waste component will require conducting careful feasibility studies. There are important questions related to deciding on the optimal location for setting up such facilities along the waste flow chain between generation and final landfills. Evaluation of the potential for 3Rs technological innovations needs good costing and efficiency data, given how expensive they are.

The trade-off of highest concern is the loss of jobs in the informal recycling activities[5] that is inevitable with introduction of formal systems of waste segregation at source. This needs to be carefully examined given the role of this group of agents in the current system of SWM in the GKC. Source separation proposals assume willingness on the part of waste generators (e.g., households, traders, retailers, providers of micro services, office and school managers, etc.) to perform waste segregation without a need for a real economic incentive in return. In fact, the CKMP2 hypothesizes that willingness of households will be realised through massive awareness campaigns among stakeholders in participating communities. This hypothesis requires careful interrogation and adequate testing against alternative direct and indirect incentives such as rebates (ie., discounts) on waste collection levies, use of deposits, direct participation of local community elements and organizations in waste management, etc., among the many options experimented with in other countries. Instituting the use of deposits on glass and plastic bottles and cans for instance, may eliminate the need for the services of KCC (e.g., a public entity responsibility), to collect recyclables, which now can be directly delivered to private recyclables' dealers in exchange of the deposit or a market sale price as in the current practices of Nakasha.

[5] The same can be said about waste collection crews reported to benefit from complementary recycling activities while in the job. The expected impact on this group of stakeholders needs to be addressed through provision of better terms of employment as noted in the CKMP2.

Table 8. Potential economic, social, and environmental impacts of alternative SWM intervention opportunities. Potential negative impacts are rated as High, moderate, and low to enable comparative evaluation of opportunities.

	Potential Negative Impacts									
Scenarios	Land use	Water pollution	Air pollution	Soil pollution	Human health	Visual & odour	Positive Economic benefits			Financial costs (considered as a negative impact)
							Jobs	Fertilizer ton	Energy KW	
STATUSCO	High	High	High	High	High	High	6,100	0	0	Current-Low
Source separation & collection	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	3,000	0	0	Moderate
Composting of organic waste added	Low	Moderate	Moderate	Low	Low	Moderate	3,000	800	0	Moderate
Composting & incineration of RW	Low	Moderate	Moderate	Moderate	Moderate	Moderate	3,000	800	+	High
Biogas & incineration of RW	Low	Low	Low	Low	Moderate	Moderate	3,000	0	50+	High
Biogas & organised informal recycling	Low	Low	Low	Low	Moderate	Moderate	6,500	0	50+	High
Biogas & thermal replacing incineration	Low	Low	Low	Low	Moderate	Moderate	3,000	0	50+	High
Biogas & RW to sanitary landfills	Low	Low	Low	Low	Moderate	Moderate	3,000	0	50+	High

One desirable institutional and policy measure would be exploring appropriate business models of organizing informal waste recyclers in cooperatives or any other small business enterprises, supported with access to skill development, concessional credit, modern recycling techniques and equipment, etc. Experimenting with such options have met big successes in a number of developing countries, including the ragpickers in India (Parishwad et al., 2016), the Zabaleen of Egypt (Fahmi and Sutton, 2006), and Catadores de lixo in Brazil (Wells, 1995), among several other cases in Africa (USAID, 2009; Wilson et al., 2009; Nzeadibe and Ajaero, 2009).

Different types of enabling institutional and policy reforms are needed to support the proposed interventions measures. Examples include regulations to deter leaving public places such as open fields, sides of symmetries, mosques, schools, hospitals, and abandoned buildings and construction sites, unfenced and easily accessible to illegal waste dumping. Prevention measures to reduce pre-generation rely mainly on economic policy and legislative rules, such as total ban on plastic bags or taxing their use, and providing an incentive to encourage use of environmental friendly alternatives. Separation of waste at source is relatively easier to regulate for business offices, university campuses, schools, and shopping malls, but economic incentives will work better and be more effective with residential premises.

This exercise illustrates how the SEA analytical framework may be employed for assessment of the desirability of alternative ISWM systems. Clearly, decision support tools (e.g. multi-criteria optimization techniques, etc.) with some weighting of policy makers' goals will be necessary for assessing optimal choices.

8. CONCLUSIONS, RECOMMENDATIONS, AND LIMITATIONS OF THE STUDY

This study applied the SEA approach to evaluate alternative opportunities for improving the current system of solid waste management in the GKC. Available knowledge about the functioning of the waste management system in place is lacking in a number of areas. One main objective of this study, therefore, is to establish better confidence in current estimates of key parameters of the GKC waste management system. With a focus on solid waste, the study employed sound data collection methods to generate credible information on principle elements of the system. Amount and type of generated waste, collection efficiency, and post-generation processing activities were the three main areas where poor quality or missing data have been identified. The study established that the GKC produces 3,340 tons of solid waste every day, at a rate of 0.42 kg per capita per day, out of which 31.5% is collected and transferred to landfills. Very different estimates of these key parameters have been used by various public and private decision makers to design policy reforms and draw investment plans, which poses risks to the financial viability of waste management planning options.

The other important area in need of improved baseline information relates to post-generation waste processing activities, where the biggest potential for improvement lies. Although the presence of informal waste pickers had been noted, available literature seems to suggest that no processing of municipal solid waste is found in the GKC, and no effort was made to generate systematic information on the role of informal pickers in the waste flow cycle. This leads to major misconceptions in technical, human resource, and financial requirements needed to sustain l environmental and socially sustainable waste management practices, with little consideration given to the role and needs of human actors, such as informal waste recyclers in policy making. Our surveys indicated that there are significant solid waste segregation and recycling activities taking place throughout the waste supply chain, from generation to disposal at landfills. These activities are performed by informal waste pickers (Nakasha/Barkata), who currently remove 233 tons of recyclables, amounting to 7% of total solid waste supply. It is estimated that the livelihoods of 3,900 people are highly dependent on these activities. The size and economic value of this informal sector is estimated at SDP 12 billion per day.

Results of this study showed that about 75% of all plastics is currently removed from the stream of solid waste and recycled mainly for export markets. Some knowledge of recycling of carton and paper materials was gained, but more research is desired on the size and value of these products. One limitation of this study however, is the lack of information provided on the state and fate of other recyclables such as used tires, batteries, electronics, and agricultural residues.

Study results also indicated that only 17% of all medical waste generated within the GKC is currently receiving separation and post-collection treatment. Segregation of medical waste at source (e.g., hospitals) is discouraged by the current policy practice. High degree of non-compliance of medical waste movers with the requirements of safe discharge at designated dumping sites separate from the general waste dumps, is reported. This poses a serious threat to the health of people engaged in medical waste collection and processing, particularly the large number of informal waste separators (Barkata) found at dumpsites. About 22% of solid waste from industrial activities is collected and transported by municipal authorities. The study found that very high rates of recycling own waste at premises is currently practiced by most factories, especially within the paper, food, and cartons industries.

It should also be noted that an emerging issue concerns the generation of COVID-related waste, which includes the large amount of disposable personal protective equipment that is generated by healthcare workers in medical facilities, as well as masks worn by the general population. The amount of COVID-related waste that is generated is significant, and will need to be factored in to solid waste estimates for quantity generated, safe handling, and safe as well as environmentally sound disposal needs. Since the majority of the surveys for this study were conducted during a period when COVID did not pose as serious a threat as it does at the time the study was finalized, the authors wish to highlight this as an important aspect of medical waste management that will need to be addressed in the near future.

Other gaps in existing baseline information needed for application of the SEA framework, relate to the type and levels of likely socioeconomic impacts and environmental risks associated with the alternative intervention strategies of ISWM under investigation. Information generated by the study on the size and economic benefits from informal waste processing provided good basis for accounting for potential socioeconomic implications of alternative strategic plans being evaluated. This study also made efforts to acquire data on potential environmental impacts of alternative ISWM options. The said data provided the basis for conducting a SEA of alternative intervention options for improved ISWM in the GKC.

To apply the SEA analytical framework, unexploited opportunities for improving the current system of SWM are defined first, based on which 7 scenarios of plausible intervention options were specified. The SEA framework was then applied to compare and evaluate the economic, environmental, and social desirability of identified intervention options' scenarios, against the baseline scenario representing the SWM system currently in place. SEA of alternative strategies for ISWM in the GKC generated useful information on the economic, social, and environmental costs and benefits of the evaluated options that are of significant value for improved policy making and strategic ISWM planning.

All tested scenarios gave a mixture of desirable and undesirable outcomes. Generally, tested intervention options achieved positive results in mitigation of the negative environmental externalities and consequent human and ecosystems health risks. Environmental quality gains however, are realized at some socioeconomic costs. Increasing collection efficiency and introducing separation of waste at source by out-scaling of currently piloted DRTDR and FTFP modalities for instance, impose a high cost on employment opportunities and the livelihoods of some of the poorest urban population groups, the Barkata. On the other hand, reuse and recovery (composting, biogas, incineration) interventions bring about economic co-benefits in terms of soil nutrients (fertilizers) and energy generation.

A sound composite measure of the net impacts of each of the compared alternatives was necessary for an objective evaluation of the implied trade-offs between these multidimensional choice options. This requires measures with a common denominator to use to aggregate the constituent elements of outcomes into one composite measure. This study was able to quantify the economic costs and benefits associated with jobs and recovery of some material and energy contents of solid waste, such as fertilizers from composting and energy from chemical and thermal treatments. The study however, could not measure values of environmental quality impacts, like reduction of pollution and human health risks for lack of needed data. Qualitative indicators of the nature and intensity of such impacts have been alternatively used, which did not allow aggregation of all impact values into a single composite measure. This points to the necessity of investing in scientific research to measure the values of identified impacts, especially on some critical environmental processes and services, as well as on human health, where we currently have the biggest knowledge gap.

To take advantage of the unexploited opportunities of recycling, reuse and recovery requires conducting careful feasibility studies. Deciding on the optimal location for setting up such facilities and proper costing and measurement of the technical efficiencies of potential 3Rs intervention options are key prerequisites. Potential loss of jobs in the informal recycling activities due to introduction of formal systems of waste segregation at source is the trade-off of highest concern. Careful interrogation and adequate testing of the effectiveness of incentive and deterrence policy, such as rebates, use of deposits, direct participation of local community elements and organizations in waste management, etc., will be necessary.

Based on the above summary of study findings, we could make the following conclusions and recommendations:

- Pre-generation waste prevention measures, such as use of taxes, incentives and regulation instruments (e.g., banning use of plastic bags) have not been exploited, and hence present intervention opportunities with high improvement potential
- DRTDR collection systems using separate bins are likely to work and need to be further tested for:
  - Institutional waste (schools, varsity campuses, office & industrial premises, hospitals, etc.)
  - Organized commercial activities (supermarkets, etc.)
  - Households in high income suburbs.
- On the other hand, FTFP collection of unseparated waste may be more suitable for low and middle income neighbourhoods

- Major job losses in the informal waste separation and recycling are expected with introduction of source collection and collection systems such as the two piloted DRTDR and FTFP methods. This presents a major concern and requires careful examination and planning before introduction, given the current role of informal waste pickers in separation and recycling of solid waste. Examples of options for intervention to mitigate this negative socioeconomic impacts include:
  - Assessment of options for integrating informal waste separators (Barkata) in the intended formal recycling & processing systems
  - Exploring appropriate business models to organize informal pickers in cooperatives or any other SMEs, supported with access to skills development, concessional credit, modern recycling techniques and equipment, etc.
- Introduction of incentives such as use of rebates (discounts) on waste collection levies, deposit refunds, and other relevant policy measures need to be tested for promotion of waste separation at source.
- Massive public awareness and education campaigns to enhance ownership, willingness, engagement and participation of local community elements and NGOs – friends of the environment initiatives are necessary for achieving environmentally sound and inclusive solid waste management systems
- Exploring opportunities to modernize and raise the efficiency of existing plastic, paper and carton recycling activities have good potential for improved SWM
- Best ways for exploiting the potential in recycling and reuse of the currently unutilized large share of organic material in solid waste in the GKC calls for urgent attention. Detailed feasibility studies are necessary to investigate key questions on optimal locations for setting up needed separation, composting and energy recovery facilities, and informing the choice between biogas and composting, among other essential technical efficiency aspects of choosing between such alternative intervention options
- Incineration and thermal processing options need good costing and efficiency data, given how expensive these technological innovations and related environmental mitigation are
- Designing and introduction of appropriate regulations of discharging waste in illegal sites and open public spaces, and fines for not protecting and fencing of private properties vacant or under construction works giving free and easy access for waste dumping, need to be explored and tested
- Regulating discharge of construction and demolition debris must be enforced
- Major knowledge and information gaps need to be addressed, including:
  - State of post-generation processing of other recyclables (tires, batteries, electronics, etc.)
  - Measuring and valuation of environmental impacts
- Enforcement of regulations and policies for the safe discharge of medical waste, particularly collection, segregation and treatment of toxic and infectious waste to prevent health risks, many agents are

exposed to along the waste supply chain. Careful assessment of available alternatives for on and off site waste treatment options must be conducted

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ANNEX I. WASTE COLLECTION EFFICIENCY SURVEY QUESTIONNAIRE

Name of site .... Date ....

Serial number	Vehicle Registration No	Capacity (ton)	Actual load (ton)	Type of waste (general, medical)	Remarks

ANNEX 2. SAMPLE DESIGN OF THE INDUSTRIAL WASTE SURVEY (NUMBER OF FACTORIES IN 2018)

Type of Industry	Omdurman	Khartoum Bahri	Khartoum	Total
Food total	180	152	405	737
Sample selected	13	10	32	55 (7.5%)
Furniture total	39	39	140	218
Sample selected	3	3	12	18 (8.2%)
Textile total	13	14	23	50
Sample selected	2	2	2	6 (12%)
Plastic total	199	71	121	391
Sample selected	16	6	10	32 (8.2%)
Packaging total	2	3	4	9
Sample selected	1	1	1	3 (33.3%)
Paper and glass	6	15	4	25
Sample selected	2	2	3	7 (28%)
Grand total	439	294	679	1430
Sample selected	37 (8%)	24 (8%)	60 (9%)	121 (8%)

ANNEX 3. INDUSTRIAL WASTE SURVEY QUESTIONNAIRE (CAN ALSO BE ADAPTED FOR MEDICAL)

Q1. Who collects waste within establishment?		
1.1 Own cleaning employees (give number of employees)		
1.2 Subcontracted service (give cost SDP per month)		
Q2. How collected waste is managed? (tick appropriate)		
2.1 Stored in own bins within premises		
Frequency of removal from premises (daily, twice/week, etc.)		
Where to from premises (municipal bins, dumping site, road side)?		
2.2 Transferred directly outside premises		
Frequency of removal from premises (daily, twice/week, etc.)		
Where to from premises (municipal bins, dumping site, road side)?		
Frequency of collection by municipal services (daily, twice/week, etc.)		
2.3 Processed at premises		
Type of further processing (composting, incineration, ….)		
What percentage of total generated waste is processed?		
2.4 Processed outside premises		
Type of further processing (composting, incineration, ….)		
What percentage of total generated waste is processed?		
Processed by own company? (Yes, No)		
If sold to other firm for further processing, at what value?		
2.4 Other (explain)		
Q3. If some of the waste is processed within premises, how processed waste is utilized?		
3.1 Recycled within (give % of total waste)		
3.2 Sold to other firms (give value estimate in SDP)		
Q4. Any waste separation done at premises? (Yes, No)		
Q5. Which materials separated? (tick for below)		
5.1 Plastics (Yes, No)		
5.2 Glass bottles (Yes, No)		
5.3 Paper (Yes, No)		
5.4 Food/other organic (Yes, No)		
5.5 Metal (Yes, No)		
5.6 Other (……………………………………………………………) (Yes, No)		
Q6. How separated items are disposed of?	Quantity	Value (SDP)
6.1 Sold to brokers/processors		
6.2 Other (……………………………………………………………………….)		
Q7. Any waste separation at dump sites outside premises? (Yes, No)		
Q8. Estimated number of informal waste separators at dump site		
Q9. Type of waste generated	Quantity	Units & frequency
9.1 Hazardous		
Solid (………………………………………………………………………)		
Liquid (……………………………………………………………………..)		
9.2 Non-hazardous		

9.2A Solid		
Plastic bags		
Plastic bottles		
Plastic other (…………………………………………………………….)		
Glass bottles		
Cans/metal		
Paper & carton		
Clothes/fabric		
Furniture		
Scraps & appliances (batteries, electronics, etc.)		
Organic (food, plants, etc.)		
Garden refuse/tree trims		
Other solid (…………………………………………………………….)		
9.2B Liquids		
Oils		
Other liquids (……………………………………………………………)		

IDN1: Name of enumerator …………………………………………… IDN2: Date …………………………………

IDN3: Name of business establishment ……………………………………………………

IDN4: Serial number of respondent ……………………………………………………..……………………………………

IDN5: Name of administrative unit ………………………………………………………

IDN6: Name of locality ………………………………………………………………………

IDN7: Number of employees ……………………………………………………………..

IDN8: Levies paid for waste collection (SDP/month) ……………………………………………………………..

IDN9: What challenges faced in managing waste

………

………

……….

ANNEX 4. INFORMAL COLLECTORS AND PROCESSORS SURVEYS QUESTIONNAIRE

Q1. Type of activity (tick where applicable)			
1.1 Separation			
1.2 Further processing 1 (Shredding & compacting plastics)			
1.3 Further processing 2 (Composting)			
1.4 Further processing 3 (…………………………………………………………)			
2. Materials separated	Quant	Unit	Price
2.1 Plastics			
2.2 Glass bottles			
2.3 Paper			
2.4 Food/other organic			
2.5 Metal			
2.6 Other (……………………………………………………………………………)			
Q3. Where/to whom are separated products sold?			
3.1			
3.2			
Q4. Processing (shredding & compacting plastic, composting, etc)	Quantity	Value (SDP)	
4.1 Shredding & compacting (baling) plastics			
4.2 Composting			
4.3 Processing 3 (……………………………………………………………………)			
Q5. Where/to whom are processed products sold?			
5.1			
5.2			
Q6. Type of equipment used	Price/value (SDP)		
6.1 …………………………………………………………………………………			
6.2 …………………………………………………………………………………			
Q7. Gender (Male, Female)			
Q8. Age (years)			
Q9. Years of education			
Q10. Residential neighbourhood			
Q11. Region of origin in Sudan (tick where applicable)			
11.1 Northern region			
11.2 Southern region			
11.3 Western region			
11.4 Eastern region			
11.5 Foreign/Emigrant			
Q12. Frequency of activity (tick where applicable)			
12.1 Every day			
12.2 Other (……………………………………………………………………………)			
Q13. Modality of activity (tick where applicable)			
13.1 Alone			
13.2 In a group			
Q14. If in group, how many people involved?			
Q15. Family business of the group? (Yes, No)			

IDN1: Name of enumerator …………………………………………… IDN2: Date …………………………………

IDN3: Name of dumpsite/neighbourhood ………………………………………………………………………

IDN4: Serial number of respondent..………………………………………

IDN5: Type of dumpsite (tick right answer):

5.1 Open landfill ……… 5.2 Intermediate centre ………… 5.3 Road side …………

IDN6: Number of pickers/scavengers on site at time of survey…………………………………………….

IDN7: Is the dumpsite on private or public land/property? …………………………………………………..

IDN8. What challenges faced in managing waste?

………

……….

……….

……….

ANNEX 5. COMMERCIAL CENTRES (CAN ALSO ADAPTED FOR BUSINESS OFFICES)

Administered by interviewing key informants/local reps/officials at centres

Q1. Any within premises cleaning? (give number of workers) ……………………………………….
Q2. Frequency of cleaning (daily, once a week, etc.) …………………………………………………..
Q3. Who does the cleaning? (municipal, contractor, etc) ……………………………………………..
Q4. How much levies/service charges paid (SDP/month) ……………………………………………
Q5. Collected waste taken to:
5.1 Municipal bin…………………………………………………………
5.2 Road side…………………………………………………………
5.3 Dumping site (formal) …………………………………………………………
5.4 Other …………………………………………………………
Q6. Who removes collected waste from premises (municipality, contractor) …………………
Q7. Frequency of collection (daily, once a week, etc.) …………………………………………………..
Q8. How many truck loads per collection? (give no. & capacity/tons) ……………………………
Q9. Levies/service charges paid (SDP/month)
…………………………………………………………………….
Q10. Any waste processing within premises? (Yes, No) ……………………………………
Q11. Type waste processing (separation, recycling, etc.) ……...……………………………………….
Q12. Materials separated/recycled (plastic, paper, metal, bottles, etc.) ……………………………...
Q13. Waste separation at dumpsites? (give estimate of number of informal pickers) …………
Q14. Frequency of informal pickers activity (daily, on collection day, etc.) ………………………….
Q15. Estimation of shares of different types of waste

Plastic bags
Plastic bottles
Plastic other (…………………………………………………………….)
Glass bottles
Cans/metal
Paper & carton
Clothes/fabric
Furniture
Scraps & appliances (batteries, electronics, etc.)
Organic (food, plants, etc.)
Garden refuse/tree trims

IDN1: Name of enumerator …………………………………………… IDN2: Date
…………………………
IDN3: Name of commercial centre/market/mall ……………………………………………………
IDN4: Serial number of respondent
……………………………………………………………………………………
IDN5: Name of administrative unit ……………………………………………………………
IDN6: Name of locality ………………………………………………………………………….
IDN7: Number of employees ………………………………………………………………….
IDN8: Levies paid for waste collection (SDP/month)
………………………………………………………………...
IDN9: What challenges faced in managing waste

………
……………………………

ANNEX 6. HOUSEHOLD SURVEYS QUESTIONNAIRE

Q1. Type of waste generated	Quantity	Units & fre-quency
1.1 Hazardous		
Solid (……………………………………………………………………………)		
Liquid (…………………………………………………………………………)		
1.2. Non-hazardous		
1.2A Solid		
Plastic bags		
Plastic bottles		
Plastic other (………………………………………………………………)		
Glass bottles		
Cans/metal		
Paper & carton		
Clothes/fabric		
Furniture		
Scraps & appliances (batteries, electronics, etc.)		
Organic (food, plants, etc.)		
Garden refuse/tree trims		
Other solid (………………………………………………………………)		
1.2B Liquids		
Oils		
Other liquids (……………………………………………………………)		
Q2. What you use for collection of waste at home? (tick answer)		
2.1. Bins		
2.2. Garbage bags (i.e. not shopper/carrier plastics)		
2.3 Other (………………………………………………………………………………………………)		
Q3. Use non-plastic shopping bags? (Yes, No)		
Q4. Type of non-plastic bags used	Number	Value
4.1 Goffa		
4.2 Other (Sack, …………………………………………………………………)		
Q5. Any waste separation done at home? (Yes, No)		
Q6. Which materials separated? (tick for below)	Yes	No
6.1 Plastics		
6.2 Glass bottles		
6.3 Paper		
6.4 Food/other organic		
6.5 Metal		
6.6 Other (……………………………………………………………………………)		
Q7. How separated items are disposed of?	Quantity	Value (SDP)
7.1 Sold to brokers/processors		
7.2 Other (…………………………………………………………………………...)		
Q8. Any further processing before collection? (tick for below)	Yes	No
8.1 Composting		
8.2 Open burns		

8.3 Other (…………………………………………………………………………)		
Q9. When do you place your waste for collection outside home? (tick where applicable)		
9.1 On collection day only		
9.2 Every day		
9.3 Other (……………………………………………………………………...)		
10. Where do you place your waste outside home? (tick where applicable)		
10.1 Formal dumping site near home on my street		
10.2 Formal dumping site on main street		
10.3 Informal dumping site near home on my street		
10.4 Informal dumping site further from home		
Q11. Who takes your waste outside home? (tick for below)	Yes	No
11.1 Own family		
11.2 Paid collector		
11.3 Other (…………………………………………………………………….)		
Q12. If paid collector, how much you pay for this service (SDP/…………….)		
Q13. What means of transport collector uses (Walking, Cart, Toktok, …….)		

IDN1: Name of enumerator …………………………………………… IDN2: Date …………………………………

IDN3: Name of neighbourhood ………………………………………………………...

IDN4: Serial number of respondent..…………………………………………………….

IDN5: Number of people living in the same household …………………………………………………….

IDN6: Levies paid for waste collection (SDP/month) ……………………………………………………….

IDN7: What challenges faced in managing waste

…………………………………………………………………………………………………… ……………………………

…………………………………………………………………………………………………… ……………………………

…………………………………………………………………………………………………… …………………………….

ANNEX 7. FLOW OF SOLID WASTE IN THE GKC 2020

GKC Waste Flow

Collection &Transportation

Transfer Stations

Localities

KCC

KCC

162 ton

Jabal Awlia Locality

Tayba Landfill (Khartoum)

464 ton

626 ton

464 ton

Khartoum Locality

Khartoum T/S

Umdurman Locality

70 ton

Umdurman T/S

Karary Locality

39 ton

109 ton

Abu Welidat Landfill (Umdurman) 231 ton

60 ton

62 ton

Umbada Locality

60 ton

Umbada T/S

Medical Waste

Sharg alnel Locality

60 ton

Hatab Landfill (Bahry)

131 ton

71 ton

Bahry Locality