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The WaterMill Working Paper Series

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As part of their training each of the 72 professionals had undertaken a 6-month research project which focuses on the achievement of the MDGs in their home country. The WaterMill working paper series presents the research outputs of these projects.

Contact information

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Abstract

The state of solid wastes in most of the developing countries is a major threat to both human and environmental resources. One of the reasons why there is little progress being made is a lack of clear objectives, coupled with a lack of information and of a strong analytical base in which various policies and strategies can be formulated or aligned during the decision making processes.

This study, a case study for Nairobi, Kenya aimed at bridging this gap by providing a methodological approach in which Millennium Development Goals (MDGs) can be aligned with SWM strategies. Performance indicators were used to relate SWM to MDGs and to compile impacts data of the ten identified SWM options. The Baseline showed a low contribution towards achievement of MDGs while Option 10 (17% recycling, 63% composting and 20% landfilling) showed the highest contribution. Option 5 (15% recycling, 15% composting and 70% landfilling) provided the most feasible approach for meeting the MDGs, given the present social-economic, legal, political and administrative conditions of the study area.

Keywords: solid waste management, recycling, composting, multi-criteria evaluation, life cycle assessment

Contents

1 Introduction

One of the key problems facing the countries in the south is the raising levels of poverty and degradation of environmental resources. If these problems continue unabated, the prospects of these countries to develop, in both human and economic realms, will remain a dream. Instead, most of the countries will continue to experience inadequate sources of safe drinking water, food shortages and deteriorating public health conditions. There is a need, therefore, for concerted efforts, not only in finding solutions to these problems, but also in creating an enabling environment in which people can develop their full potential and lead productive lives. This is especially the case in the area of solid waste management, SWM.

Appropriate solid waste management provides opportunities for reduced environmental degradation and associated problems (Cunningham *et al.*, 2007). It also expands the choices of the people to engage in livelihoods that they value. Public health and food supply conditions are also set to improve if such waste management is integrated with agriculture, renewable energy supplies and manufacturing (Dara, 2006; Skordilis, 2003; Wei *et al.*, 2000). These opportunities are enormous in urban areas where rapid demographic changes and ever changing consumption patterns contribute to large amounts of solid wastes (Leao *et al.*, 2001).

The first step in the development of an appropriate solid waste management systems is to have clear goals and objectives which must satisfy the social values and the economic aspirations of the community (Tchobanoglous and Kreith, 2002). This demands a clear understanding of the relationship between the characteristics of the waste stream and the social economic set up of the generating community and how this relationship is likely to evolve in the future. It also requires an elaborate procedure in which different management options can be evaluated and compared as part of the decision making process. While this study will present a methodological approach for gathering data and for formulating SWM strategies. The overall objective is to demonstrate how the principles of Millennium Development Goals can be integrated in the planning and the decision making process. The specific objectives of the study are: i) to establish if there was a relationship between the state of solid wastes and social-economic set up of the generating community, ii) to determine the environmental, economic and social problems associated with the solid wastes, iii) to establish, evaluate and compare options for improving the present state of solid wastes, and iv) to use the findings of the study to recommend strategies for solid waste management in Nairobi.

2 Background Information

2.1 Geographical of the Study Area.

The study area is located in the Embakasi Division of the City of Nairobi. Lying on the eastern part of the city, Embakasi is one of the eight divisions that form the City of Nairobi (Fig. 2-1). It has an area of 208 km2 (about 30% of the total area of the city).

2.2 Description of the Existing SWM System

The collection of waste and transportation is largely informal. Further waste disposal is open dumping, with little recovery activities. Nairobi City Council does not operate any transfer station or composting plant where commercial waste recovery or recycling could be carried out (Palczynski, 2002). The contribution of the informal sector is complicated by the fact that the recyclables are mixed with the other wastes, both at the household level and at the dumpsite (Karanja, 2005).

The waste components common for recovery are glass, metals, plastics and aluminium. While metals and aluminum have readily available markets, glass and plastics tend to accumulate at the dumpsite as there are fewer buyers. The most affected are the plastic films, a fact that makes them the main source of street littering within the study area (Karanja, 2005).

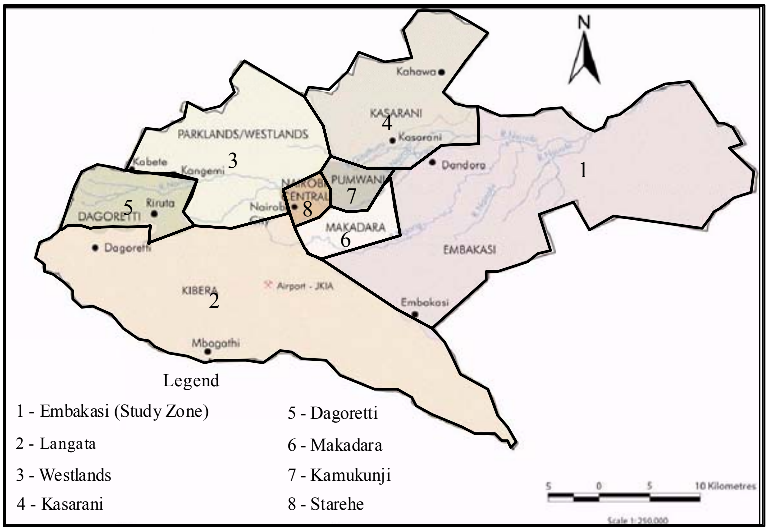

Figure 2-1: Geographical set-up of the study area in relation to the other parts of the city

2.3 Solid Waste Management Options and Technologies

The most common approaches for SWM are reuse, recycling, composting, sanitary landfilling and incineration. Other technologies, though not common in developing countries are pyrolysis, anaerobic digestion and gasification. The technical aspects of SWM are combined with the other non-functional elements (political, economic, legal, social, governance, administrative, etc) to form an integrated solid waste management system, ISWM. However, planning for an ISWM is a complex process that requires an accurate data and a clear analytical procedure. According to Tchobanoglous and Kreith (2002), such a procedure is Life cycle assessment, LCA, preceded by a comprehensive database for solid wastes. The database for LCA is created through waste characterization.

2.3.1 Waste Characterization

Waste characterization refers to the quantification of various waste components. The output is the weight and the composition of the various waste fractions (Dahlen, 2005). Statistical analysis is then performed on the data to provide mean, standard deviation and confidence level information (Reinhart and McCauley-Bell, 1996). The ASTM D5231-92 method (Standard Test Method for the Determination of the Composition of Unprocessed Municipal Solid Waste) is commonly used for measuring the composition of wastes (ASTM, 2003).

2.3.2 Life Cycle Assessment, LCA

LCA refers to the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle (Friðriksson *et al.*, 2002). To make evaluation of ISWM comprehensive, several authors have extended the application of LCA to include the environmental, the economic and the social perspectives of solid wastes (Rimaityte *et al.*, 2006). In all cases, however, the environmental, the financial and the social impacts are assessed and interpreted as if they are independent of each other. Making decisions on the basis of individual environmental, financial and social components undermines the concept of ISWM; which suggests a systems approach where all parts work together.

The above limitation can be solved by making SWM decisions on the basis of performance indicators that encompass the environmental, financial and social aspects of a solid waste management system. To ensure that the decisions being sought are sustainable for a long time, the performance indicators must entail the three aspects of sustainable development (environment, economics and social) as well as the key aspects of MDGs (poverty reduction, quick wins, global partnerships). The following section discusses the environmental, the financial and the social life cycle approaches, as prerequisites for further analysis of solid waste management options.

2.3.3 Environmental LCA

The Environmental LCA contains four methodological stages, as defined below (ISO 14042, 2000):

- **Goal and scope**: The stage at which the objectives of the LCA, the system boundaries and the functional unit are defined. The functional unit is the unit of analysis for the study and provides the basis for comparison if more than one product or system is being compared. For a solid waste management system, Environmental LCA aims to know which environmental inputs and outputs are associated with different programs of ISWM. The scope is normally confined to the activities that occur from the time waste is discarded to the time it is salvaged or disposed off (UNEP, 2005).

- **Life cycle inventory analysis (LCI)**: The process of accounting for all the inputs and the outputs of a product system over its life cycle. For solid waste management, LCI involves calculating emissions to air, water and land as waste flows in the programs under investigations. It may also be extended to include land use and energy consumed in the process of waste management. Several life cycle based models exist to provide a structured inventory of the emissions due to solid waste management activities. Such models are Simapro, ORWARE and UMBERTO Model, IWM (Rimaityte *et al.*, 2006) and (Bjarnadóttir *et al.*, 2002). Simapro, ORWARE and UMBERTO models are commercial softwares, while IMW is an excel-based free program.

- **Life cycle impact assessment (LCIA)**: The stage which associates the inventory inputs and outputs with the key environmental problems like global warming, acidification, eutrophication, depletion of resources and pollutant loading of heavy metals. According to the ISO 14042 (2000), the LCIA phase is composed of several mandatory elements;

  - selection of impact categories, category indicators and characterization models,

- classification of LCI results,
- Characterization of category indicator results. Optional elements for LCIA are normalization, grouping, weighting and data quality analysis.

The selection of impact categories should be consistent with the goal and scope of the LCA study. It must also be environmentally relevant (ISO 14042, 2000). From the works reviewed, common emissions associated with transport, recycling, composting and landfilling of solid wastes are CO_2, NO_2, NH_3, HCI, SO_2, H_2SO_4, HNO_3 and heavy metals (Tchobanoglous *et al.*, 1993). The key environmental problems associated with these emissions are global warming, acidification, eutrophication, human toxicity and smog formation. It is also important to consider land use especially in urban areas where siting of waste management facilities tends to devalue the adjoining land.

Unhygienic handling of solids waste harbors vectors that can spread diseases to human populations (diarrheal diseases, malaria, typhoid, etc). This is especially the case in areas where household waste, mixed with sanitary diapers, is dumped in the open. In addition to air and water emissions, therefore, it is recommended to include environmental burden of disease while selecting the performance indicators (impact categories).

The ISO 14042 (2000) has made a recommendation on the applicable impact category in case of global warming (kg CO_2 eq), acidification (kg SO_2 eq), eutrophication (kg PO4 eq), human toxicity (1.4 dichlorobenzene) and smog formation (kg C_4H_4). For the evaluation of ISWM programs these indicators are considered relevant. For land use, an indicator based on the hectares required annually (ha/year) could be used. For environmental burden of disease, Pruss-Ustun *et al.* (2003) suggest the use of Impact Fraction.

- **Life cycle interpretation**: This refers to the evaluation of the significance of the life cycle inputs and outputs to the environment. This includes checking on the completeness of the study, carrying out sensitivity analysis and making conclusions arising from the study.

2.3.4 Financial LCA

The goal of a financial LCA is to analyze the economic aspects of a product during its life cycle. For solid wastes, the scope of the financial study is all major costs and revenues associated with handling of the waste from the time it is discarded to the time when it is recovered or finally disposed off. The functional unit for financial analysis is the annual tonnage of solid wastes as generated by households and small-scale enterprises.

There are no standards or certification for financial LCA (Reich, 2005). However it can be used to compare economic viability of different investment options, set user fees and demonstrate how equitable distribution of resources is (Riggs *et al.*, 2005; Rimaityte *et al.*, 2006). From the literature studied, the cost per ton, equity and economic effectiveness have commonly been used as performance indicators of solid waste management programs. However Rigges *et al* (2005) suggests the use of time value of money and cost benefit ratio as key to the analysis of public projects. One aspect of time value of money is the distinction between the investments costs and the operating costs.

From the foregoing, indicators useful for the financial LCA of solid waste management are: net present value, annual discounted, cost per ton or per household, annual operating cost, benefit cost ratio, equity and revenue per ton.

2.3.5 Social LCA

According to Rimaityte *et al*. (2006), solid waste management exhibits three social dimensions: social equity, social acceptability and social function. Arising from these dimensions different LCA studies tend to use odour, noise, visual impact, employment quality, urban space utilization, comfort and traffic nuisance as indicators of the social aspects of solid wastes (Boer *et al.*, 2005; Kapepula *et al.*, 2006; Rimaityte *et al.*, 2006).

The indicators listed above are restrictive in evaluating social impacts of solid wastes; they are highly correlated with environmental indicators. To enable an objective evaluation of social issues related to SWM options, a practical plan to achieve MDGs as recommended by Sachs (2005) provides an appropriate basis. Although the recommendations are general, most of the issues provide a framework for social indicators in SWM. These are: reduction of poverty (level of employment), transparency and accountability (participatory governance), rural and urban productivity (innovation), public education, rights of women (gender parity) and social disparities (Sachs, 2005).

2.3.6 Multi Criteria Analysis of Life Cycle Impacts

Different options for solid waste management present a set of inputs and outputs (indicator results). The indicator results of the options need to be evaluated and compared so that the option with the least impacts may be picked as the most suitable option (Mattei, 2006; Rimaityte *et al.*, 2006). This is done through a multi criteria analysis, MCA, as explained below.

The MCA, as a procedural process, involves normalization of the LCIA profile, grouping and allocating weights to each of the performance indicators (Riggs *et al.*, 2005). Normalization refers to the calculations of the magnitude of indicator values (scores) relative to some reference information (ISO 14042, 2000). Grouping refers to assigning impact indicators into sets depending on the goal and scope of the LCA. The main purpose of grouping is to sort the indicators by their characteristics. Weighting is the process of converting indicator results by using predetermined numerical factors (ISO 14042, 2000).

2.4 Strategies for Solid Waste Management

2.4.1 Frameworks for Setting Solid Waste Management Strategies

Upon identification of the most feasible option for solid waste management, the next step is the specification of technical and management strategies for its implementation (Tchobanologous & Kreith, 2002). The sustainability of these strategies will depend on the overall policy framework adopted by the management (Denne, 2005). Several principles have evolved to guide the development of policy frameworks: sustainable development, cleaner production, precautionary principle, risk assessment, zero waste principle (UNEP, 2005) and Millennium Development Goals, MDGs.

Perhaps the MDGs form the most comprehensive guide towards a secure development of human capital, not only as an end, but also with clear and time-bound action plans. SWM is directly linked to most of the dimensions of the MDGs: reducing poverty (goal 1), avoiding disease (goals 4 and 6) and promoting environmental sustainability (goal 7). Target 9 calls for integration of the principles of sustainable development into country policies and programs and the reverse of the loss of environmental resources. Target 10 aims at halving the proportion of people without sustainable access to safe drinking water and basic sanitation. Target 11 aims at achieving a significant improvement in the lives of at least 100 million slum dwellers by year 2020 (Sachs, 2005)

3 Materials and Methods

3.1 Social Economic Survey

The methodology adopted for social economic assessment aimed at establishing the demographic and the social economic characteristics of the waste generating community and its perceptions on opportunities and constraints associated with the existing waste management system. To achieve this objective the following activities were carried out: sampling plan, sample sizing, questionnaire design, actual data collection and statistical analysis of the data.

The social economic survey utilized a stratified sampling approach. Three types of housing were identified: single or double dwelling houses, multiple dwelling units and temporary housing units or multiple single rooms. Sampling in each of the clusters was random; with 50%, 27% and 23% representing low, middle and high income groups respectively. A total of 100 households were sampled (95% CI, and 10% error margin). The formula: $n = k^2 r(100 - r) * \frac{1}{e^2}$ was applied. (n = required sample size, k = 1.96 for 95% CI, r = 50 and e = error of margin of 10 %.)

The questionnaire was designed to cover the demographic characteristics of the respondents: the level of education, age, the type of residence, gender, the level of income and the size of family. It also covered respondents' perceptions and practices on solid waste management: the monthly fees, knowledge of where waste was taken after collection, awareness of composting and recycling activities and the major issues affecting the management of the solid wastes in the study area. The interview was conducted randomly, on door-to-door basis, depending on the type of housing. Only persons who were 15 years or more were targeted.

The analysis of the data was based on both simple descriptive statistics and elaborate associative techniques. The simple statistics were restricted to the frequency in which the interviewees responded to the questions. The associative techniques applied Chi-Square test (χ^2-test) to investigate external forcing factors of solid waste management.

3.2 Waste Stream Survey

The survey for waste generation rates was carried out in the months of October through November 2007. The sampling was carried out at the household level, on the day of waste collection. Since waste was collected once a week, the weight of each bag represented the amount of waste generated by the respective household per week. The survey covered 36 households. The statistics calculated were the mean and the standard deviation.

The waste characterization involved the sorting out of the waste components at the Dandora dumpsite. The following waste components were identified for sorting out: paper, plastics, organic wastes, metals, glass, yard waste, sanitary diapers and the non combustible wastes.The procedure adopted for sorting out of the wastes was per the standard methods: ASTM D5231-92: Standard test method for the determination of the composition of unprocessed municipal solid waste. In total 52 lorries were sampled. From each lorry a sorting sample of about 100 kg was obtained (solid wastes were put in three gunny bags, each weighing about 35 kg). The sample was then spread on a plastic sheet and sorted out into the a fore mentioned components.

3.3 Financial Survey

The financial survey was conducted to obtain prices associated with waste collection and transportation, charges and operating costs at the dumpsite, revenue from waste recyclables and composts. For the waste collection and transportation costs, the vehicle crew was targeted as the respondents. The scavengers were interviewed in the case of value of waste recyclables. The Ministry of Public Works guidelines were used for the cost of hiring equipments at the dumpsite.

3.4 Problems of the Present SWM System

The assessment of the existing SWM was carried out to diagnose the physical, technical, economic, legal, social and administrative problems. To form a rich picture of the system, focus group discussions were held with the staff of NCC at the regional office (Umoja 1) as well as at City Hall (Department of Environment). In addition to the focus group discussions field observations were carried out to help understand the social and the environmental context of the solid waste management within the study area.

3.5 Definition of Options for Solid Waste Management

Options for SWM were defined within the context of ISWM: recycling, composting and landfilling. The existing practice of collection and transportation, dumping and disposal was assumed to be the baseline option, upon which the other options were founded. The ideal option was fixed at 20 % landfilling (to account for ash and other non-recoverable items). Assuming a 95% recycling efficiency, the maximum recycling potential was fixed at 17%. The ultimate composting potential was fixed at 63% (63%=100%-17%-20%). Other options represented a mix between (i) the amount of waste separated for reuse or recycling, (ii) the amount of waste that is recycled, and (iii) the amount of waste to be disposed of in the landfills. Ten (10) options were thus defined, in addition to the baseline condition.

3.6 Definition of the Performance Indicators

Upon assessment of the situation of SWM it was apparent that there was need to protect human life, reduce cost, reduce poverty and enhance environmental protection. Because of the multiplicity and complex nature of these objectives, performance indicators were used to model possible SWM options that could be used to meet the above objectives. The MDGs were used as guide in enlisting the performance indicators (inputs and outputs) during the life cycle of solid wastes. The indicators were quantified through life cycle analytical procedure which covered the environmental, the economic and the social aspects of solid wastes.

Environmental LCIA: The functional unit used for the environmental study was 100 tons. Use was made of the excel-based EPIC/CSR Integrated Waste Management Tool (Release 2.0.6). To parameterize the LCA tool, the following assumptions were made: the waste collection and the transportation route was 30 km, there was no gas recovery at the landfill facilities, windrow composting and the distance for transportation of recyclables was 30 km. These assumptions were held constant for all the options evaluated in order to maintain the internal consistency of the calculations. The emissions calculated were CO2, CH4, NOx, SOx, HCI, PM, VOC, Pb, Hg, Cd and dioxins. The emissions were classified according to their environmental effects: global warming, acidification, smog formation, land use, human toxicity and environmental burden of disease.

Financial LCIA: The goal of the financial LCA was to calculate all the major financial costs and revenues associated with waste collection and transportation, recovery of recyclables, composting and landfilling. Specific costs items considered were purchasing and hiring charges for vehicles and heavy equipments, labour and management costs, engineering design, investments costs for buildings and land, quality control expenses and miscellaneous cost to cover insurances and other statutory expenditures. In calculating the unit costs and revenues, investments costs were amortized using a cost recovery factor, CRF, of 0.149. Operating costs, utility costs, future revenues and investments costs were discounted to the base year using a present worth factor, PWF, of 0.463. In calculating CRF and PWF, the following assumptions were made: the interest rate was fixed at 8% (based on the average interest rates of treasury bills in Kenya, for the months of October through December 2007) and the study period was fixed at 10 years.

Social LCIA: The goal of Social LCA was to quantify the performance indicators associated with social aspects of solid wastes. The scope of the Social LCA was social function, social equity and social acceptability during collections and transportation, recycling, composting and landfilling activities. To reflect the scope of Social LCA, the following indicators were used: employment potential, social acceptability (participatory governance and stakeholder involvement), quality of services (promotion of higher standards of living and aesthetics), social transformation (public education and awareness), gender parity and social disparity. Apart from employment potential, the other social indicators are qualitative.

3.7 Multi-Criteria Analysis of SWM Options

The LCIA matrix consisted of the environmental, the economic and the social indicator values, each with different dimensions. To following equation was applied.

$$N\_score_{K,J} = \frac{ACT_{K,J} - Worst_{(1..N),J}}{Best_{(1...N),J} - Worst_{(1...N),J}}$$

where, N_score_{KJ} = normalized score of an indicator of a particular option

$ACT_{K,J}$ = actual score for indicator J of Option K

$Worst_{KJ}$, $Best_{KJ}$ = worst, best score

N = number of the Options

K = Option

The resultant profile represented indicator values between 0 and 1. Further, the indicators were grouped and weighted to reflect the needs of the residents as expressed during the household survey and the requirements of the MDGs.

Grouping and weighting: The performance indicators were grouped according to their contribution towards the attainment of MDGs (protection of public health (goal 6), reduction of poverty (goals 1, 3), reduction of the cost (goal 7 target 11) and protection of the environment (goal 7 targets 9 and 10). If an indicator had a close relationship with a particular goal, it was given one (1) mark. Otherwise a zero (0) mark was assigned where the relationship was distant or non-existent.

Further MCA served to aggregate the indicator values to give a single score. The formula below was used to calculate the single score for each of the options.

$$A\_score_K = \sum_{J=1}^{M} W_J * N\_score_{K,J}$$ where,

A_score_K = the aggregate score for Option K (1...11)

W_J = the weight coefficient for indicator J

N_score_{KJ} = the normalized score for option K for indicator J

M = the number of indicators

3.8 Establishing the Best Option for SWM

The Option with the highest aggregate score was deemed as the most desirable as it returned the best plan for achieving MDGs in solid waste management sector. However, for an option to be feasible for the study area, it was necessary to relate its attributes to the social-economic conditions of the people, the legal, administrative and political realities of the day. Sensitivity analysis was carried out to check if there were opportunities for cost reduction, either at the source or during the life cycle of the solid wastes. Use was made of the dynamic model, Stella, to project the operating costs of the most desirable option vis-à-vis the operating cost of the baseline condition.

3.9 Selection of Strategy Programs

The selected SWM management option represented the functional elements (recycling, composting and landfilling) that needed to be implemented to meet the MDGs. However, to implement and sustain the selected option there is need for the non-functional elements of ISWM (public values, politics, legal, market structures, etc) to be at par with the objectives and the technological aspects of the selected option. This calls for a change of the current status quo of the baseline condition.

To identify the necessary changes, performance indicators of the baseline condition were compared with those of selected option. Specific programs (for each of the performance indicator) were then identified to help bridge the gap between the baseline condition and the intended condition. These programs (combined with the objectives and the functional elements of ISWM) constituted the strategies for solid waste management within the study area.

4 Results

4.1 Drivers of Solid Wastes and Waste Characteristics

4.1.1 Socio-Economic Survey and Hypothesis Testing

The population of the study area was 434,884 people in 1999 (Republic of Kenya, 1999). With a growth rate of 4.8%, the population is expected to rise to about 660,000 and 1,000,000 in 2008 and 2018 respectively. The economic growth rate of the study area is expected to grow at 7% per annum as experienced during the period 2002 through 2007.

Forty two percent (42%) of the population in the study area lived below the poverty line. That is they spend less than 1US$ per day (Republic of Kenya, 2004; Ndeng'e *et al.*, 2003). The results of Household Survey showed that 53% of the residents paid less than KShs 150 (Euro1.5) service charges, while 47% pay more than KShs150 (Fig. 4-15). When asked about their satisfaction with SWM services, 57% of the respondents said they were satisfied. While 36% said they were not satisfied, 7% regarded the services as very poor.

The hypothesis that a relationship between the social economic conditions and state of solid waste management existed was accepted. The results of Chi-square test (χ^2) are shown on Table 4-1 below.

Table 4-1: Test of hypothesis for relationship between social-economic conditions of the study area and the state of solid wastes.

	O	E	(O-E)^2	(O-E)^2/E			O	E	(O-E)^2	O-E)^2/E
Satisfied (A)	57	58	1	0.01		> 150 (A)	47	58	121	1.21
Not satisfied (α)	43	42	1	0.01		<150 (α)	53	42	121	1.21
Total	100	100		0.02		Total	100	100		2.42

a) b)

a) Relationship between economic level and level of satisfaction by respondents. The calculated value of $\chi2$ =0.02 is less than table value 3.84 (CI=95%, N=100);

b) Relationship between the economic level and amount of fees paid by households. The calculated value of $\chi2$ = 2.42 is less than table value 3.84 (CI=95%, N=100).

4.1.2 Waste Streams of the Existing SWM System

The amount of household waste generated in 2007 was 210 tons per day. The amount of waste collected formally was 58%. Of the 58%, private contractors collected about 75% while the community-based organizations, CBOs, collected 25%. Two percent (2%) was collected through street scavenging. The rest (40%) was dumped in the open spaces (Fig. 4-1).

4.1.3 Waste Composition and Generation Rates

The dominant waste components as determined at the Dandora dumpsite were: food waste, yard waste, plastics, papers, glass, metals, inorganic, ceramics and sanitary diapers (Fig. 4-2). The food wastes contribute to 61% of the total household waste. The sanitary diapers contribute to 13% while plastics (all plastics) contribute to 12%. The mixed paper contributes to 6%, while the metals and mixed glass contribute 1% and 2% respectively.

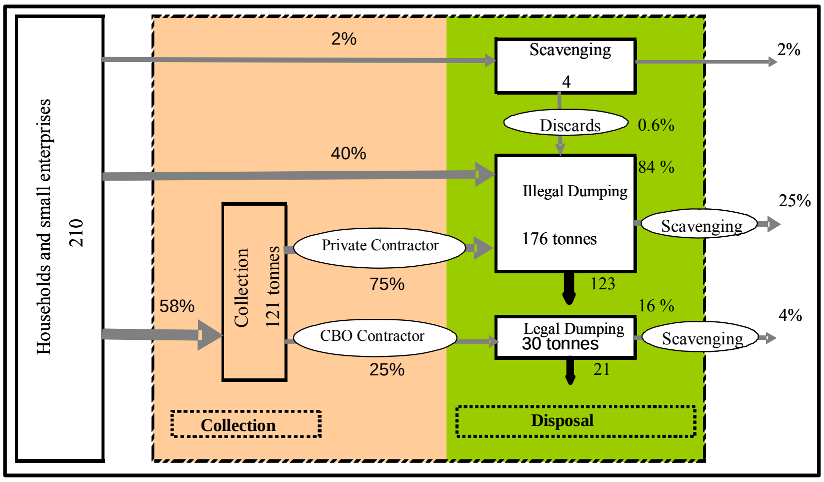

Figure4-1: Waste flow diagram of the existing SWM system.

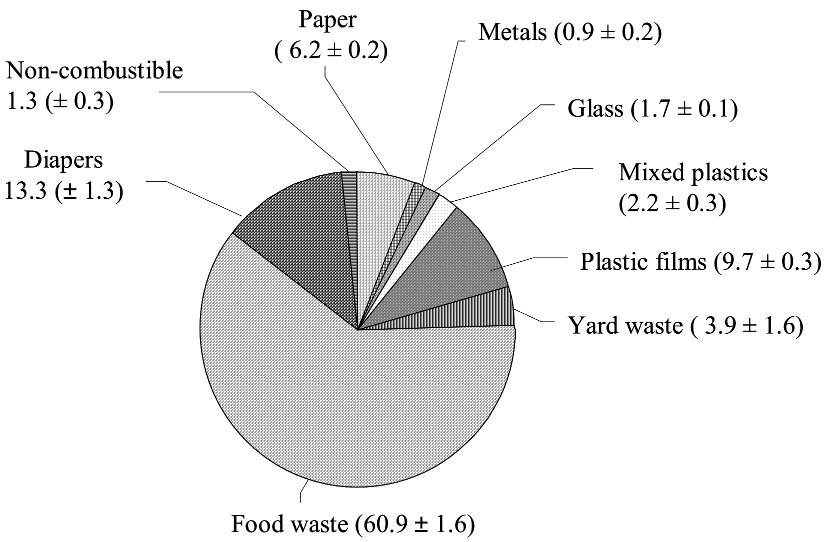

*Figure 4-2: Composition of the waste at the Dandora Dumpsite as determined during the months of October through December, 2007 (N= 52, CI=95%). Note the ± values refer to lower and upper bounds in the estimation of the mean (calculated as t- statistic * standard error). Plastic films refer to low density plastics normally referred to as shopping bags or wrapping films.*

The mean household waste generation is 8.3 (STD = 4.37, N =38) kg per week (Fig. 4-3).This translates to 0.33 (± 0.06) kg/cap/day at 95% Confidence Interval, CI.

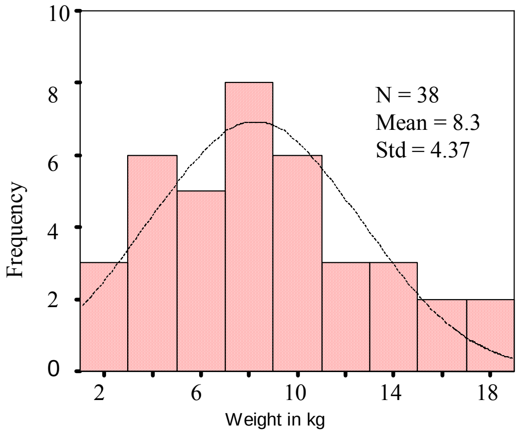

Figure 4-3: Frequency distribution of waste generation rates by households per week.

4.2 The State of the Existing SWM system

During the social economic survey, the respondents pointed out various issues that they perceived as either contributing to problems of solid wastes or are limiting to the implementation of a proper SWM system. Figure 4-4 below give a summary of some of the responses by the residents.

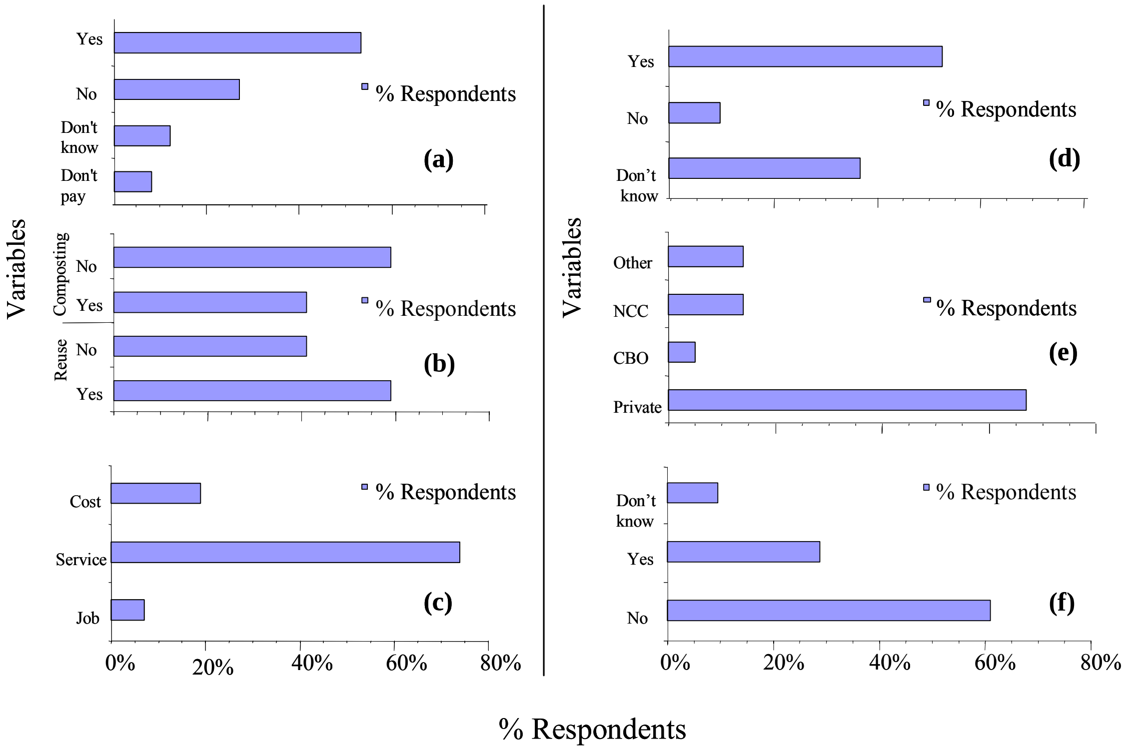

Figure 4-4: Sample of the results regarding perception of the residents on the existing SWM system.

Figure 4-5 represents % of respondents who responded to the following variables: (a) 'Do you think the fees you pay is well spent?', (b) 'Have you ever heard about waste recycling/ composting?', (c) 'What do you regard as the most important aspect for SWM in your area?, (d) 'Do you know where your waste is taken after collection?', (e) 'To whom would you prefer to pay SWM services to?', (f) Would you increase the monthly fees if SWM services are improved?'

Regarding waste recovery and disposal, the study area is characterized by dumpsites where domestic and wild animals scavenge for food. There are also a number of material recovery yards where the recycling companies get their supplies. However, most of the sorted waste components, mainly plastics and glass, accumulate in the recovery yards due to lack of adequate markets. In all the cases of observed, however, the recovery of the waste components was carried out under unhygienic conditions. System performance indicators

Table 4-2: Indicators for solid wastes (adapted from (Boer et al., 2003; Riggs et al., 2005; Sachs, 2005)

Environmental	**Economic**	**Social**
Climate change	Net present value	Employment potential
Land use	Annual cost per household	Participatory governance
Human toxicity	Annual cost per ton	Public awareness, education
Photo-oxidant formation	Operating costs per household	Gender parity
Acidification	Operating costs per ton	Social disparity
Eutrophication	Cost effectiveness	
burden of disease	Equity	
	Revenue per ton	

4.3 Possible options for solid waste management

Based on the concept of ISWM and the waste composition, ten (10) options were defined. The existing situation represented the baseline condition (7 recycling and 93% landfilling). Option 10 represented

the ultimate waste management condition (17% recycling, 63% composting and 20% landfilling). Between the baseline condition and the Option 10 were nine (9) options that were considered for evaluation (Fig. 4-5).

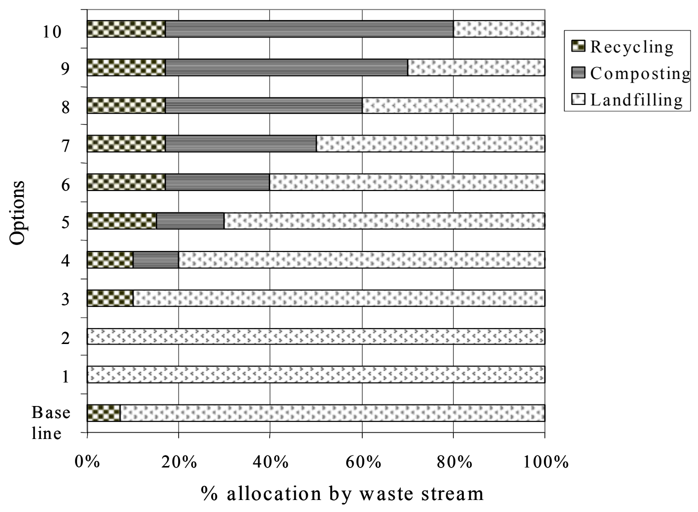

Figure 4-5: Options for an integrated solid waste management system. Selection of the options is based on the % of waste recycled, composted and/ or land filled.

4.3.1 Results of the environmental study

Further, the environmental study showed that the break-even point for the CO2 equivalents occurs around Option 7 (17% recycling, 33% composting and 50% landfilling). In the overall, however, the net carbon footprint due to solid wastes reduces as more waste is diverted to recycling and composting programs (Fig. 4-6). On land use, the Baseline and the Option 2 required more space compared to the other options. On human toxicity, Option 2 has the highest level of human toxicity compared to Option 10 (13 kg and 2 kg of 1,4 dichlorobenzene eq. respectively).

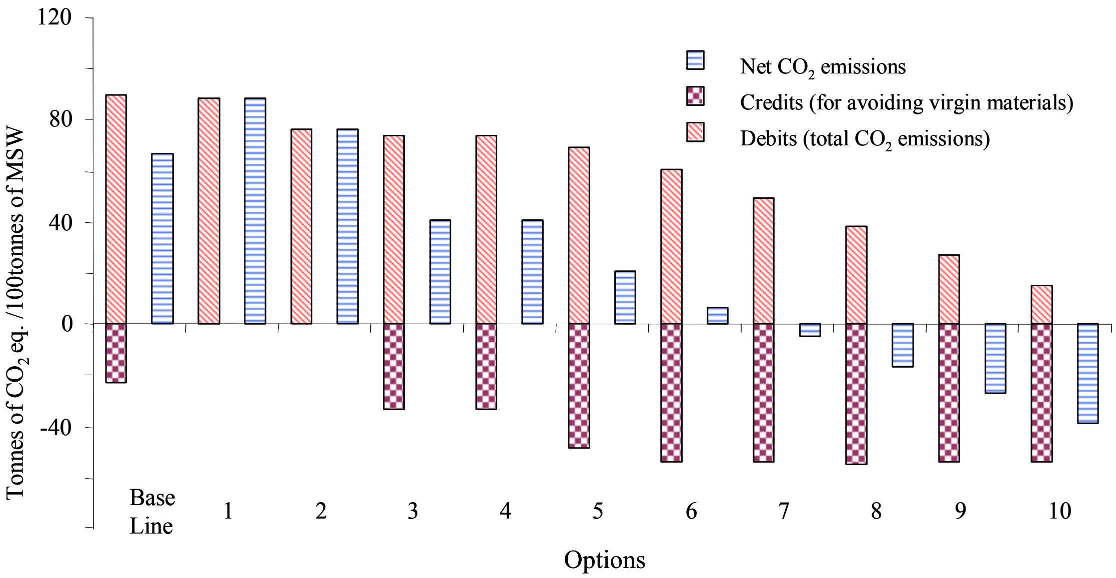

Figure 4-6: Contribution of the SWM options to the greenhouse gas emissions.

4.3.2 Results of the Economic Study

The financial analysis of SWM options showed that collection and transportation of wastes contribute to about 67% of the total life cycle costs (Fig. 4-7). Option 2 (100% sanitary landfill) has the highest annualized life cycle costs while Option 10 has the least (KShs1250 million and KShs 250 million, respectively). Most of the revenue for SWM is contributed by the user fees. The contribution of revenue by selling recyclables is about 30% in options 6 to 10. However, it is much lower in the other options (Baseline to Option 5). The contribution of compost sales to the revenue ranges from 2% in Option 5 to 7% in Option 10.

From economics point of view, disposal-oriented options (baseline to Option 5) have negative present worth while recovery-oriented options (Options 6 to 10) have positive net returns (Fig. 4-7). Option 3 (100% landfilling) showed the least positive returns while Option 10 (17% recycling, 63% composting and 20% landfilling) had the highest.

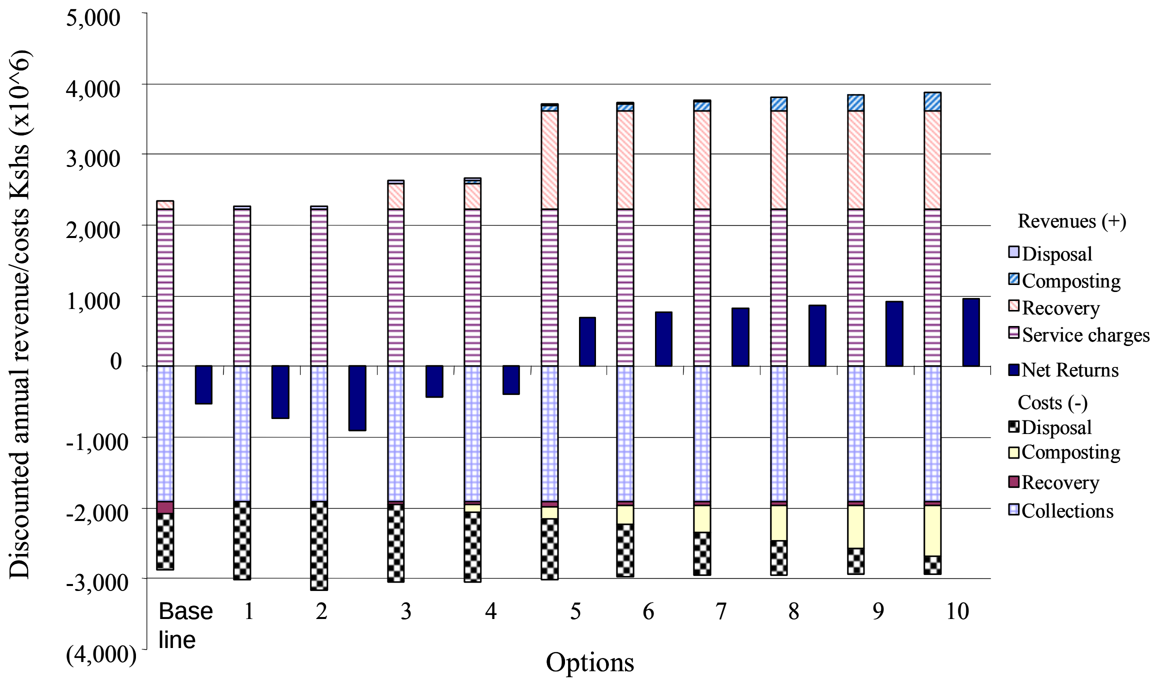

Figure 4-7: Annualized costs and revenues for the different SWM options. Note that the values are discounted to the base year using an interest rate of 8% and a study period of 10 years (CRF= 0.149, PWF= 0.463).

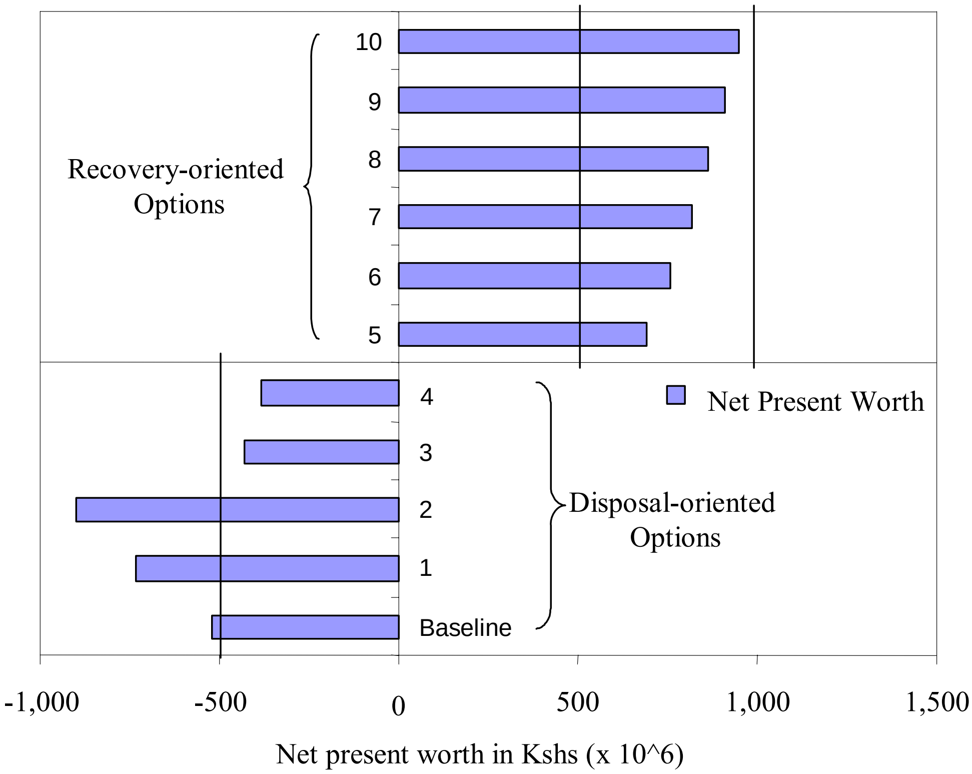

Figure 4-8: Net present worth for each of the SWM options. Note that the net present worth is the difference between the benefits and costs.

4.3.3 Results of the Social Study

The number of employees in each of the options is shown in the Figure 4-9 below. The Baseline option has the least number of direct employees (<100) while Option 10 has the highest (>300).

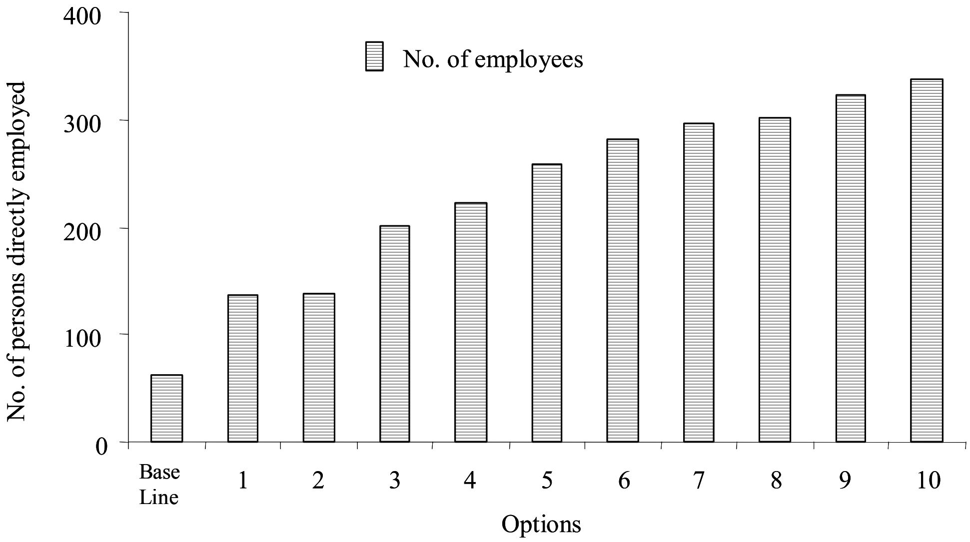

Figure 4-9: Number of direct employees for each of the SWM options. Direct employees refer to the casuals and their supervisors during waste collection and transportation, recycling, composting and landfilling activities.

4.4 Weighting of SWM indicators in relation to MDGs

Table 4-3: Weight of performance indicators towards meeting MDGs.

MDGs / Performance indicators	Protection of Human Life (G_6)	Cost Reduction (G_7T_{11})	Poverty Reduction (G_1T_1)	Protection of Environment ($G_7T_{9,10}$)	Indicator Weight
Weight of MDGs (%)	40	20	20	20	
Human toxicity	1				10.0
Land Use				1	4.0
Climate Change				1	4.0
Photo-oxidant formation				1	4.0
Acidification				1	4.0
Eutrophication				1	4.0
Environmental Burden of Disease, EBD	1				10.0
Annual discounted cost per household		1			5.0
Annual discounted cost per ton		1			5.0
Annual cost per household- operating		1			5.0
Annual cost per ton- operating		1			5.0
Cost effectiveness- Benefit/ cost ratio			1		3.3
Equity			1		3.3
Revenue per ton			1		3.3
Employment potential			1		3.3
Governance	1				10.0
Public Awareness and Education	1				10.0
Gender parity			1		3.3
Social disparity			1		3.3
No. of indicators	4	4	6	5	100.0

When the environmental, economic and social scores were aggregated, different options showed different contribution towards the MDGs. The Baseline condition has the least contribution (30%) while Option 10 has the highest (78%), as shown in Figure 4-10 below.

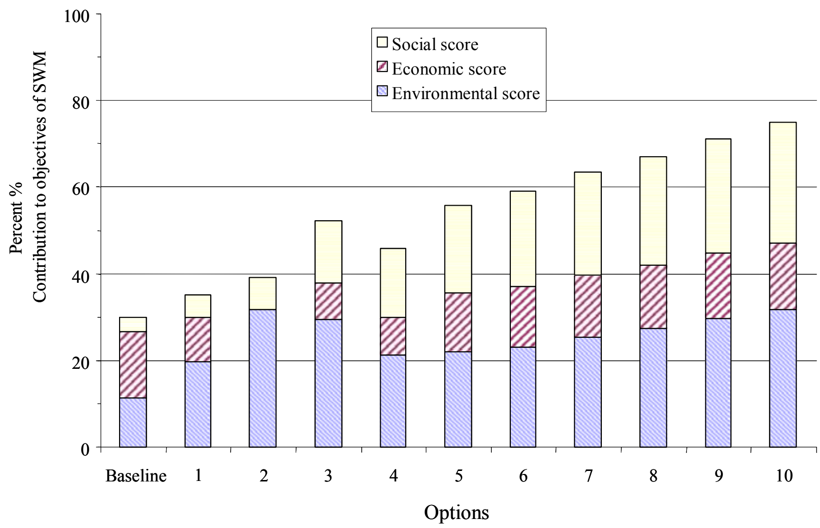

Figure 4-10: Comparison of the SWM options in meeting the MDGs. The goals considered were related to protection of human life (goal 6, target 8), reduction of costs (goal 7, target 11), poverty reduction (goal 1, target 1) and protection of environment (goal 7, targets 9 and 10). The environmental, economic and social scores refer to the normalized and weighted LCIA indicator values. Key attributes of the selected SWM options

All the options evaluated showed different strengths and weaknesses in meeting the needs of the waste generating community. Table 4-4 below compares the positive and negative attributes of the Baseline condition and Option 10, respectively.

Table 4-4: Comparison of the performance indicators between the Baseline condition and the Option 10

Performance Indicator	Baseline Score	Option 10 Score	Is Option 10 better?
Human toxicity	0.05	1	√
Land use	0	1	√
Climate change	0.04	1	√
Photo-oxidant formation	0.95	0.27	x
Acidification	0.85	0.35	x
Eutrophication	0.84	0.29	x
Environmental Burden of Disease, EBD	0	1	√

Performance Indicator	Baseline Score	Option 10 Score	Is Option 10 better?
Net Present Value- NPV	0.2	1	√
Annual discounted cost per ton	1	0.8	x
Annual cost per household- operating	1	0.55	x
Annual cost per ton- operating	1	0.55	x
Cost effectiveness- Benefit/ cost ratio	0.16	1	√
Equity	1	0.57	x
Revenue per ton	0.43	1	√
Employment potential	0	1	√
Social acceptability	0	1	√
Standards of Living	0.21	1	√
Public Awareness and Education	0	1	√
Gender parity	0	1	√

NB:√ represents strength (positive attribute); x epresent weakness (negative attribute)

5 Discussions

5.1 Social-Economic Conditions and Waste characteristics

5.1.1 Socio-Economic Conditions of the Generating Community

The Chi-square test (χ^2-test) showed that there is a strong relationship between social-economic conditions and the state of solid wastes in the study area. This observation can be supported by the fact that the poor people live in filthy conditions while the rich live in cleaner environments as they can afford to pay for better services.

The above observation is important as it identifies poverty as one of the key drivers for solid waste management. Pro-poor programs need to be included in the waste management strategies if the goals of waste management programs are to be met. This condition is in agreement with recommendations of UN Millennium Project: the MDG-based poverty reduction strategies should focus on water and sanitation, environmental sustainability and public health (Sachs, 2005).

5.1.2 Waste Composition

The main waste fractions identified within the study area were: kitchen and food waste, yard waste, plastics, papers, glass, metals, inorganic, ceramics and sanitary diapers (Fig. 4-3). The % of organic wastes is very high compared to the other waste components (>60%). This can be explained by the fact that most of the food items in the developing countries are unprocessed and

therefore contain high moisture content. A key lesson arising from the waste composition survey is that a proper management of organic wastes may hold the keys to a sustainable state of solid wastes in the developing countries.

5.1.3 Waste Generation Rates

The mean household waste generation is 8.3 (STD= 4.37, N=38) kg per week (Fig. 4-4) Assuming an average household size of 3.59, the per capita waste generation rate is 0.33 ± 0.06 kg/capita/day (N=38, CI=95%, t95=2.02). For a proper planning of SWM programs, forecasting of the future waste amounts is of paramount importance (Tchobanoglous *et al.*, 1993). The study area has been experiencing a high population growth over the years (4.8% possibly because of rural –urban migration). As shown, the per capita waste generation in 2018 will be 0.57 kg/capita/day (an increase of 72% from the current 0.33 kg/capita/day). In financial terms, this means the cost of waste management per capita is set to increase with time. This is undesirable considering that one of the objectives of SWM is cost reduction. There is need, therefore, for the planning and management of solid wastes to be a dynamic process if changes in cost and other future challenges (e.g. change in waste composition and technologies) are to be surmountable.

5.2 Situational Analysis of the Existing SWM system

The social economic survey showed that about half of the households did not participate in paying for solid waste management services. This causes low service coverage, hence the high level of dumped wastes. When asked about location of waste disposal sites and waste reuse activities, a large number of respondents expressed lack of knowledge. Only 53% affirmed knowledge of where their waste was taken upon collection. Close to 60% of the respondents were not aware of waste composting while 40% did not know about recycling. This indicates that the level of knowledge for the existing SWM services or of other opportunities thereto is very low.

Regarding mandates for various activities, it was clear that respondents wanted a clear separation of duties and responsibilities. On payment of fees, 67% of the respondents expressed confidence with the private collectors. Only 14% of the respondents said they would be willing to pay to the NCC. Regarding overall responsibility of SWM services, 67% of the respondents wanted NCC to take charge, with only 31% trusting private collectors. There was no preference for community based organizations. This indicates that the level of coordination between different stakeholders is very low. In the overall there is poor enforcement of NCC Bye-laws. The fees charged to households are also set arbitrary, thus disadvantaging those who could not afford.

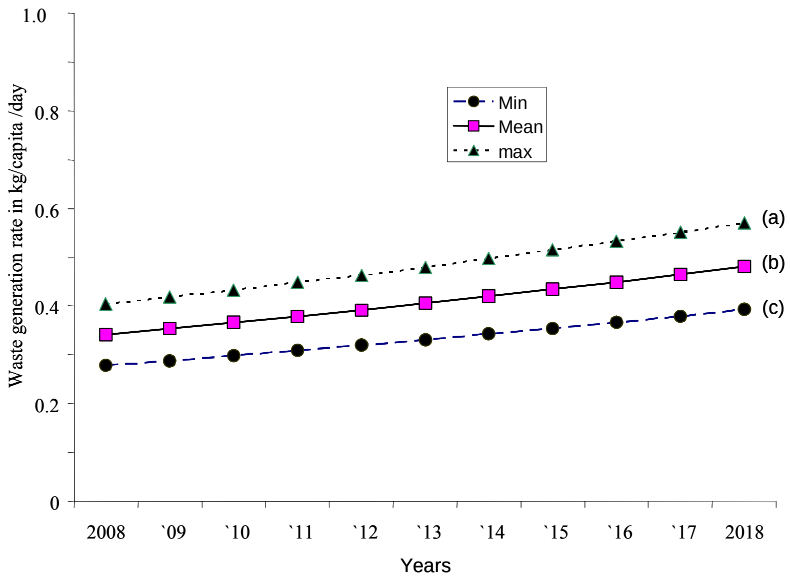

*Figure 5-1: Waste generation rates for the period 2008 through 2018. The trends are calculated as: (a) 0.33+t_{95}*SEM, (b) 0.33 (mean), (c) 0.33-t_{95}*SEM. (t_{95} = 2.02, STD= 0.17, SEM= 0.03, N= 38, CI= 95%).*

When asked about their expectations from SWM services, respondents had conflicting opinions. While 74% expected high standards of service, 19% cited the cost as an important aspect. Only 7% regarded employment as a key aspect of SWM services. This was not expected considering the high levels of unemployment within the study area.

Table 5-1 below summarizes the characteristics and specific problems associated with the current solid waste management system.

Table 5.1: Specific problems with the existing SWM system

Aspect	**Key characteristics**	**Specific problems**
Waste generation	No waste separation at the source	Contamination of the recyclables at the source, unhygienic due to hazardous household wastes.
Collection and transportation	Low coverage (58%)	Increased littering problem, clog drainage, harbour disease causing organisms.
	Non-uniform fees administration	Discriminates against the poor.
Disposal method	Open dumping	Incidences of smoke, contamination of recoverables, unhygienic.
Waste recovery	Scavenging	Low efficiency, lack of markets due to contamination, costly due to transportation.
Legal requirements	NCC Bye-Laws applicable	Low enforcement, non compliance by residents.

Arising from the social economic and waste characterization studies and the specific problems cited above, the need for very clear objectives to guide the planning and the decision making process cannot be over-emphasized. For such planning to be relevant, the goals of SWM must focus on: (i) protection of the public health, (ii) reduction of the cost, (iii) reduction of poverty, and (iv) protection of the environment. Various options which aimed at meeting these objectives were compared and contrasted, as explained below.

5.3 Options for Solid Waste Management

5.3.1 Feasibility of the evaluated Options

It was shown that the Baseline condition and Option 1 had higher levels of human toxicity compared to the other options. The Baseline condition and the Options 1 to 4 had negative financial returns (Fig.4-8). In investment terms these options are considered not worthwhile. Option 5 (15% recycling, 15% composting and 70% landfilling) showed the minimum positive present worth while Option 10 (17% recycling,

63% composting and 20% landfilling) recorded the highest. Option 10 provides a very important aspect of solid waste management; the need for continued improvement. It provides a guiding principle (Zero Waste principle) in which policies and strategies for SWM could be formulated.

Although Option 10 could be the ultimate goal of SWM, inherent risks and uncertainties make it a less worthwhile financial investment. For example, the social and organizational limitations that characterize the Baseline condition are still intact. While the markets for the compost manures are largely not available, the regulatory mechanisms that would ensure a good quality are not yet in place. From management point of view, therefore, it is imperative to plan for a gradual but systematic transition from the Baseline condition towards a more sustainable solution. Option 5 (15% recycling, 15% composting and 70% landfilling) provides such an opportunity. It is financially, socially and environmentally attractive compared to the Baseline Condition and Options 2, 3 and 4. It also requires less social and organizational transformations compared to Options 6, 7, 8, 9 and 10.

5.3.2 Recommended option for solid waste management in Nairobi

Option 5 (15% recycling, 15% composting and 70% landfilling) returned a positive net present worth (+KShs 689,520,503) at a cost of KShs 1,400 per household per annum. The option also returned higher environmental and social benefits compared to the existing condition. However it compromised on the objective of reducing the cost of solid waste management in the area. Sensitivity analysis showed that the cost of the solid waste services can be reduced from Kshs 1400 to 1110 per household per annum if waste minimization and reduction and transport costs are enforced. This makes Option 5 the most feasible target for solid waste management within the study area.

5.3.3 Management challenges towards improved SWM

Option 5 presents a number of management challenges compared to the Baseline condition. The coverage for waste collection is much higher than the current 58%. This calls for strong advocacy and public education, not only on the need for increased coverage, but also on the role of the residents in the subsequent processes like the recycling and the composting. Further, market outlets for paper, glass, metal and plastics need to be established to cater for the increased recovery of solid wastes. There is the need to regulate the political environment in which solid waste planning and management operates.

The success of the composting program will depend on whether the composts can be sold readily. The marketability of composts is greatly affected by the presence of contaminants such as glass, plastic and metals. On the other hand, the micro-biological aspects of composting process may be affected by the presence of heavy metals, ammonia and other toxic substances (Tchobanoglous *et al.*, 1993). The other aspect that tends to complicate the design and the operations of the composting plants is the control of pathogens (elimination of pathogens requires a highly controlled temperature profile and aeration process).

From the foregoing, the importance of integrating the functional (unit processes) and non-functional (drivers of SWM) aspects of SWM becomes apparent. For example, it is extremely difficult to achieve 15% composting without changing the tradition of mixing household hazardous wastes with the organics. It is also very difficult to achieve 15% recycling if the recyclable components continue being contaminated, as is currently the case. The agricultural and manufacturing industries must also be reformed in order to accommodate waste recovery programs. There is need, therefore, for both social and organizational changes if Option 5 is to be implemented successfully. The guiding principle for such changes could be Zero Waste Principle (prevention of pollution, reduction of waste and the consumption of resources, and commitment to recovery and recycling, as opposed to disposal where feasible) to ensure there is continued improvement. Sub-section 5.4 below discusses various strategies that can be used to stimulate both social and organizational transformations.

5.4 Strategies for Solid Waste Management in Nairobi

5.4.1 Measures to Improve SWM

Table 4.2 compared the performance of the Baseline condition and the Option 10.

The negative aspects of the Baseline condition need to be improved in line with the needs and capabilities of the community. The positive ones need to be enhanced as well as to ensure they remain relevant even when social values and priorities change.

To move from the Baseline condition to a more sustainable way of solid waste management, Table 5-2 following is a summary of strategic measures.

Table5-2: Summary of strategic measures to improve the state of Solid wastes

Aspect of ISWM	Measures
Technological	• Promote and actively enforce waste recycling programs through establishment of waste recovery points at community level and next to waste disposal points. • Promote home composting of green and kitchen waste
Environmental	• Reduce contamination of recyclables by encouraging source separation • Reduce emissions of greenhouse gases, • Promote cleaner production in material and energy use • Increase coverage for waste collection and transportation
Economic	• Promote entrepreneurial activities for women and the youth by establishing small and medium scale recovery and recycling enterprises • Establish partnerships with other city programs like landscaping and urban agriculture to expand markets for compost manures.

Aspect of ISWM	Measures
Legal	• Impose deterrent taxes for landfilling and uncontrolled waste disposal, • Enact appropriate waste recovery and disposal laws
Governance	• Promote participatory governance and decision making at the community level, regional and national level.
Structural	• Promote regional resource management (e.g. waste recycling and composting programs should be decentralized to reduce bureaucracy and incidental costs
Social values and traditions	• Undertake comprehensive waste education and awareness campaign explaining waste management issues • Promote waste management ethics in schools and other institutions of learning
Administrative	• Prepare action plans for meeting the set objectives • Establish appropriate procedures for internal and external communications regarding solid waste management. • Provide resources essential to the implementation and control of solid waste management programs • Establish procedures to ensure that all personnel whose work has a significant impact upon solid waste management have received appropriate training.

5.4.2 Overall Strategies for SWM

To implement the above measures, specific programs need to be carried out through a collaboration of the Government, NCC, community and other stakeholders. The programs must be consistent with community short- and long- term needs. They must also be dynamic to allow modifications in SWM systems as the social values, concepts and technologies change. Table 5-3 below gives a summary of strategies that would guide and stimulate the application of the above measures.

Table 5-3: Summary of Strategies for Municipal SWM

Strategy Objectives	i) Protection of public health ii) Reduction of poverty iii) Reduction of cost iv) Protection of environmental resources
Guiding principles	Zero Waste Principle (Waste is a resource that can be harnessed to create wealth, employment and reduce pollution of the environment)
Long-term-goals	achieve 50% waste recovery (17% recycling, 32% composting, 50% landfilling)
Short- and medium-term goals	achieve 30% waste recovery (15% recycling, 15% composting and 70% landfilling) in key urban area by 2018 (period of 10 years)

Priorities	• Capacity building at all levels of planning and decision making (national and the local government levels) to promote transformative leadership. • Preparation of municipal-based action plans that are consistent with national strategies and policies. • Enact laws to regulate waste recovery and disposal (e.g. Waste Recovery and Disposal Act to serve as a regulatory regime for the use of waste as a resource).
Performance indicators	• quantity of CO_2 equivalents emitted throughout the life cycle of solid wastes • amount of waste recovered through recycling and composting
Instruments	**Specific action programs**
Legal instruments	solid waste recovery and disposal laws (emphasis for SWM should be on reuse and recycling), enactment/ enforcement of regulatory and supervisory statutes (e.g. National Solid Waste Strategies)
Financial instruments	tax as disincentives for landfilling, encourage source reduction, improve coverage for service charges, carbon markets, waste exchange programs, preferential use of recovered materials over virgin materials
Communication instruments	advocacy for behavioral change in schools and households, promotion of information, communication and technology (ICT), training of SWM managers, demonstration projects, promotion of research and development in SWM
Structural instruments	decentralized SWM, public-private partnerships (e.g. voluntary agreements), strengthened entrepreneurial activities (e.g. for SMEs)

6 Conclusions and Recommendations

Formulating strategies is the most important aspect of solid waste management. It is during this process that:

- a database for solid waste characteristics and the drivers thereof can be created,
- a detailed situational analysis of SWM can be made, devoid of pressure to offer quick fix and often short-term solutions,
- options for SWM can be developed and evaluated in manner that integrates the needs of the society to the functional and non-functional elements of ISWM,
- strategies can be formulated and aligned with other policy statements to help a paradigm shift from the traditional notion of solid wastes as a nuisance to the modern concept of resource recovery and management,

It is however recognized that planning and formulating strategies alone will not solve the problems posed by solid wastes. Implementation and effective follow-up of such plans and strategies is the surest way towards a sustainable management of solid wastes in the developing countries.

6.1 Recommendations for further actions and investigations

There is an urgent need for the relevant authorities to prepare action plans for SWM, in consultation with other stakeholders. Such plans should focus on resource recovery and at the same time stimulate social-economic transformations that can help in sustaining the waste management programs.

Waste collection and transportation have the greatest contribution to the overall costs of solid waste management (about 60%). This warrants further studies that aim at optimizing the modes of waste collection and transportation within the study area.

The findings represented in this study reflect the waste characteristics and the social-economic conditions of the study area. However, these conditions may vary from one place to another and from time to time. It would therefore be necessary to carry out similar studies in other parts of the country to check if there are significant differences that may warrant review of the strategies set herein.

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Appendix 1

Table A-1: LCIA matrix for the environmental, economic and social studies of solid waste management.

No.	Indicators	Units	Baseline	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10
	Environmental LCIA												
1	Human toxicity	kg 1,4 dichlorobenzene	12.83	13.42	7.32	7.24	6.62	5.73	5.06	4.24	3.42	2.60	1.78
2	Land Use	m^2/ yr	4.16E+05	3.85E+05	1.55E+04	1.40E+04	1.24E+04	1.09E+04	9.39E+03	7.82E+03	6.27E+03	4.72E+03	3.18E+03
3	Climate Change	kg $CO_{2\ eq}$	8.52E+04	8.82E+04	7.65E+04	7.65E+04	6.93E+04	5.80E+04	4.90E+04	3.76E+04	2.63E+04	1.50E+04	3.69E+03
4	Photo-oxidant formation	kg C_2H_4- eq	0.06	0.06	0.06	0.06	0.08	0.08	0.08	0.08	0.08	0.08	0.08
5	Acidification	kg $SO_{2\ eq}$	2.69	2.57	2.57	2.75	3.33	3.36	3.34	3.28	3.21	3.15	3.08
6	Eutrophication	kg PO_4^{-3} eq	0.29	0.27	0.27	0.29	0.37	0.38	0.38	0.37	0.36	0.35	0.35
7	Environmental Burden of Disease, EBD	%	0.89	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
	Financial LCIA												
8	Net Present Value- NPV	KSh	-5.22E+08	-7.35E+08	-9.01E+08	-4.28E+08	-3.85E+08	6.90E+08	7.60E+08	8.17E+08	8.64E+08	9.11E+08	9.59E+08
9	Annual discounted cost per household	KSh/ household	1.48E+04	1.55E+04	1.64E+04	1.58E+04	1.57E+04	1.56E+04	1.53E+04	1.53E+04	1.52E+04	1.52E+04	1.51E+04
10	Annual discounted cost per ton	KSh/ton	3.20E+04	3.36E+04	3.54E+04	3.40E+04	3.39E+04	3.37E+04	3.31E+04	3.30E+04	3.29E+04	3.28E+04	3.27E+04
11	Annual cost per household-operating costs	KSh/ household	1.13E+03	1.32E+03	1.81E+03	1.49E+03	1.49E+03	1.40E+03	1.45E+03	1.45E+03	1.44E+03	1.44E+03	1.44E+03
12	Annual cost per ton- operating	KSh/ton	2.45E+03	2.85E+03	3.91E+03	3.22E+03	3.21E+03	3.02E+03	3.14E+03	3.13E+03	3.12E+03	3.11E+03	3.10E+03

No.	Indicators	Units	Baseline	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10
13	Cost effectiveness- Benefit/ cost ratio	Ratio	0.82	0.76	0.72	0.86	0.87	1.23	1.26	1.28	1.29	1.31	1.33
14	Equity	Ratio	0.04	0.04	0.06	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05
15	Revenue per household	KSh/ household	1.19E+03	1.15E+03	1.15E+03	1.33E+03	1.35E+03	1.85E+03	1.89E+03	1.91E+03	1.93E+03	1.95E+03	1.97E+03
16	Revenue per ton	KSh/ton	2.57E+03	2.49E+03	1.29E+03	2.87E+03	2.91E+03	3.99E+03	4.07E+03	4.13E+03	4.17E+03	4.21E+03	4.25E+03
	Social LCIA												
17	Employment potential	No	62.00	136.00	138.00	200.00	222.00	258.00	282.00	296.00	301.00	323.00	337.00
18	Social Acceptability	Ratio	0.40	0.47	0.74	0.78	0.79	0.95	0.97	0.98	0.98	0.99	1.00
19	Innovation	Ratio	0.21	0.00	0.00	0.29	0.29	0.56	0.68	0.76	0.84	0.92	1.00
20	Public Awareness and Education	Ratio	0.12	0.20	0.20	0.49	0.57	0.59	0.68	0.76	0.84	0.92	1.00
21	Gender parity	Ratio	0.00	0.00	0.00	0.29	0.37	0.56	0.68	0.76	0.84	0.92	1.00
22	Social Class Inequality	Ratio	1.00	1.19	1.51	1.34	1.34	1.26	1.31	1.30	1.30	1.30	1.29

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