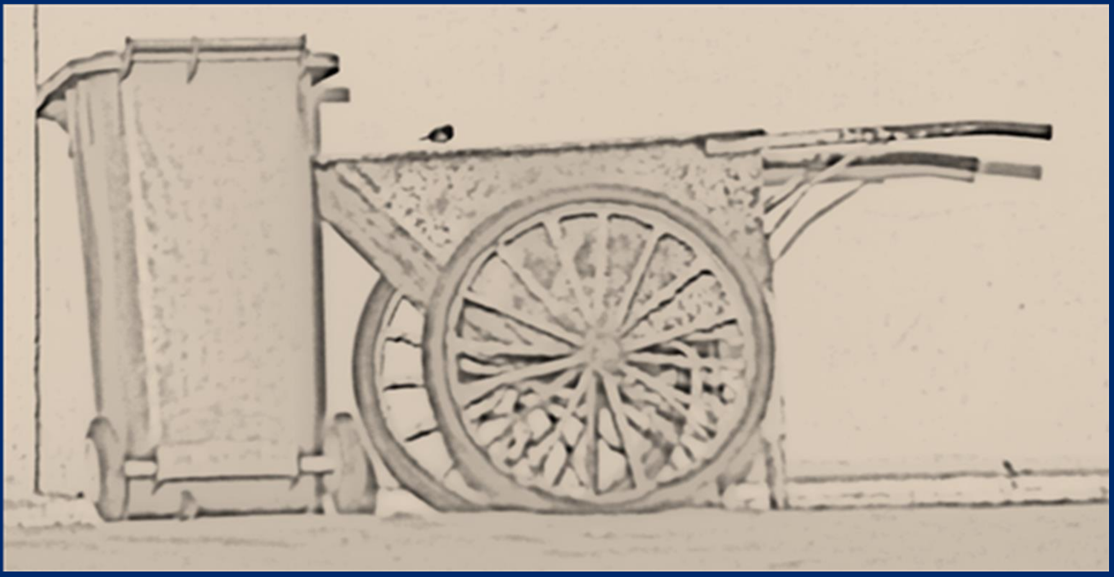
TA-8566 REG: Mainstreaming Integrated Solid Waste Management in Asia

Integrated Solid Waste Management Plan

Buriram



October 2016

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Executive Summary

The Integrated SWM (ISWM) Plan is a document that causes City staff and advisors to consider waste management from cradle to grave and review current activities, as well as look into the future for alternatives and opportunities to improve the system overall. Success of the Plan depends upon understanding the development context and implementation priorities and responsibilities. Guidance is provided in the initial Plan chapters on how this should be done in a structured manner. This includes guidance on issues such as formation of appropriate SWM committees and even Boards as required for larger facilities.

The nexus between the various stakeholders including the political arm of the municipality, their technical staff, and private sector organizations involved in any facet of Waste Management and civil society is addressed in the Plan. This even extends to the issue of information, education and communication plans to maximize Plan effectiveness not only for the initial implementation but during the entire life cycle of the Plan.

Initial sections of the Plan provide an overview of SWM at present within the municipality. This section of the Plan describes the current status and relationship between the various stakeholders in the municipality, relating to all stages of Waste Management from generation through to disposal. The Plan provides data on the physical assets such as the waste haulage trucks as the haulage responsibilities remain with the municipality rather than being outsourced. Similarly a description is provided on the current waste disposal facility and how it can be upgraded to provide a better standard of operation and much extended operational life.

Understanding the legislative environment is critical to preparing a future Plan for Waste Management. This is typically divided into three levels of government, namely national or central, provincial or regional and finally municipal. In many cases, the most relevant legislation is a combination of national and municipal. Buriram has developed some local ordinances relating to SWM such as plastic waste management.

It is important to understand the historical context for the city or municipality. This background is provided in the municipal profile chapters. Geophysical information is also provided relating to the geographical location and boundaries, overview of population, land area and topography as well as climatological data.

All aspects of ISWM Plans are predicated on a sound knowledge of the waste components and quantity that needs to be managed. These waste data are essential not only for the sizing and design of the infrastructure requirements, but also allow the social elements be better understood in terms of assistance required to increase recycling activities and other recovery operations. It was initially expected that site specific waste audits would need to be conducted. However, recent waste audits have been conducted within the city or in nearby municipalities that were of a sufficient standard to ensure that the SWM Plan would still be based on appropriate data sets.

Waste Minimisation is a key component of overall SWM interventions. The Plan provides background information and a number of options including various legislative opportunities as well as noting the relevance of information and education campaigns. Some of the interventions particularly relate to plastic bags and plastic beverage containers. This section also mentions household hazardous waste which based on the audit results to date that indicated HHW is not a major problem but still requires ongoing monitoring.

Buriram City has an Anti-Plastic Ordinance in place which limits certain plastics in specified localities, such as Styrofoam in city hall. Further additions to the Ordinance are proposed in the future to further restrict plastic bags and containers.

The existing recycling facilities have been reviewed, including the local recycling centres and smaller junk shops. This review is primarily to determine the causative factors limiting recycling quantities at present. An outcome of this section is to list the issues currently limiting recycling and provide a program for improving recycling where appropriate.

The ISWM Plan notes that composting can occur at three different levels, namely household, community or centrally. Many examples are provided both in the text of the Plan and also in the appendices on the advantages and disadvantages of composting organics at these three levels. The default position is that household based composting should be supported and that greenwaste wherever possible should be segregated for chipping and mulching or giving back to the community for gardening mulch. The city has interest in considering a number of pilot composting plants as part of neighbourhood level MRFs.

Estimates have been made for both the future population and waste generation rates for a 30 year period. It is recognised that significant error bands must be placed around these projections however it does provide a guide to ensuring that any new waste facilities, especially landfill sites, are suitably sized to avoid having to find new sites on a frequent basis. It was estimated that the new landfill site had approximately 30 years' life which should be sufficient.

Collection services in Buriram are adequate and the City indicated it did not wish to corporatize or privatise the collection activities at this stage.

Guidance is provided in the Plan on the management of specific waste types such as difficult wastes, sometimes acceptable waste and prohibited wastes. This includes wastes such as hospital or medical waste, liquid waste and specifics such as asbestos.

All successful integrated SWM Plans involve a component related to information and education, particularly if sustainability is a key city focus. A number of typical IEC components are presented together with a possible approach including community training elements. The importance of the correct communications strategy is also addressed together with options and opportunities for the implementation of such a program. This includes aspects such as radio, television or community outreach through contracted NGOs, and through to mainstreaming through a school's curriculum program. The city currently has some IEC activities through various media outlets and will remain a key focus for the city.

Climate change issues are addressed and the review notes potential climate change impacts on SWM as well as climate change adaptation and mitigation steps to be considered.

There is no benefit in providing large capital interventions unless these are operated efficiently and effectively. Therefore guidance is provided on appropriate evaluation and diagnostic tools to ensure that the municipality is maximizing returns on their capital interventions, be it financial or human capital.

City Summary and Project

The city of some 150,000 persons is a relatively wealthy community in Northeast Thailand, and this is reflected in the quality of the collection fleet and also the general standard of operation of the landfill. Furthermore there are extensive recycling activities occurring, which are supported by the ongoing IEC campaigns. The city just recently installed deposit booths for household hazardous waste at selected locations throughout the city for example.

The current landfill is reasonably well operated but design approach and operational changes are required to improve environmental performance and maximize overall site life. A concept design has been prepared together with indicative costings merely to guide this city on upgrade options. However this landfill upgrading is not the proposed project for this investigation as refuse derived fuels was agreed to be the focus of the Pre-Feasibility Study.

This is because the city is strongly focused on diverting as much waste as possible from land filling.

There was extensive discussion in both the first and second rounds of meetings concerning waste to energy opportunities, and in particular refuse derived fuels.

Initial meetings have been held with major cement companies to further investigate this opportunity and more meetings are programmed as part of the Pre-Feasibility Study. Preliminary technical investigations indicate that having a refuse derived fuel facility for such a small daily tonnage located such a long distance from the modern kilns capable of utilizing supplementary fuels is unlikely to be financially sustainable however.

It was agreed with the city that a strategy would be developed where RDF would be investigated under the current conditions and the Pre-Feasibility Study would list those conditionalities that need to change in the future to make RDF feasible. This assumes that it is not financially sustainable at present which is in alignment with the technical investigations conducted to date.

In summary RDF will be the subject of the Pre-Feasibility study however the road map will also note that an improved design and operational approach at the landfill is essential to maximize site life and reduce the current leachate problems experienced with the operation. If a more effective site design and operation is adopted, then the landfill has many decades of life even without the major diversions that would be associated with a successful RDF facility. This is critical as it means the landfill will be able to be utilized until the RDF facility can be operationalized (possibly) sometime into the future.

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1. Introduction

1.1. What is an ISWM Plan

The Integrated Solid Waste Management (ISWM) Plan is a document that causes Municipal staff and advisors to consider waste management from cradle to grave, review current activities as well as looking into the future for alternatives and opportunities to improve the system overall.

In summary, the ISWM planning process aims to:

a) Ensure the protection of public health and the environment;

b) Utilise environmentally-sound methods that maximise the utilisation of valuable resources and encourage resources conservation and recovery;

c) Set guidelines and targets for solid waste avoidance and volume reduction through source reduction and waste minimisation measures, before collection, treatment and disposal in appropriate and environmentally-sound solid waste management facilities in accordance with ecologically sustainable development principles;

d) Ensure the proper options are considered for segregation, collection, transport, storage, treatment and disposal of solid waste through the formulation and adoption of the best environmental practices in ecological waste management;

e) Consider greater private sector participation in solid waste management;

f) Retain primary enforcement and responsibility of solid waste management with local government units while establishing a cooperative effort among the national government, other local government units, non-government organisations, and the private sector;

g) Encourage cooperation and self-regulation among waste generators through the application of market-based instruments;

h) Institutionalise public participation in the development and implementation of national and local integrated, comprehensive and ecological waste management programs; and

i) Strengthen the integration of ecological solid waste management and resource conservation and recovery topics into the academic curricula and formal and non-formal education in order to promote environmental awareness and action among the citizenry.

In summary, developing the ISWM Plan provides an opportunity to jointly consolidate a new focus on ISWM within the Municipal environment, and use this as a base to incorporate that recent paradigm shift into all future ISWM decisions and operations.

1.2. Development Context for an ISWM Plan

This document provides the details for and structure of a solid Waste Management plan. However the plan cannot be developed and implemented in isolation of political support and civil society engagement.

The following section provides guidance on how the solid Waste Management plan should be developed and implemented in a structured manner.

1. Convene an ISWM Working Group of Cleaning and Greening or equivalent Departmental staff involved in ISWM, and any technical advisors as required such as provincial or national advisors or hired consultants, and other municipal staff involved in ISWM. The group is responsible for the actual Plan development and implementation.

2. Convene the ISWM Committee of elected representatives, MAB nominees, national or provincial government specialists, external stakeholders, technical advisors as required, and finally municipal staff from other departments such as finance, involving the Mayor or nominee and gaining general support. The ISWMC sets the priorities and policies to then be implemented by the Working Group

3. Prepare background data summary and status such as current and future serviced areas, population growth forecasts, technical assessment of existing haulage fleet, bins as well as the disposal site. This work is strictly a technical process with the political support to come at the next stage

4. Advise ISWM Committee and gain endorsement and agreement on background status. Some political input is essential at this stage to confirm current and future serviced areas etc.

5. Undertake the waste audit to determine the current waste constituents as well as the current waste density and mass leading to a better understanding of the current waste problem

6. Develop the integrated ISWM Plan including community engagement and education aspects. The details of the plan are established below involved looking in a holistic way from cradle to grave of Waste Management issues.

7. Present the Plan to the committee for endorsement. Following this endorsement, identify clusters of similar or related activities which can be converted to projects.

8. The Solid Waste Management committee would then agree criteria to prioritize projects for implementation, and the funding required. Personnel required duration of implementation, project impact on other operations and the municipality generally and deep that is a patient of external stakeholders. Overall the consensus of the Solid Waste Management committee members is required to agree the priorities and content going forward

9. As soon as the projects are prioritised, the appropriate committee member will then formulate the detailed concept including setting the objective, coverage implementation activities, funding requirements personal responsible, resource requirements and relevant timeframes

10. Depending upon the project type, the committee may need to conduct community consultation to present the project concept, obtain feedback and improve the project concept by incorporating external recommendations

11. The final project concept would then be presented to the Mayor or equivalent, in the presence of the Solid Waste Management committee and the possible presence of representatives of the beneficiary community

12. Following obtaining the Mayor's support, the assigned department will then ensure that the required personnel and logistics are prepared and/or made available as planned. Some of the projects may not require additional budget but merely a change in the way that the activities are implemented or the closer integration with the private sector or civil society. It is expected that training activities will be required for various roles and responsibilities. Some media launching activities may be appropriate to signal the start of the project. Progress reports and budget status will be reported to the committee and then to the Mayor as appropriate during project implementation.

These activities may be summarized as shown in the table below, together with guidance on the lead actor as well as the desired output:

- **Table 1-1 Activities, actors and outputs of ISWM Plan**

No.	Activity	Actor	Output
1	Convene a Working Group and establish the Solid Waste Management Committee (SWMC). These can be part of existing committees or groups.	SWMC and advisors	Problem analysis
2	Ensure the Mayor is involved with the process and gain support for preparing the ISWM Plan	SWMC	Political engagement
3	Prepare city background data summary and present waste management status	Working Group members and advisors	Current status documented
4	Advise Solid Waste Management Committee (SWMC) and gain endorsement and agreement on background and status	Working Group members and advisors	Agreement on current status and shortcomings
5	Undertake the waste audit	Working Group members and advisors	Quantified waste composition and waste mass data
6	Develop the integrated ISWM Plan including community engagement and education aspects.	Working Group members and advisors	Structured plan for solid Waste Management
7	Present the ISWM Plan to the ISWMC	Working Group members and advisors	Adopted ISWMP
8	Agree criteria and prioritize projects for implementation	SWMC	Prioritised activities for Plan Implementation
9	Formulate the detailed concept	Working Group members and advisors	Activity definition and costings
10	Conduct community consultation	Working Group members and advisors/SWMC	Engaged, educated and supportive community
11	Final project concept would then be presented to the Mayor and ISWMC	SWMC	Political support for specific project implementation
12	Organize logistics for implementing project and implement	Working Group members and advisors	Basis for project implementation
13	Conduct regular monitoring and inspection during project implementation	Working Group members and advisors	Project implementation understanding
14	Modify future projects based on lessons learned from this implementation	Working Group members and advisors/SWMC	Improved future projects

1.3. Implementation Arrangements for the ISWM Plan

The Municipality is primarily responsible for developing and implementing the ISWM Plan which must respond to the local solid waste problems and also be in accordance with the national policies. The ISWM Working group, in general, is composed mainly of 2 municipal divisions: “Division of public works”; and “Division of public health and environment”.

The ISWM plans proposed by these two divisions are to be compiled by the “Division of Technical Services and Planning” with other plans prepared by all other municipal divisions. The assembled plan is then submitted to the Municipal Council for consideration and approval. The Municipal Council acts as the ISWM Committee. After the plan is approved, the municipality will incorporate it in the “Three-year development plan” and issue related ordinances. The relevant municipal divisions can then start the Plan implementation.

In addition to the plans submitted by municipal divisions, local communities can also submit their action plans regarding solid waste management (usually much lower budget projects) to the “Division of Technical Services and Planning”. The proposed projects are subject to the consideration and approval of funding by the Committee of local heath assurance funds which is nominated by the Municipal Council.

2. ISWM Plan Background

2.1. Overview of Solid Waste Management Locally

Buriram Municipality is a middle size municipality located in Buriram Province. Its area covers all of the sub-district named “Nai Maung” which is equivalent to 6.0 square kilometres. The municipal area, also the centre of Buriram province, has various administration offices, schools, colleges and university, hospitals, healthcare facilities. It is the transportation hub of Buriram province. Since it is a centre of education and transportation, the municipality has to take care of a large amount of waste. The solid waste management system could be divided into 3 stages: (1) waste management at source, (2) waste collection, and (3) final disposal at a landfill.

2.1.1. Waste management at source

The municipality and communities support a number of projects that encourage 3Rs (reduce, reuse, recycle) and waste sorting. Recently, organic waste, recyclable waste and hazardous waste are to be separated from the residual waste portion sent to landfill.

As of 2016, waste generation rate is approximately 90 tons/day: with about 58% being recycled while the remaining 41% is disposed in the landfill.

2.1.2. Waste collection management

The municipality provides community based waste collection services for its residents. The task is carried out by the Division of public health and environment. MSW is collected twice a day and transported to the landfill using 13 haulage vehicles: 8 waste compactor trucks and 5 open tip trucks.

Two of these vehicles are used only for special requests (about 18 runs per months). It is noted that a significant portion of recyclable waste are separated out through various community projects and private sectors. As a result, there are on average approximately 1 vehicle movements a day for the special waste trucks to and from the dumping site.

2.1.3. Final disposal management

Collected waste is transported to dispose at the municipality-owned sanitary landfill site. The site is located in Phrakroo sub-district, Muang Buriram, Buriram province about 16 km from downtown. The site has been in operation since 2000. The area is 16 hectares divided into 4 phases.

Currently, the operation is at the final phase area and the Municipality has estimated the lifetime remaining is 4 years. The operation is of a fairly good standard. There is a good control over where waste loads are dumped, as well as an attempt to provide some waste profiling and application of cover soil. However the profiling is at a flat grade which is inappropriate as it maximises leachate generation.

There is no open burning of waste on the site. Overall, the collection and disposal of waste is at a reasonable standard.

Currently, the total quantity of solid waste that is disposed to the sanitary landfill is 86 tons/day (41 tons/day from Buriram municipality and 45 tons/day from other municipalities/cities).

The municipality collects fees for its waste management services. For example, the waste collection fee is 30 THB/household/month. The tipping fee, 500 THB/ton, is collected from the institutions inside the municipality and also any other organizations outside the municipality.

2.2. Legislative Environment

2.2.1. National

The Local Administration Organizations (LAO) are responsible for management of municipal solid waste, infectious waste generated from hospitals or clinics, and hazardous waste generated from communities including E-waste.

Relevant national laws and regulations regarding solid waste management in LAO and LAO responsibilities include:

- The Constitution
- Public Health Act, B.E.2535 (A.D.1992) and its 2nd revision, B.E.2550 (A.D.2007)
- Enhancement and Conservation of National Environmental Quality Act, B.E.2535 (A.D.1992)
- Maintaining Cleanliness and Tidiness of the Town Act, B.E.2535 (A.D.1992)
- Hazardous Substance Act, B.E.2535 (A.D.1992)
- Municipality Act, B.E.2496 (A.D.1953) until the 13th revision, B.E. 2552 (A.D. 2009)
- Sub-District Council & Local Administrative Organizations Act, B.E.2537 (A.D.1994)
- Provincial Administrative Organization Act, B.E.2542 (A.D.1999)
- Decentralization to Local Administrative Organization Act, B.E.2542 (A.D.1999)
- Ministry of Public Health Regulation on Fees from Waste Collection, Waste Disposal and Other Related Services, B.E.2545 (A.D. 2002)

The industrial waste, radioactive waste and laboratory waste are not the responsibility of the LAO

On 26 August 2014, the Government has undertaken key actions pursuant to the "Roadmap on Waste and Hazardous Waste Management" approved by the National Council for Peace and Order (NCPO), according to which four major steps have been implemented:

- Disposal of accumulated waste
- Management of new solid waste and hazardous waste
- Developing rules and regulations regarding solid waste and hazardous waste management
- Promotion of discipline in waste management among the public

On 3 May 2016, the Government approved the "National Waste Management Master Plan (2016 – 2021)" which emphasizes on 3Rs principle for sustainable solid waste management, waste management cluster, integrated municipal solid waste management, waste-to-energy, the commitment and involvement of all sectors in the management of solid waste and hazardous waste. The Ministry of Interior is appointed to oversee the provinces and LAO to construct their new "Waste Management Plan" as well as the "Provincial Action Plan for the Environment" in accordance with the approved Master Plan.

2.2.2. Provincial

All national-level laws, regulations, ordinances and guidelines relevant to SWM are applicable at provincial level.

2.2.3. Municipal

All national-level laws, regulations, ordinances and guidelines relevant to SWM are applicable at municipal level. In addition, the municipality had issued few ordinances as follows:

- Buriram Municipality Ordinance on Waste Management, B.E.2558 (A.D.2015) (containing information on waste collection fees and operating license fees)
- Buriram Municipality Regulation on Waste Disposal, B.E.2559 (A.D.2016) (containing information on waste disposal fee, permission process for waste disposal).

2.3. Institutional Environment

A number of municipal divisions are involved in solid waste management. The key divisions are the "Division of Public Health and Environment" and the "Division of Public Works". The Division of Public Health and Environment is responsible for cleaning up the public areas in the municipality, collecting and transferring waste to the disposal site. The Division of Public Works is in charge of operation and maintenance of the disposal site.

Other divisions involved in solid waste management include the "Division of Finance" which supports the annual budgeting and procurement of tasks that related to solid waste management; the "Division of Technical Services and Planning" which take a lead in setting up short term and long term strategies of waste management.

The Municipal Council oversees all operations. It can constitute ad-hoc committees or working groups to support activities related to solid waste management, for example, the Committee of local heath assurance funds.

2.4. Previous Studies and Investigations

There are two studies that have been undertaken relating to solid waste management in this municipality:

- The Feasibility study and detailed design of solid waste management system for Buriram province – Cluster 1. The Cluster 1 in this study included 4 districts, 6 municipalities including Buriram Municipality, and 47 sub districts. The study was conducted by a private company named “NS Consultant Co., Ltd.” in 2007. It suggested waste reduction at source, waste sorting, waste recycling, improving the efficiency of waste collection system, material recovery (composting of biodegradable portion and RDF preparation), sanitary landfill and avoiding incineration.
- Analysis of greenhouse gas reduction potential of solid waste management at municipality level of Thailand. This study was conducted by the Joint Graduate School of Energy and Environment for the Thailand Greenhouse Gas Management Organization (TGO). The study estimates, of all municipalities separately, the waste generation, the potential for RDF and compost production, power production potential, GHG mitigation potential under different scenarios up to 2050.

2.5. Proposed Guiding Framework

The current project will build upon the previous work and take it to a level which has community, civil society, commercial and government support for a sustainable project and appurtenant activities.

Whilst the terms of reference provide clear direction for this activity, an umbrella framework is proposed as set out below which brings together the various elements of an eclectic integrated Solid Waste Management plan.

This approach is built upon the UNDP/UNCHS (Habitat)/World Bank/SDC Collaborative Programme on Municipal Solid Waste Management in Low-Income Countries Conceptual Framework, SKAT Working Paper No. 9. This document provides an effective guideline for the goals and overall aim of such a project, taking account of the key political, institutional, social, financial, economic and technical components. The programmatic approach below has been prepared to include a number of key elements and activities which directly reflect the needs of the current project.

Table 2-1 Goals, Objectives and Strategic Issues of ISWM Plan

Goals

To promote the health and well-being of the entire urban population	To protect the quality and sustainability of the urban environment	To promote the efficiency and productivity of the urban economy	To generate employment and income

Overall Aim

To establish sustainable MSWM systems which meet the needs of all citizens, including the poor

Strategic Objectives

Political	Institutional	Social	Financial	Economic	Technical
Determine MSWM goals and priorities Define clear roles and jurisdiction for MSWM Establish an effective legal and regulatory frame- work	Devolve responsibility and authority for MSWM to local governments Establish effective municipal institutions for MSWM Introduce appropriate management methods, procedures and service targets Build municipal capacity for MSWM Increase efficiency and through private sector involvement Extend lower cost	Orient MSWM to the real needs of people, including the poor, women & children Encourage proper waste handling patterns by the population Raise people's awareness of MSWM problems and priorities Mobilise community participation in local waste management Protect health and socio-economic security of waste workers	Establish practical and transparent cost accounting and budgeting systems Mobilise adequate capital investment resources Raise sufficient revenues for recurring expenses -ensure adequate O&M Improve the efficiency and reduce costs of MSWM service	Promote economic productivity & development through adequate MSWM service Environmentally sound waste collection, recovery and disposal Ensure long-term economic effective- ness of MSWM systems Promote waste minimisation and material efficiency Generate employment and incomes in waste management	Achieve low life-cycle cost of waste management facilities and equipment Technology that facilitates user and private sector collaboration Ensure that technical systems effectively limit environmental pollution

Strategic Issues

Relative priority of collection services in relation to safe waste disposal Priority attributed to waste minimisation -reduction and recovery Meeting the service needs of irregular and illegal settlements Mix of instruments for waste management: regulations, incentives and/or motivations Contribution of ESAs to MSWM policy formulation	Optimal distribution of functions and responsibilities? Devolution of MSWM responsibility in spite of limited local government capacity Involving local governments in system planning and development Responsiveness of waste management to real needs and demands Raising the professional standing of waste managers	Adaptation of waste management services to the needs of poor households and women Effectiveness of awareness building or direct community involvement Equity of MSWM service access to the poor Collaboration with and support of informal waste workers	Failing incentive of local institutions to use available cost accounting methods Use of collected revenues for the intended MSWM purposes Incorporating incentives for cost reduction and efficiency	Trade-off between low-cost waste service and environmental protection Control of industrial and hazardous waste in spite of small, scattered sources Trade-off between efficiency of waste service and employment creation	Coherence of technical systems in spite of differing requirements and decision makers Estimation of life-cycle costs of technical alternatives Appropriate standards for sanitary landfill design and operations

3. City/Municipal Profile

3.1. Historical Background

Buriram Municipality was established by Royal Decree of Buriram Municipality, Buriram Province, B.E. 2479 (A.D.1936) which was enacted on 11 February B.E.2479 (A.D.1936) during the reign of King Ananda Mahidol Rama 8. In the following years, the municipal areas and nearby areas had grown to become more populated. In order to expand the municipal boundary, a new Royal Decree for Boundary Change of Buriram Municipality, Buriram Province, B.E. 2504 (A.D.1961) was enacted on 30 April B.E.2504 (A.D.1961) in the reign of King Bhumibol Adulyadej Rama 9. The decree states the boundary of Buriram Municipality to be increased to cover all of the Nai-Maung sub-district (which is located in Maung district, Buriram Province). The municipal area of Buriram Municipality has become 6.0 square kilometers since then.

Buriram Municipality has become the center of Buriram province. It has various administration offices, schools, colleges and university, hospitals and healthcare facilities. It is also the transportation hub of Buriram province.

3.2. Geographical Location and Boundaries

Buriram Municipality is in the northeast region of Thailand. It covers all of the Nai-Maung sub-district equivalent to 6.0 square kilometers. It is located in Maung district, which is in the middle of Buriram Province. From Bangkok, it is 385 km by car and about 376 by train. Approximately the distances from other province are as follows:

- Buriram – Surin: 50 km
- Buriram – Nakhon Ratchasima: 130 km
- Buriram – Maha Sarakham: 145 km
- Buriram – Khon Kaen: 200 km
- Buriram – Sra Kaew: 230 km

Its boundaries connected with 2 neighboring sub-districts. It is bordered to the north by Chum Het sub-district, to the east, south and west by Isan sub-district (Maung district).

3.3. Population

The Municipal population is 28,361 persons who actually reside locally (4,726 persons/km^2 as of 30 June 2015) and 100%are within the serviced area where collection services are currently provided. However, the actual number of persons living/working/studying in the municipal area is much greater than this registered value. The university alone has at least 20,000 registered students.

From the "Feasibility study and detailed design of solid waste management system for Buriram province – Cluster 1" conducted in 2007, the population growth rate was estimated. The Municipality is expected to grow at a rate of 0.61% per year (from 2007 to 2026) meaning that the total actual residential population will be approximately 33,518 in the next 10 years (2026).

A 20 year planning horizon is required to ensure that the landfill site has sufficient capacity.

3.4. Land Area and Topography

Buriram municipality is at the south end of the Khorat Plateau. The area is generally flat with a slight slope from west to east and from the north to the south. The highest surface elevation in Buriram municipality is about 163 meters above mean sea level (AMSL).

3.5. Climate

The climate is tropical with three seasons:

- Summer from mid-February to mid-May
- Rainy season from mid-May to October
- Winter from October to February.

Annual precipitation is 1,331 mm from 108 rain days per year. There is no data on the annual evaporation. The average temperature is 27.2C with minimum of 10.7C in winter and maximum of 40.1C in summer.

The annual average humidity is 76% with the highest of 93% in October and the lowest of 53% in March. (Data taken from Nang Rong Hydro meteorological Station, 2014).

3.6. Current Disposal Site Soils and Hydrogeology Details

The current disposal site is approximately 16 km from Buriram municipality. The total area is approximately 16 hectares (100.3375 Rai or 16.054 hectares).

Locally the soil profile is medium-hard clay over hard sandy clay and over hard clay.

The water table depth is at about one metre but varies seasonally.

The nearest groundwater user is approximately 1 km from the disposal site and the water depth in their well is unknown.

The nearest surface water user is a substantial distance from the waste disposal site.

Details from the "Feasibility study and detailed design of solid waste management system for Buriram province – Cluster 1" conducted in 2007:

- Boring no.BH-1: Very stiff clay with sand, over hard sandy clay with gravel, over hard clay. Groundwater level is -1.48 m.
- Boring no.BH-2: Medium clay, over very stiff clay with sand, over hard clay. Groundwater level is -1.02 m.
- Boring no.BH-3: Medium clay, over very stiff clay with sand, over hard clay. Groundwater level is -1.08 m.

4. Waste Audits and Load Determination

4.1. Introduction

All aspects of this ISWM Plan are predicated on a sound knowledge of the waste components and quantity that needs to be managed.

These waste data are essential not only for the sizing and design of the infrastructure requirements, but also allow the social elements be better understood in terms of assistance required to increase recycling activities and other recovery operations.

4.2. Previous Waste Audits

There are 4 studies conducted in the past. Details are as follow:

1. The Feasibility study and detailed design of solid waste management system for Buriram municipality.

   The study was conducted by a private company named "Vis consultant Co., Ltd." in 1996. Waste components were analysed from 3 days of waste sampling, 14 – 16 June 1996. Details could no longer be located.

2. The Feasibility study and detailed design of solid waste management system for Buriram province – Cluster 1.

   The study was conducted by a private company named "NS Consultant Co., Ltd." in 2007. The "Cluster 1" referred to in this study included 4 districts, 6 municipalities (including Buriram Municipality) and 47 sub-districts, equal to 221,691 hectares. The study investigate the quantity of waste collected per day by weighing all waste trucks and all collection routes. The paper did not publish details on how many days and how the weighing was conducted.

   It reported that the waste collected from Buriram municipality was 28,826 kg/day. This resulted in waste generation rate of 0.9 kg/person/day. It also reported the waste density ranging from 0.07 – 0.14 ton/m^3 with an average of 0.09 ton/m^3. The waste components were investigated during November – December 2006. Details about number of samples as well as sampling days were not provided in the report.

   The results of waste components, moisture content, heating value, combustible content, ash content, carbon and nitrogen contents were reported as average values of Cluster 1 (not specifically for Buriram municipality).

   The average waste compositions, % dry weight, are as follows: paper 25.12%, glass 19.98%, food waste 18.27%, plastic 14.95%, textile 6.19%, metal 5.73%, wood 5.13%, foam 2.69%, others (stone, ceramic, animal bone and shells) 1.85%, rubber and leather 0.09%.

3. The study on waste components surveyed in 2011

   The results were published in the "Five-year plan for solid waste management in Buriram province (2015 – 2019)" by the Buriram Provincial Office for Natural Resources and Environment, Ministry of Natural Resources and Environment in 2014. The average results of 3 samplings showed compositions of waste as follows: food waste 71.41%, plastic 13.80%, paper 11.14%, metal 1.25%, glass 0.91%, textile 0.78%, wood 0.64% and rubber 0.08%.

4. The study on waste components conducted by municipality's officers.

The study was conducted during 9 – 13 December 2014 (5 days). Each day, waste from 2 collection trucks arriving at the landfill site were analysed for waste components. The average results (of 10 sampling) showed compositions of waste as follows: food waste 30.59%, plastic 28.26%, paper 11.36%, glass 6.99%, wood 5.54%, rubber 5.42%, textile 4.81%, metal 2.62%, others 2.52%, ceramics 1.02%, and hazardous waste 0.87%.

4.3. Waste Audit Results

It is the overall waste stream entering the landfill that will determine the equipment requirements, as well as the possibility for enhanced recycling efforts together with waste minimisation activities. Therefore because of the accepted limitations of the site specific audits described above, a more detailed end-of-pipe style audit was undertaken to assess the mixed waste as it entered the landfill. This also afforded an opportunity to determine the quantity of waste actually reaching the landfill. The approach is presented in **Appendix B – Waste Characterisation and Density Determination Audit Protocol**.

However the above results from previous audits were considered sufficient.

4.4. Volume Determinations

The task is carried out by the Division of Public Health and Environment. MSW was collected and transported to the landfill by using 13 haulage vehicles: 8 waste compactor trucks and 5 open tip trucks. Two of open tip trucks are used only for special requests (about 18 runs per months). One open tip truck is used only for garden waste. The rest of vehicles are used to collect MSW daily, once a day.

A total of 10 vehicle loads of waste were measured to determine the waste volume within the vehicles. These 10 vehicles can be divided into 2 groups: large size 10 cubic metres x 6 trucks, and small size 7.65 cubic metres x 4 trucks.

Based on averaging the volume from the 10 vehicle loads, the total volume of waste entering the dumpsite each day is 98.23 cubic metres from the Municipality, but this excludes the waste delivered by neighbouring municipalities.

4.5. Density Determinations

A weighbridge is available on site. Each truck is weighed every time it reaches the landfill site.

A total of 10 trucks were selected at random to determine the density of the waste contained therein

Using the total volume and kilograms weighed from municipality's data in April 2016, the average density of trucks entering the site was estimated at 409.3 kg/m^3

4.6. Mass Loads

Using the average truck load volumes and density above, it was determined that the average vehicle entering the site carries 4 tonnes.

Reviewing the gatehouse keeper's reports for the last year, the average number of vehicles entering the site was 10.

Therefore, on average, a total mass of 40 tonnes a day is entering the site, seven days a week, excluding waste from other municipalities going to the landfill.

This total was used to work backwards to determine the average amount of waste generated per person per day.

4.7. Waste Components

Information of waste components was taken from waste survey in 2011 which was published in the "Five-year plan for solid waste management in Buriram province (2015 – 2019)" by the Buriram Provincial Office for Natural Resources and Environment, Ministry of Natural Resources and Environment in 2014.

There is no description of procedure used during waste audit.

The results of the audit are shown in the **Table 4-1** below.

- **Table 4-1 – Municipal Waste Audit Results**

Waste Type	Audit (Percent)
Paper/cardboard	11.14
Glass	0.91
Plastic bags	13.80
Other Plastic	
Aluminium	1.25
Other Metal	
Food waste	18 - 71.41
Green/Garden waste	0.64
Builders Waste	-
Timber/Lumber	-
Soil and dirt	-
Hazardous Waste	-
Fabric and Leather	0.78
Miscellaneous	0.08 (Rubber)

4.8. Discussion of Results

4.8.1. Paper and Cardboard

Paper and cardboard content was 11.14 %, by mass. These figures appear slightly high based on site inspections and visual observations of the waste at the landfill.

The majority of the "Paper and Cardboard" was in fact dirty paper. There was little newspaper or the more valuable bond paper. Clean cardboard is recycled before MSW reaches the landfill site. However, the municipality does not have information on the amount of paper and cardboard recycled.

On average a large proportion was old tissues, paper wipes and very dirty/wet cardboard, with very little recycling potential. Paper recycling plants may accept a very small percentage of dirty paper, but expect that it is sorted into different categories to facilitate easier processing, such as bond paper, newspapers, glossy page magazines, etc. In general though, recyclers do not accept paper items that have been exposed to water. The fibres may be damaged, and there are contamination risks.

Given a further 4.5 tonnes per day is being dumped, then there may be a small opportunity for greater recovery rates for cardboard and paper.

4.8.2. Glass

The class content was 0.91%, by mass.

In most cases the glass was in whole bottle form and not as cullet resulting from either bottles or plate glass. In general these cullet mixes attract a much lower price than whole bottles because of the difficulty in recycling the different colour and glass types.

While the percentages are low, this still represents over 0.36 ton per day of glass being dumped. The bottles and cullet would have to be collected, but could probably only be sold as cullet given the wide mix of bottle types.

However, it is recognised that until there is a local bottling plant able to directly reuse the glass bottles locally, recycling of intact bottles will be difficult. In current practice, both cullet and glass are recycled by sending it to waste recycle shop. The merchant transports recycled materials to sale in other province.

Local reuse of the bottles as containers for other liquids is preferred as one option or crushing and use as concrete aggregate

4.8.3. Plastic Bags

There is no information on separated type/portion of plastic. Overall plastic including bags and bottles is 14% by mass or 5.55 ton per day.

To make plastic bags more attractive to recycling companies, they require cleaning which can result in significant water pollution. Most plastic bags observed during the site audit and other inspections and the primary dumping location were dirty and this would require wiping/scraping and then washing before recycling.

In some countries, such as in Quezon City in the Philippines, selected types of plastic bags are cleaned and then recycled into high value recyclable such as handbags and casual jewellery. However the amount of water pollution resulting from washing these bags is very significant and must be considered as part of the overall impacts of recycling. It is of course possible to clean the plastic bags using a wastewater recycling system that would involve sedimentation and possibly filtration, but this is not considered to be appropriate locally at the time

Further, the bags are obviously low density and expensive to transport unless they are processed through chipping or granulating. Even with these interventions, there are very few junk shops in developing countries, even in major cities, that recycle plastic bags. The profit margin is relatively low even with local buyers, and the large storage volumes required to generate any significant turnover means that the available junk shop storage areas are not being used efficiently. Therefore the operators tend to focus on other materials such as aluminium, metals or perhaps even plastic bottles.

There are some exceptions to this in Vietnam where clean plastic bags are recycled in some cities. However, these activities are in significantly larger cities than Buriram. The definition of clean and dirty plastic bags needs to be defined. In countries such as Viet Nam, “dirty” plastic bags are purchased for recycling. However, the definition of dirty in this case is that there is some inorganic soil making the bag dirty rather than being exposed to or containing quantities of organic waste such as food scraps. So therefore any references to recycling dirty plastic bags refer to those bags which have some soil contamination rather than plastic bags used for disposing of food scraps. Any plastic bags contaminated with food wastes will need both scraping and then washing and drying before recyclers will accept the bags, which is clearly not commercially viable. Plastic bags are being recycled in some cities in Thailand as well.

Overall, given the fact that the great majority of the plastic bags are dirty (both from inorganics and also organics) and would require significant cleaning, and the fact that the city is a significant distance from the possible recycling market in Thailand, recycling plastic bags would not seem viable at this time. The recycling benefits must also be offset against the expected pollution that would result from cleaning all plastic bags which would be essential. Much larger volumes are required and also a higher proportion of clean bags to make it viable.

Other options include driving oil from plastic plants, or low temperature burning in peri-urban households.

A better approach would be waste minimisation – using reusable bags and waste bins to carry waste to the primary dumping areas, rather than plastic bags.

Alternative types of plastic bags are available which are:

- “degradable” (physically break down into much smaller pieces of plastic),
- “biodegradable” (an additive in the plastic makes the bags chemically break down into basic elements over a proscribed time) or
- “compostable” (organic-sourced bags often containing starches which are compostable and do not leave smaller plastic residuals).

However all these are possibly too expensive to be considered as a viable alternative at this time.

Both recycling and waste minimisation will be continually reviewed during project implementation.

4.8.4. Other Plastic Containers

There is no information on separated type/portion of plastic. Overall plastic including bags and bottles is 14% by mass or 5.55 ton per day.

As with plastic bags, the bulk density of plastic bottles is very low and therefore, the amount of plastic bottles within the waste stream can attract significant recycling attention. Once the plastic bottles are actually compacted within the landfill, they will only occupy a very small percentage of the airspace and are therefore are not a critical factor in landfill life or operating costs. However, they do remain a recyclable commodity and all efforts should be made to keep these out of the landfill and facilitate recycling.

At this stage, plastic PET and HDPE containers are already being recycled by some major local enterprises. There is also interest in recycling Poly-Propylene containers as well.

The plastic collar and cap on PET water bottles is made from a different plastic to that of the main bottle itself, usually HDPE. At some stage in the recycling process, the collar and cap has to be removed as the mixture of HDPE and PET cannot be processed successfully. This is not a problem until a chipper or granulator system is installed as the presence of the collar or cap is obvious. Even a small amount of the collar or cap material can contaminate a very large mass of PET plastic and make the chipped material far less valuable.

A decision needs to be made by the recycling companies whether they wish to continue with segregation or just accept the slightly lower margin for contaminated PET product. This decision becomes especially critical if a chipper or granulator is to be purchased to allow much greater densities to be achieved and therefore reduced haulage costs.

One other way of improving the recycling efficiency would be to have the city or agencies provide some secure compounds so that larger volumes of these materials can be stockpiled prior to sale. In all cases and for all materials, the junk shop will achieve a higher price for selling larger volumes because of the reduced transaction and haulage costs.

4.8.5. Aluminium

There is no information on separated type/portion of metals. Overall metals including aluminium is 1.25% by mass or 0.5 ton per day.

There are no other specific interventions required for aluminium as this is clearly being recycled effectively at present.

4.8.6. Other Metals

There is no information on separated type/portion of metals. Overall metals including aluminium is 1.25% by mass or 0.5 ton per day.

This category was mainly comprised of steel cans, wire and other assorted household and commercial metalwork. There was no one particular component of this waste stream that needs to be specifically addressed, apart from metal cans.

In many developing countries, metal cans are not always recycled because the market prices are low, and it may not be economic to recycle. Furthermore to make the metal cans suitable for recycling at higher prices, the cans have to be cleaned out and labels removed which is a very labour intensive process.

A dedicated recycling program for the tins and other metals is unlikely to be warranted. Ongoing scavenging is the best option. If the option of installing recycling product cages near primary dumping locations is adopted, then higher recovery rates may be expected.

4.8.7. Food Waste

Food waste represented 18 - 71.41% of the total waste stream, based on mass from the various audits. It was composed of mainly rice, vegetables, fruit residue and peelings, but with very little meat scraps. The higher number is likely to be associated with portions of greenwaste mixed with the overall organics, termed just as food waste in the audit results.

There are few recycling options for food waste apart from feeding domestic animals at the household level, feeding semi-commercial scale animals such as pigs or chickens, use for fish food in commercial ponds and composting at household or commune level, or centrally.

Household composting can be by shallow burial and retrieval, simple slatted containers or commercial plastic bin systems with inversion capabilities.

Feeding domestic animals is strongly supported, but is not possible in all areas due to households having small or no yards to run chickens or goats.

In summary, household composting is strongly recommended for further investigation. Commune level composting has some guarded support and centralised composting has many hurdles to overcome for it to be sustainable economically. The issues include waste segregation efficiency, compost quality (such as seeds not being inactivated), foreign objects (glass shards or metal pieces) and most critically, developing a sustainable commercial market where users are willing to pay enough for the product to cover all the composting costs.

4.8.8. Greenwaste

Greenwaste represented 0.64% of the waste stream, based on mass, however significant portions are likely to have been mixed with the overall organics waste but termed Food waste.

It consisted mainly of grass clippings, leaves and small branches. This material could not be processed for any productive use, but would provide organics for compost if required, or just contribute to the landfill gas generation for possible later harvesting.

However, if there was a significant amount of larger tree material by mass, it could be chipped for recycling and then used as batter protection on landfill slopes or road dust control. Alternatively the chipped greenwaste could be composted on a larger scale in the future.

The local greenwaste could be composted either alone or with food scraps or digested sewage sludge, as it provides a better balance of carbon to nitrogen than food scraps alone which often have too much nitrogen for optimal composting.

Because the greenwaste is presently mixed through with other waste in most cases, it cannot be easily separated and reused centrally after collection without mechanical equipment such as rotating trommels or screens.

4.8.9. Builders and Demolition Waste

Builders and demolition waste was not detected during the various waste audits.

In the future when the building activity involves the construction of larger commercial structures where existing structures already stand, then there will be more construction waste requiring disposal. At this time a crusher may be appropriate to allow the concrete and other building products to be broken down into aggregate size particles for reuse in road and building construction and recovery of any steel reinforcement.

This crusher equipment could well be purchased and operated by the private sector as is common globally.

4.8.10. Timber

No information.

4.8.11. Fabric and Leather

Fabric and Leather waste comprised 0.78% of the waste stream, based on mass.

4.8.12. Soil and Dirt

Because the soil is mixed through with other waste, it cannot be easily separated and used as cover material without mechanical equipment such as rotating trommels or screens. This mechanical equipment is inappropriate at this stage of ISWM development and the soil should just be disposed of with the other waste material.

As the city develops, and the proportion of open blocks and exposed areas decreases, the amount of dirt to be swept up and also removed from drains during drain cleaning activities will naturally decrease in any case.

4.8.13. Household Hazardous Waste

The amount of household hazardous waste discovered during the audits was too small to weigh.

It consisted mainly of broken CFL lights which can contain small traces of mercury. However, the quantity recovered was too small to indicate the need for specific management plans for controlled disposal. Some dry cell batteries were also recovered, but again in quantities too small to require specific management.

The usual items of concern include biocides and solvents, but these were not detected at all during the audits. This may change over time as the community becomes wealthier and these products become more commonly used.

4.8.14. Miscellaneous

Miscellaneous waste represented around 0.08% of the waste stream, based on mass.

It contained a mix of rubber and other unidentified items.

None of these would really be recyclable in a planned manner, just incidental recovery depending upon the specific item encountered.

There are no common methods of significantly reducing or reusing this component, and it just has to be landfilled.

4.9. Detailed Comparison with other Waste Audits

While a rigorous audit protocol was followed and a large mass of waste sampled, there is still the possibility that the audit results may have been skewed by some external factors. Therefore it is important to compare the audit results with results from not only other parts of Thailand but internationally as well.

This comparison not only provides some comfort that the local detailed audits are representative, but also provides some comparisons that can be used when deciding a local 3R strategy. For example, if wealthier developing countries have a good 3R market for say glass, then that material should be monitored in the future as it may become a viable commodity for recycling/reuse as Buriram becomes wealthier and this waste component becomes more prevalent.

More details are provided in **Appendix C– International Waste Audit Comparisons.**

- **Table 4-2 Comparison with Other Audit Results**

Waste Type	Buriram	Afghanistan	East Timor	Philippines	Cambodia	Vietnam	Pakistan
Food Waste	71.41	13 - 22	12	9 - 19	19 – 23	15 – 35	10 – 15
Green Waste	0.64	10 - 21	33	40 - 54	31– 40	15 - 38	20 – 25
Paper and Cardboard	11.14	1 - 8	22	4 - 8	2 – 6	3 – 8	4 – 8
Plastic	13.80	11 – 15	18	15 - 17	3 – 15	9 – 16	15 – 18
Textiles	0.78	-	2	1 - 3	1 – 4	0.1 –0.9	1 – 4
Glass	0.91	2 – 3	2	1 - 3	1 – 8	0.4 –5.0	1 – 3
Metal	1.25	0.02 – 0.95	1	2 - 3	0.6 – 8	0.3 –1.5	1 – 5
Wood	-		0	0 - 2	-	0.5 – 3	0.5 – 2
Soil and Dirt	-	5 - 11	28	10 - 15	10 - 30	10 - 15	15 - 25
Miscellaneous	0.08	4 - 12	2 – 10	7 - 14	2 - 8	2 – 12	2 – 10

The results in **Table 4-2** shows that the food waste proportion of Buriram is too high from the last audit at over 70% but earlier audits indicate the mass is more like 18%. In general, share of food waste in Thailand is between 31-62 % due to several factors include nature of habitants, size of municipalities and local environmental condition. In case of Buriram, high percentage of food waste can be the result from rapid development and expansion of municipalities with numbers of migrants and visitors. As the municipality has plans to promote as the ASEAN sport city in the future, the football club and sport activities currently welcome visitors to spend a day trip at Buriram. It is therefore possible that the share of food waste is higher than usual. Another reason is that waste recycling activity in Buriram is quite strong. This may increase the share of food waste in the waste collected to landfill. Nevertheless, it is recommended to resurvey the food waste content in the future if and when centralised composting is more closely considered.

In general, some of the higher value recyclables are being recovered or reused resulting in very low levels remaining in the waste stream. This includes materials such as glass and metals, especially aluminium and copper.

However, paper and cardboard is a candidate for much greater recovery efforts.

Plastic bags and containers are at a level typical of similar countries, and options exist for a greater recovery rate, especially for plastic drinks containers.

The other major component is the organics, combining both food scraps and greenwaste. Food scraps would have to be segregated at source to be compostable.

Greenwaste is generally mixed with other municipal waste at present and will be very hard to separate economically, unless a separate bin approach described elsewhere is adopted. This would mean that greenwaste will be kept separate and readily available for chipping and reuse.

Soil and dirt is a significant component, but cannot be reused as soil on roads, as cover material at a landfill or placed on landfill batters without mechanical separation using trommels and screens.

In summary, there is nothing unusual with the results and the dataset exhibits no obvious outliers, hence these results provide a sound basis for the study going forward.

5. Legal Environment for 3Rs

This chapter provides the National legal framework relating to the issues of source reduction or waste minimisation. The following chapter addresses the local opportunities and notes the advantages and disadvantages of the various systems.

5.1. Mandatory Solid Waste Diversion

There are no mandatory waste reduction or recycling targets set by legislations or by laws. However, the targets are explicitly set in the national development plan. Hence the action plans and activities follow accordingly.

The key national development plan, “the 11th National Economic and Social Development Plan (2012 – 2016)” published by the Office of the National Economic and Social Development Board, sets a target for waste recycle at 30.0%. This should be achieved by

- Improve the efficiency of the waste management system to better response to the local problems and its potential.
- Encourage public-private partnership
- Waste reduction at source and maximize waste recycle
- Implementing economic motives/tools such as pollution tax, carbon tax, etc.
- Put priority on the critical areas
- Speed up the investment process of sustainable and integrated waste management system.
- Encourage community business & recycling business of private companies
- Encourage waste utilization, waste to energy.
- Issue or revise the regulations to enable municipality to collect sufficient service fees for waste management system.

In accordance to the national plan above, the Environmental Quality Management Plan (2012 – 2016) by the Ministry of Natural Resources and Environment (MONRE) as well as the Pollution Management Plan (2012 – 2016) by the Department of Pollution Control, MONRE, set the targets, action plans, and provide supports and encouragement accordingly.

On 3 May 2016, the Government approved the “National Waste Management Master Plan (2016 – 2021)” which emphasizes on 3Rs principle for sustainable solid waste management, waste management cluster, integrated municipal solid waste management, waste-to-energy, the commitment and involvement of all sectors in the management of solid waste and hazardous waste. The Ministry of Interior is appointed to oversee the provinces and LAO to construct their new “Waste Management Plan” as well as the “Provincial Action Plan for the Environment” in accordance with the approved Master Plan.

However, at the moment, Buriram has a “Five-year plan for solid waste management in Buriram province (2015 – 2019)” issued by the Buriram Provincial Office for Natural Resources and Environment, Ministry of Natural Resources and Environment in 2014. It set a target for municipal solid waste that by 2019 all communities in the province should manage their waste at source by 3R principles.

At the municipal level, there is no municipal legislation nor laws mandating waste reduction or recycling targets in addition to national and provincial targets. However, the municipality strongly support the waste reduction and recycling activities in its responsible area as can be seen in the "Three-year development plan of Buriram Municipality (2016 – 2018)". A number of projects related to solid waste diversion are financially supported such as:

- Waste sorting and recycle project (2016 – 2018)
- Waste exchange for useful items and food (2016 – 2018)
- Composting of garden and wreath waste (2016 – 2018)
- Green office project (2016)

Furthermore, the municipality also reported that recently its citizen successfully separates all hazardous waste out of the MSW stream collected for landfill disposal.

5.2. Timetable for Mandatory Solid Waste Diversion

The "**National Waste Management Master Plan (2016 – 2021)**" recently approved by the Cabinet in May 2016 has the following targets:

Short term targets (2016)

- At least 80% of old or accumulated waste is managed correctly
- At least 50% of MSW is managed and disposed sanitarily
- At least 10% of municipal hazardous waste is collected and sent to proper disposal
- 100% of infectious waste is managed and disposed sanitarily.
- 100% of industrial waste is managed and disposed appropriately.
- All of city municipalities and town municipalities have waste sorting at sort. At least 10% of sub-district municipalities have waste sorting at source.

Long term targets (2017 – 2021)

- At least 100% of old or accumulated waste is managed correctly
- At least 60% of MSW is managed and disposed sanitarily
- At least 30% of municipal hazardous waste is collected and sent to proper disposal
- At least 50% of sub-district municipalities have waste sorting at source.

The plan addresses 3Rs strategy but it does not specify target of waste reduction and recycle.

There were 3Rs targets set in the "National 3Rs strategy (2011)" but this could be irrelevant at the moment. The targets for 3Rs activities are as follows:

- **Table 5-1 3Rs Targets for "National 3Rs Strategy (2011)"**

	Period		
Targets	2012-1016	2017-2021	2022-26
Waste reduction	1%	3%	5%
Waste recovery	20%	22%	25%
Energy recovery from waste	5%	10%	15%
Biodegradable recovery (composting & biogas)	5%	30%	50%
Reduction of waste going to final disposal	-31%	-65%	-95%
Use of reused or recycled waste in industry	70%	75%	85%
Glass	75%	75%	85%
Paper	60%	70%	80%
Plastic	45%	55%	75%
Metals	95%	95%	95%
Aluminium	75%	80%	90%

The Municipal ISWMC has to determine the waste streams that can be diverted from disposal. This will be based from the combined results of the actual waste characterisation activities.

5.3. Plans to Exceed Mandatory Diversion Target

Further plans to exceed the mandatory diversion target and address issues being posed by the handling of other waste streams will be determined by the Municipality, in consultation with concerned organisations and groups. This can include, but is not limited to, targeting a higher percentage of solid waste sorting and organic waste composting, mobilising generators to implement source reduction strategies to minimise waste generation levels, and implementing holistic recycling campaigns for the other waste streams.

6. Waste Minimisation Approach

The approach is based on the principles listed in **Appendix D – Source Reduction Policy Options.**

Appendix E – Waste Minimisation for Special Wastes and Appendix F – Minimisation of Plastic Bags and PET Bottles also refer**.**

6.1. Integrated Resource Recovery (IRR)

Integrated Resource Recovery (IRR) is the recommended approach to waste management for the Municipality. This aims to *"instil an understanding and support within the community of waste management principles".*

Fundamentally, this can only be achieved by creating the opportunity for members of the public to play an integral and valued role in the decision making process, from initial planning through to system implementation and operation. This has to cover all aspects including resource recovery systems and technology.

It should be developed in three phases, as follows;

- The Strategic Framework – rationale, opportunities, vision, goals, implementation paths, and evaluation of public sector participation
- The Strategy; Why should communities participate in waste management decisions – detailed assessments of international practices in waste management aspects, including analysis of different communication methods
- Principles of Public Participation – Develop rules for the IRR, including roles and responsibilities for the Municipality (elected representatives and staff), National agencies such as civil society, NGO's, industry, Neighbourhood representatives and other interested parties

6.2. Legislation

Waste minimisation legislation has been utilised in many parts of the world in order to control the generation of waste. Examples of such legislation follow.

6.2.1. Container Deposit Legislation (CDL)

Many countries have CDL, including Australia and a number of EU countries and State in the USA. This legislation requires a deposit on containers for products defined as beverages under the Act, with exemptions granted by Regulation. Refunds on containers with deposits are paid at point-of-sale or collection depots and are collected from there for reuse or reprocessing. The primary reason for the introduction of CDL was as a litter-control measure.

However a recent waste industry commission considered CDL as part of its study and found that there was no convincing case for container deposit legislation. The Commission found that deposit schemes are expensive to operate and impose high costs on both producers and consumers and are inefficient compared with other available economic instruments.

CDL operates as a disincentive for the kerb-side collection of recyclables because it lowers the value of the remaining waste stream by lowering the quantities of high-value recyclables such as glass and aluminium.

The degree of success will probably not be too high as there is already very efficient recovery of glass and bottles, first at source by users and by jumper boys in the collection vehicles and scavengers at the dumpsite.

This is addressed further in later chapters relating to PET bottles.

6.2.2. Packaging and Plastic Bag Legislation

In 1991 Germany introduced the "*Ordinance on the Avoidance of Packaging Waste*" (Verpakungsverordnung). This Ordinance was designed to ensure manufacturers take more responsibility for the packaging they create, by giving consumers the right to leave excess packaging behind or return it to the point-of-sale later. As a result, far greater pressure is placed on manufacturing, via retailers, to establish alternative collection schemes and ensure that their packaging is reusable and recyclable.

Two cities in North America, Minneapolis and St Paul, have also enacted ordinances which require that food packaging sold in retail outlets be reusable, recyclable or biodegradable.

Manila in the Philippines has simply banned plastic bags and paper bags or cardboard boxes are supplied instead.

Although this type of legislation is usually enacted at federal or state/provincial government level, it is appropriate that municiplaities and agencies lobby and support the introduction of such legislation.

Another option is the introduction of compulsory charges for all plastic bags used at supermarkets. This has been used in other developing countries such as Fiji in the Pacific. The charge is in the order of 2 US cents per large plastic grocery bag. The aim is twofold:

- Firstly, it is to encourage people to only use the actual number of bags required.
- Secondly, it encourages people to reuse the bags, either for later trips to the supermarket or to use the bags for storing garbage rather than buying special garbage bags and liners. It has also had the effect of people now bringing hessian and other reusable bags to the supermarket and not using many if any plastic bags.

A further option discussed separately below is the mandatory use of biodegradable bags, which is common in both developed and less-developed countries.

With the leadership of current Buriram's Mayor, a plan has been initiated to use bioplastic (biodegradable) bag in substitute to plastic bags. This bioplastic bag can be promoted in the department store and in the markets. However, as sources of bioplastic in Thailand are quite limited, plans to use bioplastic bags will be delayed until sources are readily available.

Nevertheless, Buriram municipality has promoted NO PLASTIC BAG within the municipality office and hope to expand this plan to be implemented widely in the municipality. Officers have to come with their own lunch box and container.

6.2.3. Prohibition of Non-Environmentally Acceptable Packaging

The Municipality will consider establishing localised guidelines pursuant to the prohibition of the use of non-environmentally acceptable packaging, in association with National initiatives. Currently, the municipality encourage its people to avoid using foam in the municipal markets and weekly fairs.

6.3. Education

A major key in any Government body achieving reduction of waste to disposal is the education of the community, both general society and business. Locally a National Government initiative is required to support education with respect to waste management. This effort could possibly be best directed through a combination of national campaigns, supplemented with funding for local level education through local NGO's.

The USEPA has produced booklets such as "The Consumers Handbook for Reducing Solid Waste", 1996. This booklet is particularly comprehensive and addresses the integrated waste management approach, or the cradle to grave approach. This addresses all phases of waste management including advice on reducing the amount of unnecessary packaging. The handbook also covers the issue of adopting practices that reduce waste toxicity, and the associated issue of household hazardous waste collection that is often overlooked in these publications. The composting section is also very basic and provides the details for constructing and operating a household or Neighbourhood level compost scheme.

Also the UNDP funded Project "Public and Private Sectors Convergence for Solid Waste Co-governance in Urban Poor Communities" being trialled in Calamba, Philippines would provide good educational material as input to developing a local plan and strategy. These booklets could be used as a basis for developing local educational information.

It is considered that education is the fundamental key to a successful waste reduction strategy.

6.4. Landfill Scavengers

Another method of removing useable items from the waste stream is controlled scavenging at the landfills. Some countries ban scavenging from Controlled Landfills and entirely from landfills. However, such schemes can be successful even in developed countries such as the "Revolve" scheme in Canberra. In this type of scheme, a community group has a designated area of land set aside at the landfill for the receipt and sale of reusable items. Other cities establish "dump shops" at or near the landfill to sell recovered items. These schemes can be operated in a safe and sensible manner to avoid health risks and manage safety issues.

The alternative of a mechanised Materials Recovery Facility is really only appropriate with segregated or select waste. Waste segregation options and the locally adopted approach are discussed elsewhere.

The most common approach is to allow scavenging but introduce some rules such as no children allowed and provide some training on the health risks involved, etc.

It is proposed that controlled scavenging will be allowed at Controlled Landfills to continue to achieve good recovery of recyclables and re-usables. Currently, there is one family (4 persons) allowed to be on site.

6.5. Pricing

A major influence on the success of waste minimisation and, indeed, recycling is the pricing regime for waste disposal. In addition, charging the full cost of disposal will provide a commercial incentive for business and industry to become involved with waste minimisation and recycling.

In setting the appropriate waste disposal charges the following factors need to be considered;

- operational costs
- present and future costs of purchasing and developing disposal sites
- costs of new equipment in the future
- rehabilitation and long term site monitoring and after-care
- possible costs associated with environmental disadvantages, and
- charges set by external waste management or environmental authorities.

Worldwide experience has shown that merely providing recycling services is not sufficient to reduce waste volumes significantly. Only where there is a direct link with increased pricing of waste services do improvements in recycling rates occur.

Incentive schemes include:

- Garbage by Volume - householders are provided with a specific size waste bin, for a prescribed annual payment; the larger the bin, the higher the annual fee. In Seattle, the charges were gradually increased resulting in a dramatic drop in the number of large bins being used. However, the scheme does not encourage reductions in waste that is difficult to compact, due to the waste frequently being denser.
- Garbage by Weight - each householder's bin is identified by a bar-coding, or similar device and weighed before being collected. Householders are charged on a weight basis for the actual waste disposed of. Separated recyclable materials are not subject to this charge. This scheme promotes illegal dumping and favours the disposal of plastics and packaging which, whilst bulky, weigh relatively little.

6.5.1. “Pay as You Throw” Charging Policy

This is a method of introducing a financial incentive to dispose of less waste, by having the Municipality charging the householder/business on the basis of the amount of waste actually given over for collection and disposal. This internalises the cost of waste services, and provides a strong incentive for generators to minimise waste production. This may be in the form of waste avoidance or greater focus on reuse and recycling, such as composting for domestic situations.

In developing countries, the legislation and ordinances are usually in place but the community culture and enforcement is such that increased littering and waste dumping will usually occur. This has the result of diverting waste away from the collection service and associated correct disposal systems, to encouraging illegal dumping in vacant lots, watercourses and drains.

A further issue noticed even in developed countries is that waste generators will place their waste in other people’s bins or receptacles, and not their own. This transfers the waste cost to innocent parties, and can have the effect of introducing neighbourhood tensions.

For less fortunate communities, the Municipality can issue vouchers to partially cover waste costs. This avoids inequalities in service between wealthy and less fortunate Neighbourhoods.

An example of the implications of PAYT charging is the Landfill at Kalangitan, Luzon, Philippines. During the feasibility studies and subsequent design of the site, a daily waste load of 2000 tons was predicted from the CSEZ waste generators. Upon opening the site to receive this waste, the waste load quickly dropped to 1000 tons per day. This was a result of waste generators having developed recycling and waste avoidance/minimisation schemes. The quantity going to the Landfill has now dropped to around only 100 tons per day, as most waste is now illegally disposed of in other locations or controlled dumps with much lower cost gate fees. The CSEZ locaters are legally obliged to use the Kalangitan Landfill.

Therefore until the penalty provisions are firmly and consistently applied in the region, and a culture of responsibility for waste generated is engendered in the domestic and commercial community, then a "Pay As You Throw" system may be inappropriate. Rather it is preferable to provide a good collection service that discourages illegal dumping and back yard burning. The other options such as waste management education and better packaging are a better approach for this project.

6.6. Household Hazardous Waste Management

The management of household hazardous waste (HHW) is one area of waste minimisation that can significantly reduce both water system and landfill pollution.

The proper management of HHW is an issue that emerged in the 1980's in the US along with the awareness of problems caused by toxic chemicals and hazardous waste. Collection of HHW at single-day events has been the standard approach adopted by local government.

In many places, collection days have become institutionalised as annual or semi-annual events. In other places, permanent drop-off sites have been established for the ongoing collection of HHW. Established recycling markets for a number of hazardous materials allow materials to be diverted from the waste stream through special collection programs. Used motor oil, one of the largest single categories of hazardous waste generated from homes, is currently collected throughout several cities and states. Scrap battery collections attracted interest in order to reduce heavy metals in landfill leachate and incinerator emissions. Household batteries are targeted for collection in many areas of the US.

In addition to the regular collections, the Municipality should provide facilities at each waste facility for the drop-off of HHW to reduce the impact of these wastes on leachate quality. This should comprise a securable impervious area with separate areas for the storage of oil, batteries, chemicals and paints. The imposition of a fee on these items is not considered appropriate as it discourages people from "doing the right thing" with these wastes.

The disadvantages of the HHW collection days are:

- Management of the individual containers on the collection vehicle. Due to the unknown nature of the wastes a common disposal tank on the vehicle is not practicable and potentially dangerous.
- Kerbside collection is not practical. Personal contact with the householder would be required to collect the HHW.

The advantages of an annual collection of HHW include:

- Remove HHW from the municipal landfills and sewage treatment plants.
- Clear households of these dangerous wastes, particularly where children are present.

6.7. Special Wastes

Special wastes require separate consideration due to the deleterious effects on landfill capacity and leachate quality and are described in Adopted Approach to Waste Minimisation

Based on the above background to waste minimisation, it is considered that efforts should initially focus on managing plastic bags which make up a significant portion of the 28.26% of the total waste delivered to the dumpsite (survey data, 2014), and PET bottles.

Both represent a major litter issue and following protracted storm events, are washed out of the local unofficial dumping areas and litter areas through the local drainage canals and into local rivers.

Also they degrade very slowly meaning that these materials are present in the environment for decades impacting both aesthetics as litter and the environment.

Finally plastics are often associated with stormwater drain blockages possibly leading to flooding in municipal precincts.

Therefore management of plastic is a high priority.

Plastic bags can be replaced with paper bags or a charge applied to customers for plastic bags at large shops. Alternatively various types of degradable plastic bags are available.

Application of a tax to the manufacture of PET bottles is preferred, where the tax is then passed on to recycling NGOs or private companies to maximize collection and recycling efficiency. However, it should be noted that this is not easy to implement in Thailand particularly at the municipality level.

Regardless of the scheme adopted, ongoing education will be essential in terms of achieving overall waste minimisation ideals being adopted by the community.

7. Approach to Recycling

7.1. Introduction

Recycling is a form of resource recovery that allows the use of recovered materials in a form similar to its original use, as in recycling paper for use again as paper or cardboard. The Solid Waste Management Plan will advocate such practices as it diverts a considerable amount of useful materials present in the waste stream from being disposed of in landfills.

Recycling issues are also addressed in other sections in this Plan, such as Container Deposit Legislation in Source Reduction Options and generally the section on Legal Environment for Source Reduction, and are not repeated in this Section.

7.2. Background

7.2.1. Evaluation of Existing Programs

There are some recycling programs that have been implemented by the Municipal government.

The current formal practices are "No foam for food", "Recycle waste donation", "Waste separation at community". "Waste separation at school", "Food waste separation", "Waste separation in collection process", "Exchanging household hazardous waste with points", and Exchanging household hazardous waste with eggs". However, the informal practices by waste collectors are one of the main recycling approaches.

7.2.2. Junk Shops and Pricing

The main junk shops in the Municipality were visited.

The shop obtains its waste from waste collectors that use pushcarts to go through the Municipality to collect recyclables. The shop owner does not direct the waste collectors on where to collect recyclables, but allows them to source products independently.

Individuals and collectives also bring materials directly to the junkshop for sale. A more structured approach to sourcing the recyclables would no doubt increase the quantity of recyclables obtained.

Current sale prices are listed in **Table 7-1**.

- **Table 7-1 Local Current Rcycling Quantities and Prices**

Item	Price Paid (THB/kg)				Quantity (kg/week)	Sold to Whom and Where.	Comments
	Wongpanit	Teitamrai Shop	Totong recycle	Chaitawee Burirum			
Plastic bags	3	-	2	-			
Clear plastic		6	5	5			
Common plastic		7	7	6			
Plastics – PET, such as water and soft-drink bottles	6-7	15	14	13			
Plastics – Thermoplastic, such as drinking cups, yoghurt containers, cleaner bottles	2-5						
Cardboard	4						
Newsprint	5	5	4	4.2			
Black and white paper		6	4	5.5			
Bond paper	5-6						
Shredded paper		2	1	2			
Iron/steel	2-5						
Tins/cans	1.2-2.5						
Aluminium	25-30						
Bottles (general)	5						
Bottles – cooking oil	5						
Bottles – Table sauces	5						
Bottles – medicines	5						
Broken Glass (cullet)	0.8-1.8						
Copper – grade A	130						
Copper – grade B	110						

The junk shop owner sells the product to the Wongpanit, a private sector waste-buying business based in Phitsanulok Province that has been expanding across the country. Wongpanit purchases various types of municipal and industrial waste including plastics, steel, precious metal scraps, paper and glass for recycling into value-added products.

International prices for recycled products are listed in below and are current as at 2015.

- **Table 7-2 International Recycling Material Prices**

Material	Form provided	$/Tonne	Remarks
PET Bottles	Clear flake	254- 308	600 mL = 78,000/ tonne
HDPE postconsumer	Natural flake	258-276	
HDPE industrial		199-221	
PVC clear industrial	flake	186-213	
Aluminium Cans	Baled (crushed)	850- 1200	35,000 / tonne
Steel White Goods		60	
Steel – cars	flattened bodies	140 - 217	High rate green strip body
Steel	Sections, plate	340	
Lead	Drained battery	300- 800	
Lead	solid	2600	
Glass	Clear bottle cullet	200 typical	

7.2.3. NGO’s

There are no NGO’s in the Municipality who are involved with recycling.

7.3. Issues Limiting Recycling

Factors that limits recycling volumes and decrease recycling efficiency:

- Few junk shops in the municipality
- Transport costs as shops are very distant from markets
- Lack of material as comingled waste still collected

7.3.1. Categories of Recyclable Wastes for Diversion

The results from the conduct of waste characterisation activities to validate waste generation estimates will be the main information input to determine other categories of recyclable waste present in the waste streams for diversion.

7.3.2. New and Expanded Recycling Facilities

To encourage the participation of the general public in the recycling activities and to stimulate the market for these recyclables materials, facilities will be set-up in strategic locations all over the Municipality, following the IEC recommendations and programs. Likewise, mechanisms that will facilitate the coordination with manufacturers and recyclers to collaborate in the implementation of such programs will be put in place.

The Municipality will seek the assistance of various resource groups to implement proactive recycling measures such as buy-back and material reclamation programs.

Products with toxic components must be appropriately dealt with. Reclamation programs for these products will be organised in close coordination with its manufacturers and recyclers who can deal with them.

7.3.3. Demand for Products Containing Recovered Materials

The Municipality welcomes proposals that will stimulate the demand for production of products containing post-consumer and recovered materials for as long it meets the acceptable quality standards and consistent with the set guidelines. Members of the Municipality coming from the recycling, manufacturing/packaging sectors and NGO should spearhead the development such proposals.

7.4. Specific Waste Types

The international recycling trends in glass cullet, paper, cardboard and some metals such as iron are highly varied. Some components have been over-subscribed, such as paper and cardboard and the market value once reduced from $200/ton to $20/ton internationally but has now recovered. In 2015, the cost of virgin PET pellets was lower than the cost of recycled pellets because of low oil process. Others remain perennially attractive such as aluminium and copper.

Organics (Food waste and green waste) and plastics represent major waste components and these are addressed in separate chapters following.

Not all materials have to be sold to be recycled. For example, builder's rubble can be used for drainage blankets or gas collection layers in landfills rather than just dumped into the cell as waste, or using excess soil for cover material. This type of recycling just requires some forward planning. Similarly, greenwaste can be chipped and then as a protective layer for the exposed cover material prior to grass establishment to prevent erosion of landfill batters, or used on internal roads during wet weather.

Basic charging policies, container deposit legislation and extended producer responsibility are not considered suitable and effective approaches for maximising the recovery and recycling of PET bottles.

7.5. Adopted Approach

7.5.1. Overview

The Municipality supports the concept of recycling. Based on this, the Municipality will;

- Commit to the principles of encouraging and supporting recycling efforts. The improvement will come through activities such as;
  - Implementing waste segregation
  - Municipality investigations of recyclables' markets, including regional junk shop operators
  - Municipality identifying specific people from the Municipality to assist with recycling
- Accept that the private sector and particularly the market will decide what items and how much is to be recycled
- Accept that the most efficient schemes are those operated by the private sector such as existing junk shops.
- If the volume of goods being recycled increases substantially, the Municipality will develop some livelihood programs for Municipality residents
- Investigate the use of non-saleable recyclables as raw materials for making a range of handicrafts
- Scavengers at the Controlled Landfill will be licenced by the Municipality to avoid any disagreements over who can undertake the recyclables recovery activity and subsequent sale.
- Organics and plastics are addressed separately below

7.5.2. Recycling Program

Recycling Programs are required to address the generation of both biodegradable and non-biodegradable wastes. Specifically for biodegradable wastes, the Municipality will mobilise programs since these wastes can be converted into compost – a useful product that the agricultural activities within and outside the Municipality can benefit from or use as animal feed at householder level:

- **Table 7-3 Proposed Recycling Focus**

Areas to address	Recycling Program
Bio-degradable wastes	Facilitate collection services to obtain the domestic, commercial and possibly some agricultural waste for conversion into compost soil conditioner/organic fertiliser for use in the area.
	Encourage at source segregation so food scraps are used for animal feed at the household level
	Promote liquid fertilizer by fermented food waste and market waste semi-anaerobically. Set up donation and collection system of restaurant waste and market waste to be fermented at community level.
	Produce compost from biodegradable waste such as bouquet and funeral flower from temples
Non-biodegradable wastes: post-consumption	Manufacturers to set-up 'Buy-back/redemption centres' for these wastes
	Promote the use of post-consumer recyclable materials in production (material cycling)
	Educate the junk shop operators to better coordinate their eco-aides to improve collection efficiencies at the household level
	Focus recycling on products presently not recycled such as plastics and paper/cardboard, as well as expand the metals and glass recycling.
	Processing of materials into products that can be reintroduced into the market (i.e. tin cans can be re-sized into smaller units for consumer use, polystyrene can be moulded to produce new products like mouldings and frames)
	Initiate recycle bank at primary and secondary school
	Establish municipality recycle shop buy back recyclable waste from community
	For materials that the Municipality does not have any technology for recycling, the Municipality will coordinate with agencies and academic institutions dealing with R&D on this area.

The results of waste characterisation activities and waste composition analysis described earlier in this document and any further information obtained in the course of past collection of solid waste by the Municipality can define the type of waste streams available for recycling. Recommendations with respect to increasing the number of materials designated for recycling will be generated and will form part of the actions necessary in order to operate the ISWM Plan.

7.5.3. Implementation Schedule

Guided by the simple goal setting specified above, the Municipality will develop a municipal-wide implementation schedule that reflects their commitment to the internal 3 year master plan (from 2016-2019) which sets the timing for all recycling initiatives in their area. The Municipality must also ensure that resources are mobilised towards the achievement of these deliverables.

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8. Organics Composting

8.1. Introduction

Composting is often promoted as a suitable scheme for managing organic wastes such as food scraps (18.3 – 71.4% of total waste stream; survey data during 2007 - 2014) and green waste (0.6 – 5.5%; survey data during 2007 – 2014). However it has not been a consistent success in many other developing and even developed countries where it has been adopted, especially where food scraps are introduced into a centralised facility.

Composting trials and facilities were very popular in the 1970s and 1980s. However the failure rate for these facilities approached 100% for a variety of reasons discussed elsewhere. Lately there has been renewed interest in composting however the focus is more on composting chipped green waste rather than the waste food and vegetable scraps.

Composting is the biological process in which organic matter is broken down into simpler compounds by the action of micro-organisms. Compost is the product of decomposition of organic matter. It is a suitable soil conditioner, as differentiated from fertiliser.

8.2. Suitable Materials for Composting

Food wastes that are vegetable or fruit based are fine not compost, as are greenwaste, papers and other carbon sources. Generally meat and dairy products and anything containing oil should be avoided at the household scale

The need to reach a certain C:N ratio of about 30:1 as well as the right moisture content impacts upon what is finally added to the compost system.

In summary for household scale schemes

- YES: fruits and vegetables, such as apples (peels and core), cabbage, carrots, celery, coffee grounds (and filters), eggshells, grapefruit, lettuce, onion peels, orange peels, pears, pineapple, melon rinds, potatoes, pumpkin shells, squash, tea leaves, tomatoes, turnip leaves, etc. Also greenwaste can be added provided that it is not too big. (In composting terms, greenwaste is called “browns” indicating a higher C:N ratio.) Paper can also be added (good source of C) provided that it is not waxed or plasticised in any way.
- NO: dairy and meat products, including butter, bones, cheese, chicken, fish scraps, lard, mayonnaise, meat scraps, milk, sour cream, rice and yogurt. Do not compost foods containing oils or fats such as peanut butter, salad dressing, margarine, and vegetable oil

For commercial or centralised schemes, meat and dairy products can be accepted in small quantities. These schemes have sufficient mass to facilitate higher temperature compost reactions which minimise the odours and general attractiveness of these items to pests.

The collection system must ensure that these types of waste are appropriately segregated and handled during collection to facilitate transfer to the municipal MRF.

The ongoing waste characterisation and generation estimates will be the main input in determining the categories of biodegradable/organic waste present in the waste streams. The data gathering activities will be conducted at the Neighbourhood level, to be consolidated by the designated Municipal ISWM team.

8.3. Greenwaste

Because of the relatively low income status of the communities, and lack of extensive common area parklands and road plantings, there is very little green waste collected at present. Most greenwaste is in fact used as a fuel source at present, and is mainly leaves together with small shrubs and bushes. However as community wealth increases, there will be an increase in green waste for disposal. Other developing countries experience green waste making up at least half of the total organic waste stream.

Once the amount of greenwaste reaches such a percentage locally, a chipper should be purchased to allow the green waste to be broken down into small pieces if larger sized material is being collected. These greenwaste chips can then be composted, perhaps with the addition of animal or treated human waste to provide the correct carbon and nitrogen ratio. Alternatively greenwaste can be used around the landfill site for applying to gravel roads during wet periods and also applying to external batters to limit erosion of the cover material.

The greenwaste is mixed throughout the comingled total waste stream and rarely is collected as a consolidated entity from one location. Because of the small size and non-rigid nature of the greenwaste, it would be very difficult to specifically remove it from the comingled waste mechanically using a screen or trommel.

Separating it out by hand would be exceedingly labour intensive for the benefits gained, based on the waste audit experiences.

At source segregation will also be virtually impossible as the major source is street and compound sweeping where green waste is comingled with dirt and soil.

8.4. Food waste

There are limited options for the reuse or recycling of food waste.

The food waste consisted mainly of fruit and vegetable peelings and trimmings, or spoiled fruit and vegetables.

There was also some rice as well as some meat and cooked food in the samples audited and observed in primary dumping locations as well as waste disposal sites.

The most obvious recycling opportunity given the current financial capacity of the communities is to simply feed the household food waste to animals such as chickens or goats or use home composting. This presupposes that households segregate their food waste so it can be recycled directly at-source by the householder.

Once the community wealth increases and the quantity of food waste increases, then consideration could be given to centrally composting the food waste.

However as the photographs indicate, the food waste is fully mixed throughout the comingled waste and is not in selected pockets, and therefore would have to be segregated at source. This at-source segregation will be required of the following:

Householder will have to segregate prior to either placing the food waste in a dedicated food scraps bin for door to door collection or carrying it to the primary dumping location where separate community bins will have to be provided for food scraps

Commercial premises such as restaurants and hotels will have to segregate waste and then dispose of the food scraps as for the households, depending upon whether there is door to door collection or not.

Market vendors will have to keep food waste separate and place in dedicated food scraps bins.

At all levels, an IEC campaign will be required to ensure that only things that can be composted are placed in the Food Waste bins.

8.5. Composting Scale Options

8.5.1. Domestic Scale

Subsidised or government supported domestic composting schemes are used extensively throughout the world to reduce the amount of organic waste going to disposal. Studies determined that a household composting participation of 15-20% is achievable, realising a 25-30% reduction in domestic garbage quantities in those households. It follows, therefore, that home composting is a valid waste minimisation tool.

Home composting, or at most Neighbourhood level composting, is generally regarded as the most effective level for composting household waste when waste is not source segregated. This allows the organic waste to be used before mixing with contaminating non-compostable materials during haulage and disposal. One exception is market waste that could be composted centrally provided that it is collected in a dedicated service to avoid cross-contamination.

There are several types of manufactured home composting bins available. Municipalities could have schemes whereby bins are made available to the public at discounted rates through either subsidising, passing on savings of bulk purchase to the public or savings associated with sales tax.

Basic low-cost designs are available in the literature, such as in the USEPA "*The Consumers Handbook for Reducing Solid Waste*", 1996. This manual also describes how to operate the compost system and what materials to use.

Alternatively used tyres can be used in a column.

Assuming at least 15% reduction in domestic garbage quantities per participating household, and an average of 3 people per household (survey data, 2016), this indicates that the economic benefits of composting are substantial, when considered in terms of Controlled Landfill and collection services costs.

The home compost approach is the generally preferred option in the long term, for middle class areas or peri-urban areas where the households have sufficient yard areas to use the compost generated.

The basic scheme can involve above an above ground compost system using old tyres placed in a stack, an in ground pit provided the water table is sufficiently low or a specifically designed system made of plastic trays and bins.

8.5.2. Neighbourhood

This is probably the most appropriate level for the informal settler areas, where there is insufficient land in each individual household for using the compost. However if lot owners still wish to compost the material it can be used in pot plants or given to other potential users via the Neighbourhood network.

These facilities are located within the residential area and such facilities internationally have in the past resulted in odour complaints even if the facility is roofed.

See **Appendix G – Larger Scale Composting Facility Details** for details on real world experience with neighbourhood and centralised schemes internationally**.**

8.5.3. Large Scale Composting/Mulching

Depending on the type of biodegradable wastes, the following aerobic methods can be used:

- In-vessel composting using motor driven drums or silos.
- Static pile method – using permeable membranes stacked in such a way to allow maximum ventilation, as used at Sun Valley currently.
- Windrow method – 2-3 metre high windrow heaps turned regularly for aeration, utilising compost activators.
- EM Technology – another method of aerobic composting using concentrations of beneficial bacteria to provide high quality compost.

For most schemes, static pile composting would be appropriate.

All composting operations must maintain a maximum temperature of 60 ^{o}C. Exceeding this level will result to the extermination of the beneficial microorganisms in the composting process. This can be done using thermometers inserted in compost piles. Methods of reducing heat include watering and constant turning of the compost piles until the temperature goes down to the ideal level. Those portions of compost waste with high nitrogen component should be reduced to lower the compost temperature. An ideal carbon-nitrogen ratio must be maintained to avoid over-heating.

Schemes are being trialled internationally for the separate collection of garden waste and the subsequent composting of this material. All green waste is composted in Melbourne Australia at the Deer Park landfill serving over a million people.

Internationally*,* some Municipalities have proposed schemes whereby the householder can pick up "free of charge" the composted green waste product. However, in doing this, Municipality should be aware of their liability and need to also inform the public of possible weed and plant disease problems. Rehabilitation of former controlled and open dumps, and landscaping of buffers at current operational dumpsites, are other possible uses for the mulch. Mulch has also been used as a substitute for "*end of day*" cover in landfill operations although this is not advised due to the low barrier to rodent and rainwater intrusion.

There are few if any functioning full scale MSW compost schemes operating in developing countries in SE or South Asia. All have failed through a lack of a viable market for the product, poor product quality, lack of funds to continue operation (as they are not self-funding) or ultimately conversion to composting other more suitable material such as animal manure. The one exception is a large scheme handling 1000t/d operates in Lahore, but that is a PPP arrangement where compost contamination is not an issue (as one of the PPP partners is the adjacent farmer using the compost and he does not mind if the compost has foreign objects therein) and finally compost is applied to high value food crops.

Therefore centralised composting must at least await full waste segregation and then undertaking a comprehensive marketing effort to confirm (or otherwise) that market demand is sustainable. Sustainability investigations must include the fact that users are willing to pay a gate price that makes composting economic for the Municipality or that the Municipality is willing to fund the composting scheme with an ongoing financial loss.

One issue to be considered is the risk management required. For example, Municipalities have been sued for damages due to poor compost such as causing crop damage due to excessive microbial activity, or personal injury from sharps accidentally included in the compost product in some countries. Even if the compost is given away, there is an inferred warranty that the material is fit for purpose.

Waste must be fully segregated at source to make this option sustainable as centralised waste segregation of mixed waste is unreliable and costly. This means that centralised schemes are possible only for long term consideration locally, not for immediate introduction.

If there was a larger fraction of greenwaste that could be separated out at source, then that may be viable to compost as it is many other countries, provided that there is a sustainable market and that there is a supplementary source of Nitrogen such as dried sewage sludge (biosolids) from a sewage treatment plant.

To facilitate the processing of biodegradable/organic waste into compost, the following must be put in place:

Table 8-1 Actions of waste composting at different levels

Household Level	• Information Campaign on Household level Waste segregation: (bio and non-bio waste, etc.) • Appropriate containers or bins (Compost bins can be shared among a number of households to maximise resources. Also basic designs using used tyres or in-ground trench system can be developed at low cost) • Distribution of free mulch/compost for use in home composting
Neighbourhood/ Community Level	• "Eco-Sheds" strategically located in urban communes. Common Eco-Sheds can be shared among a cluster of communities, wherever applicable. • This system may not be appropriate now, but may be developed at a later date if required to supplement the household facilities.
Municipal/City Level	• Municipal Composting Centre designed to handle the consolidated volume of pre-segregated wastes to its final conversion to compost • Coordination of compost sales and marketing activities within and outside the City. • Transport system that can facilitate the transport of final product or pre-processed compost to its destination. • Possibly not appropriate at this time given waste is comingled (and is likely to continue to be mixed for some time) and little established market for compost at this time.

In all levels of these activities, the Municipality has the option to consider partner entities or groups to facilitate program implementation and augment resource limitations, as most of these activities might require additional investment.

8.6. Market Development Activities

The organic products that will be derived from the organic processing operations will need to be marketed using a range of schemes. All large volumes of organic products from composting activities should be sold to farmers and agricultural cooperatives. In order the develop the market and demand for compost, the Municipality should consider a partnership or Joint Venture options with regards to developing the potential economic activities that will need a steady supply of compost such as farms for various crops.

Many of the local agricultural soils are poorly structured, and would greatly benefit from applications of compost. The compost will improve soil moisture retention capabilities, increase soil CEC levels to improve fertiliser retention and also a general improvement in soil structure with the addition of compost organics.

However experience elsewhere suggests that few farmers are willing to pay a significant price for compost especially when it used on lower value crops and when supplementary fertilising is still required. In the Philippines, there was a stockpile of over 8000 tonnes of compost which the operators cannot even give away as local farmers are insisting that the landfill operators pay the haulage and distribution costs of the compost throughout the farm.

Storage sites will be required;

- for off-specification product,
- during periods of no sales or wet weather when farms cannot accessed, or
- when there is no market demand due to cropping cycle constraints.

The international trend is to have substantial buffer requirements around compost facilities, because even the best run compost scheme is odorous at some times. Some countries require up to a 5 kilometre buffer from large facilities to residential development, but up to 1 kilometre would be appropriate for a Municipal level scheme.

8.7. Alternative Biodegradation Schemes

Vermiculture is an alternative to composting. Locally there has not been too much success with vermiculture schemes because of worm deaths and the costs involved. Generally the market does not seem willing to pay the additional costs of the vermicast.

There is potential for worm sale (fish food) and castings sale (soil conditioner, like compost). Advantages are less odour risk, no enzyme costs, castings are safe from sharps, pathogens but may still be toxic due to heavy metals or inorganic biocides, etc and disadvantages such as labour intensive, need some technological skills, cannot handle all putrescible wastes, etc.

8.8. Summary

The compostable material must be completely separated from the rest of the waste. This is best done at the source - by the householder or commercial operator. However, this requires considerable co-ordination and encouragement from Municipality's and Neighbourhoods. Separation can be done at the MRF or Landfill, however this adds significantly to the cost and effort required and is never 100% successful with residual contaminants remaining in the compost.

Separation of the waste needs to be thorough as an occasional piece of metal or other solids in the waste stream causes faster wear or even partial destruction of the shredding equipment and lowers the overall quality of the compost, and presents health and safety risk as do glass shards or sharps.

The initial outlay and operating costs of a centralised composting facility would be substantial. Well in excess of USD100k is required to establish a mechanised system that will handle only a few tonnes per day. Technical expertise would be required to operate the facility and market the end product. Basic systems using open weave bags and little mechanisation are more appropriate locally, if the Municipality is interested in centralised composting of just some selected waste stream components.

A sustainable market needs to be found for the compost generated from the material. This often proves difficult as demand is low and there are many other better and cheaper sources of compostable material. Also farmers' advice that they are disinterested in having to apply two items to their crops namely compost and supplementary artificial fertilisers. Composted waste is relatively low in nutrients and so farmers need to add additional nutrients in most cases.

It may be better to encourage home level composting by subsidising the cost of composting bins and by providing free advice on the associated benefits and methods. This would help to reduce the overall volume of waste.

Neighbourhood level composting may be appropriate where the community is impoverished and individual households do not have the compound area available to utilise the compost produced. However all compost operations are odorous at some time. Some operations emit odours which are almost continuously detectable at a distance of more than one kilometre from the operation. This odour issue has resulted in many neighbourhood schemes being forced to close.

The other factor is heavy rain. Excess water in the compost pile reduces pile aeration, which reduces efficiency and increases odours. Roofing the operation would be prohibitively expensive, unless a high rate in-vessel system was adopted. In-vessel composting systems require purpose built reactor tanks and are expensive to construct and operate.

Assuming that all the above issues can be overcome, a sustainable market needs to be found for the compost generated from the waste material. This always proves difficult as generally demand is low. The addition of chicken manure, treated sewage sludges or inorganic fertilisers to increase nutrient content may assist in making the compost more marketable. If this later stage is to be undertaken, then a PPP should be established with a local landholder who will commit to taking all compost generated and not suing the Municipality in case of any compost-derived crop or soil contamination, or worker injury from glass or metal shards.

Therefore, at this stage, encouraging householders to undertake composting at home is strongly supported. This will require Municipality and Neighbourhood support in terms of education and/or supply of subsidised compost bins or used tyres. In the longer term, trials of regional or centralised composting facilities using chipped greenwaste together with sewage sludge or some or other nutrient rich source may be worthwhile.

However the fact remains that a compost scheme, be it a household, Neighbourhood or centralised facility, will not be able to manage all wastes generated, either in terms of volume or waste type. It is a worthy supplemental scheme however, and is discussed in later sections in more detail.

8.9. Adopted Approach

The Municipality is interested in supporting composting schemes, through;

- Primary support for household level composting, but NOT making it compulsory. Support would include the following;
    - Issuance of compost starter kits or leaflets if using shallow burial method to households and also running an IEC advising them how to compost. This will be as part of the overall IEC, and is to be funded by the Municipality and Neighbourhood in partnership.
- Funding of Neighbourhood composting facilities is not supported at this time (IEC and starter kits were provided by municipality). However, some neighborhoods have already started their own compositing project without financial support from the municipality. The compost produced is used by the neighours locally.
- For centralised facilities such as at the proposed landfill, the Municipality notes that while food waste is a high percentage of the total waste stream, the total mass of food waste remains small (survey data 2014). Therefore, the Municipality considers that a centralised facility could not be justified for such a small waste component at this time, unless expensive chipping and milling systems were installed to process the greenwaste for co-composting. However, if the overall waste stream volume increases dramatically, then a centralised composting scheme for residual biodegradables and processed greenwaste will be investigated.
    - This level of composting will only succeed if a stable market for the compost is developed and maintained and a rigorous quality control program is in place.
    - At the moment, the municipality has a few chipping and milling machines previously used for wood waste cutting. They are now broken. The municipality has no plan to fix the machines at the present.

9. Population Projections and Waste Generation

9.1. Background

Preliminary estimates have been made for both population projections and waste generation rates for 30 years.

The information and calculation method shown below are largely taken from a project called “Analysis of greenhouse gas reduction potential of solid waste management at municipality level of Thailand” prepared by The Joint Graduate School of Energy and Environment for the Thailand Greenhouse Gas Management Organization (TGO), Thailand in 2015.

The population projections are primarily based on the Census figures and adopted growth rates.

9.2. Waste Generation Allowance

Accurate waste generation data in the municipality is very limited. There are very few if any functioning public weighbridges, and no portable truck scales for hire, so accurate aggregated waste generation figures are non-existent. Added to that, most cities do not have a high level of collection service efficiency to allow the mass of waste being hauled to be accurately related to a service area population in any case. Most local waste generation rates are based solely on mass estimates or very small samples being weighed and then grossly extrapolated. In summary, little credence should be placed on local per-person waste generation rates.

Projects in other developing countries like Vietnam and the Philippines often use a rate of at least 0.5 kg/p.d going up to 0.65 kg/p.d for provincial cities. However in Thailand for example it can be as high as 1.5kg/p.d or even 2.5kg/p.d. Developed countries can generate up to many times this amount.

These amounts account for at source (in-house or in-institution) recycling and reuse. Higher value recyclables such as glass, metal and paper are already being recycled at source. This is typical of most developing countries where these high value recyclables traditionally account for 3 to 5 per cent of the total waste stream for each component.

The Ministry of National Resources and Environment (MoNRE) has set waste generation target for all municipalities to be less than 0.80 kg/capita/day. In 2016, waste generation rate of the Buriram municipality is about 1.15 kg/capita/day or 89.75 ton/day. It was predicted to be decreasing following the MoNRE’s target by 2026.

From the previous study (JGSEE, 2015), the waste generation allowance was set at 2.74 kg/p.d which result in 85.16 ton/day in 2015, it is then increasing to 3.02 kg/p.d or 138.16 ton/day over 20 years (in 2035) to account for increasing community wealth and therefore, higher per capita waste generation.

It is also assumed that there will be waste reduction at the household level during this period.

Based on all the above factors and comparison with similar community generation rates in Thailand, the waste generation has been set at 0.9kg/p/d increasing to 1.1kg/p.d over 30 years.

9.3. Collection Allowance

The current percentage of waste collection is estimated to be 100% in the municipality area according to municipal advice. The municipality reports that the amount of waste generated is approximately 89.75 ton/day. About 58% of this amount (52.38 ton/day) is recycled, whereas 42% (37.37 ton/day) is sent to the disposal site (Municipality data, 2016).

In reality, waste collection efficiency in developing countries is never 100% as there is always some illegal dumping on vacant lots and into local water bodies, as well as some remaining litter around commercial and industrial establishments using community based bin systems. However it is recognised that collection in the city is at a high level and therefore a percentage collection efficiency of 90% has been adopted.

Because the tonnage to landfill is based on external municipalities and not just Mahasarakham city, then it has been assumed that the collection efficiency will remain the same in the future at 90% which is a good target for this type of community.

The ultimate aim is of course to approach 100% collection efficiency, but this may only achieved in the very long term following cultural changes which accept that littering is not desirable, and supported as well by a campaign of fines associated with littering. However, significant changes in the community attitude towards littering will be generational and not expected to be significant in the life of the controlled landfill proposed.

9.4. Recycling Allowances

As the wealth of the community increases, the amount of waste generated will increase.

However, this does not translate into a proportional increase in the quantum of waste to be collected and disposed of. The key changes with increasing wealth relates mostly to increased packaging, for such as paper, cardboard, tins and bottles. So as the amount of waste generated per person increases, so does the amount of recyclables, resulting in much smaller growth rate for the waste to be disposed of compared with the total increase in the mass of waste generated.

The percentage of waste recycled from the households and primary disposal locations, as well as during transport to the landfill has been set at 2% at present increasing to 10% in 2035. If the quantity of waste generated per person actually increases significantly in this period, it is most likely to be in the form of packaging material which could be readily recycled. Therefore it is expected that any significant increase in the per person contribution quantity will be directly offset by an increase in recycling efficiency of these high value recyclables. Therefore the net effect is zero and it is just the nett quantity per person going to landfill that is critical.

At the landfill itself, the recycling percentages is not expected to increase significantly from the current 10%.

Significant changes in the future may be associated with perhaps green waste recycling, as well as perhaps expanded composting schemes or waste-to-energy activities being incorporated prior sending residuals to landfill. Any such changes will result in a reduced tonnage going to landfill and therefore will simply increase the life of the facility.

9.5. Soil Cover Allowance

Three types of soil cover are required to operate a landfill correctly. The first and possibly most critical is the application of daily cover to a thickness of 100 to 150 millimetres. This cover provides a multitude of engineering interventions including a reduction in water infiltration leading to less leachate generated, less vermin on site, reduced bird numbers on site, reduced litter and reduced odours.

If an area of the controlled landfill is to be left unused for a period of a few months or more, intermediate cover to a thickness of 300 mm should be applied.

Final cover usually consists of two layers. The first layer is a 600 millimetre thick clay or silty clay cap to prevent rainfall infiltration. This should be topped with a layer of growing medium of compost or top soil to facilitate plant growth.

The application of cover can contribute some 15 and to 25% of the total landfill volume. However, smaller percentages are possible at well run landfills by recovering the daily soil application prior to commencing another lift of waste.

For this study, it has been assumed that 10% of the total landfill volume will be cover material initially. This is because it is expected that the daily cover may in fact be only applied on a weekly basis or at some other lesser frequency. Over time this will increase to 20% as operations improve.

9.6. Compaction Allowance

There are two options for providing compaction at the controlled landfill. The most common is the use of a tracked bulldozer which at the usual size of a D6 or D7 equivalent. However, for larger landfills, a purpose built landfill compactor can be used:

The typical waste density then achieved at the landfills assuming that the waste arrives relatively uncompacted as it was hauled in a mix of compactor trucks and open trucks:

- no compaction - 300kg/m^3
- 500kg/m^3 minimum with bulldozer or tracked loader
- 650kg/m^3 minimum with smallest specialised landfill compactor (handles 500t/d working with a bulldozer)
- 1,000kg/m^3 minimum with largest specialised landfill compactor (handles 1000t/d working with a bulldozer, so only for very large landfills)

Because of the size of the controlled landfill, it is proposed to use a large bulldozer which will be a suitable size to be able to push and shape the waste quantities and provide some compaction, say D7 or equivalent.

The adopted initial density is 650 kg/m^3 throughout.

9.7. Waste settlement

Waste settles over time and it has been assumed that 5% of the volume will be lost in the first year, in accordance with recorded results from many landfills.

The waste will continue to compact at 0.5% per year on average over the following 30 years.

9.8. Airspace Consumption

Based on the above assumptions, the cumulative waste volume taken up at the controlled landfill has been calculated on an annual basis.

Based on this theoretical waste volume, the controlled landfill stages have been sized. Traditionally the first major stage or cell at a controlled landfill should provide some 5 year's capacity. Typically, the overall controlled landfill site selected should have capacity for at least 20 plus years operation.

In reality there are numerous factors that could eventuate and impact upon the assumptions and predictions for this predicted landfill life in the coming decades. However, these impacts can be counteracting, such as a lower growth rate than that predicted could be contrasted against a higher per person waste generation rate and so on.

Therefore, it is recommended that the following table of cumulative waste volume be adopted as the best available predictions at this time. Any variations to the many components intrinsic to this prediction will only alter the life of the controlled landfill and not the concept nor the basic design approach. If the cumulative waste volume at the controlled landfill is either significantly larger or smaller compared with the predictions below, then the later cell sizes can be amended to compensate for these variations.

These projections will obviously be refined as the possible waste diversion interventions are refined and agreed, and also at the time of detailed design.

In summary, the adopted figures represent the worst case scenario for landfill sizing and life estimates.

- **Table 9-1 Population and Waste Load Projections - Summary**

YEAR	TOTAL Population (of all Municipalities using landfill)	Projected Serviced Population (of all Municipalities using landfill)	Rate of Waste Generation (post HH Direct Recycling)	Daily Waste Generated in Serviced Area	Waste placed into landfill	Annual Totals (with no allowance for settlement)		Cumulative Totals	
	Persons	Persons	kg/person.day	Tons/day	Tons/day	Tons disposed/year	Total Airspace Consumed	Tons Disposed	Cubic Metres of Airspace Consumed (Allowing for settlement)
2016	142000	114000	0.9	102	81	30000	46000	30000	46000
2021	147000	118000	0.95	111	88	32000	49000	184000	269000
2026	152000	122000	0.95	116	89	33000	50000	349000	500000
2031	158000	126000	1	126	97	35000	55000	524000	741000
2036	164000	130000	1.05	137	101	37000	48000	705000	986000
2041	170000	136000	1.1	149	109	39000	61000	896000	1238000
2046	176000	140000	1.1	154	112	41000	63000	1098000	1501000

Table 9-2 Population and Waste Load Projections - Detailed

YEAR	Burriram Annual Growth Rate	Burriram TOTAL Population	Serviced Area Percentage of Burriram Area	Projected Serviced Population	Rate of Waste Generation (post HH Direct Recycling)	Daily Waste Generated in Serviced Area	Percent Collected in Serviced Area	Percent Recycled Post HH	Daily Waste Delivered to Landfill	Percent Recycled at Landfill	Waste placed into landfill	Landfill Insitu Waste Density	Annual Totals (with no allowance for settlement)			Cumulative Totals					Landfill Capacity Stages	YEAR
	%	Persons	%	Persons	kg/p.d	t/d	%	%	t/d	%	t/d	kg/m^3	t/yr	%	Cubic Metres	t	Cubic Metres	Cubic Metres	Cubic Metres	Cubic Metres	Cubic Metres	
		Agree base population and percentage growth rates		Persons	Input current rate and increasing over time. Based on recycling at home or at source	Tonnes/ day		Includes recycling from primary disposal locations, any recycling cages and greenwaste diversion. Usually increases over time.	Tonnes/ day		Tonnes/ day		Tonnes/ year	Percentage of Cover (Often initially 10% and increasing to 20% or more as operation improves)	Total Airspace Consumed (with no allowance for settlement)	Tonnes Disposed	Cover material required (m3)	Total Airspace Consumed (with no allowance for settlement)	Settlement and Consolidation	Cubic Metres of Airspace Consumed (Allowing for settlement)	Show volumetric capacities of selected landfill stages here to confirm landfill stage life	
2016	0.68%	142,000	80%	113,600	0.90	102.2	90%	2%	90.2	10%	81.2	650	29,630	10%	45,640	29,630	4,150	45,640		45,640		2016
2017	0.68%	143,000	80%	114,400	0.90	103.0	90%	2%	90.8	10%	81.7	650	29,840	10%	45,960	59,470	4,180	91,600	2,290	89,310		2017
2018	0.68%	144,000	80%	115,200	0.90	103.7	90%	2%	91.4	10%	82.3	650	30,040	10%	46,270	89,510	4,210	137,870	5,040	132,830	**143,000**	2018
2019	0.68%	145,000	80%	116,000	0.90	104.4	90%	2%	92.1	10%	82.9	650	30,250	10%	46,590	119,760	4,240	184,460	8,020	176,440		2019
2020	0.68%	146,000	80%	116,800	0.95	111.0	90%	2%	97.9	10%	88.1	650	32,150	10%	49,520	151,910	4,510	233,980	11,240	222,740		2020
2021	0.68%	147,000	80%	117,600	0.95	111.7	90%	2%	98.5	10%	88.7	650	32,370	10%	49,850	184,280	4,540	283,830	14,830	269,000	**292,000**	2021
2022	0.68%	148,000	80%	118,400	0.95	112.5	90%	2%	99.2	10%	89.3	650	32,590	10%	50,190	216,870	4,570	334,020	18,670	315,350		2022
2023	0.68%	149,100	80%	119,300	0.95	113.3	90%	2%	100.0	10%	90.0	650	32,840	10%	50,580	249,710	4,600	384,600	22,760	361,840		2023
2024	0.68%	150,200	80%	120,200	0.95	114.2	90%	2%	100.7	10%	90.6	650	33,090	10%	50,960	282,800	4,640	435,560	27,100	408,460	**450,000**	2024
2025	0.68%	151,300	80%	121,100	0.95	115.0	90%	2%	101.5	10%	91.3	650	33,340	11%	51,350	316,140	5,090	486,910	31,700	455,210		2025
2026	0.68%	152,400	80%	122,000	0.95	115.9	90%	5%	99.1	10%	89.2	650	32,560	11%	50,150	348,700	4,970	537,060	36,550	500,510		2026
2027	0.68%	153,500	80%	122,800	1.00	122.8	90%	5%	105.0	10%	94.5	650	34,500	11%	53,140	383,200	5,270	590,200	41,570	548,630		2027
2028	0.68%	154,600	80%	123,700	1.00	123.7	90%	5%	105.8	10%	95.2	650	34,750	11%	53,530	417,950	5,310	643,730	46,980	596,750		2028
2029	0.68%	155,700	80%	124,600	1.00	124.6	90%	5%	106.5	10%	95.9	650	35,000	11%	53,910	452,950	5,350	697,640	52,650	644,990		2029
2030	0.68%	156,800	80%	125,500	1.00	125.5	90%	5%	107.3	10%	96.6	650	35,250	11%	54,300	488,200	5,390	751,940	58,580	693,360		2030
2031	0.68%	157,900	80%	126,400	1.00	126.4	90%	5%	108.1	10%	97.3	650	35,510	11%	54,700	523,710	5,430	806,640	64,770	741,870		2031
2032	0.68%	159,000	80%	127,200	1.00	127.2	90%	5%	108.8	10%	97.9	650	35,730	11%	55,030	559,440	5,460	861,670	71,220	790,450		2032
2033	0.68%	160,100	80%	128,100	1.00	128.1	90%	5%	109.5	10%	98.6	650	35,980	11%	55,420	595,420	5,500	917,090	77,930	839,160		2033
2034	0.68%	161,200	80%	129,000	1.00	129.0	90%	7%	108.0	10%	97.2	650	35,470	12%	54,640	630,890	5,860	971,730	84,900	886,830		2034
2035	0.68%	162,300	80%	129,900	1.05	136.4	90%	8%	112.9	10%	101.6	650	37,100	12%	57,150	667,990	6,130	1,028,880	92,070	936,810	**938,000**	2035
2036	0.68%	163,500	80%	130,800	1.05	137.3	90%	8%	113.7	10%	102.3	650	37,360	15%	57,570	705,350	7,510	1,086,450	99,620	986,830	**988,000**	2036
2037	0.68%	164,700	80%	131,800	1.05	138.4	90%	8%	114.6	10%	103.1	650	37,650	15%	58,010	743,000	7,570	1,144,460	107,440	1,037,020		2037
2038	0.68%	165,900	80%	132,800	1.05	139.4	90%	8%	115.5	10%	103.9	650	37,930	15%	58,450	780,930	7,630	1,202,910	115,530	1,087,380		2038
2039	0.68%	167,100	80%	133,700	1.05	140.4	90%	10%	113.7	10%	102.3	650	37,360	15%	57,570	818,290	7,510	1,260,480	123,890	1,136,590		2039
2040	0.68%	168,300	80%	134,700	1.05	141.4	90%	10%	114.6	10%	103.1	650	37,640	15%	58,000	855,930	7,570	1,318,480	132,460	1,186,020		2040
2041	0.68%	169,500	80%	135,600	1.10	149.2	90%	10%	120.8	10%	108.7	650	39,690	20%	61,190	895,620	10,200	1,379,670	141,300	1,238,370		2041
2042	0.68%	170,700	80%	136,600	1.10	150.3	90%	10%	121.7	10%	109.5	650	39,990	20%	61,650	935,610	10,280	1,441,320	150,560	1,290,760		2042
2043	0.68%	171,900	80%	137,600	1.10	151.4	90%	10%	122.6	10%	110.3	650	40,280	20%	62,100	975,890	10,350	1,503,420	160,100	1,343,320		2043
2044	0.68%	173,100	80%	138,500	1.10	152.4	90%	10%	123.4	10%	111.1	650	40,540	20%	62,500	1,016,430	10,420	1,565,920	169,930	1,395,990		2044
2045	0.68%	174,300	80%	139,500	1.10	153.5	90%	10%	124.3	10%	111.9	650	40,840	20%	62,960	1,057,270	10,500	1,628,880	180,040	1,448,840		2045
2046	0.68%	175,500	80%	140,400	1.10	154.4	90%	10%	125.1	10%	112.6	650	41,100	20%	63,360	1,098,370	10,560	1,692,240	190,440	1,501,800	**2,160,000**	2046

10. Development and Evaluation of Collection Alternatives

10.1. Background

The collection system can impact upon 3R implementation, particularly the recycling aspect, and less so the waste minimisation/reuse issues. These later aspects can be impacted by source segregation requirements if for example a multiple bin collection approach is adopted.

Appendix H – Background to Waste Containers, Segregation and Collection System provides an overview of the options and how they interact, as well as description of the types of equipment available and their relative advantages and disadvantages.

Therefore some consideration of the collection system, and therefore the waste segregation issues and their interactions, is appropriate.

Further, significant recycling happens during waste hauling as the collection staff scavenge through the waste on the way to the dumpsite. Therefore if compactor vehicles are proposed in the future, then waste recovery needs to happen either at source (Household or enterprise), in the primary dumping areas or at the dumpsite, but obviously not during haulage activities.

10.2. Collection System Planning

In terms of haulage capacity, Identifying goals, objectives, and constraints can help guide the planning process. Issues that should be considered include the following:

- **Level of service**: What level of services is required to meet the community's needs? What materials need to be collected and what are the requirements for separate collection of these materials? What needs and expectations exist with respect to the frequency of pickup and the convenience of set-out requirements for residents?
- **Roles for the public and private sectors**: Is there a policy preference regarding the roles of the public and private sectors in providing collection services for wastes and recyclables? If collection is to be performed by private haulers, should the municipality license, franchise, or contract with haulers?
- **Waste reduction goals**: What are the community's waste reduction goals and what strategies are necessary or helpful in achieving those goals? For example, source reduction and recycling can be facilitated by charging customers according to the volume of wastes discarded, by providing convenient collection of recyclables, and by providing only limited collection of other materials such as yard trimmings and tires.
- **System funding**: What preferences or constraints are attached to available funding mechanisms? Are there limits on the cost of service based on local precedence, tax limits, or the cost of service from alternative sources?
- **Labour contracts**: Are there any conditions in existing contracts that would affect the types of collection equipment or operations that can be considered for use? How significant are such constraints and how difficult would they be to modify?

Communities can select the level of services they wish to provide by choosing how often to collect materials and the point from which materials will be collected at each residence. The greater the level of service, the more costly the collection system will be to operate. Factors to consider when setting collection frequency include the cost, customer expectations, storage limitations, and climate. Internationally, most municipalities offer collection once or at most twice a week in tropical climates. Some wastes such as segregated greenwaste is only collected every two weeks quite often.

Crews collecting once per week can collect more tons of waste per hour, but are able to make fewer stops per hour than their twice-a-week counterparts. A USEPA study found that once-a-week systems collect 25 per cent more waste per collection hour, while serving 33 per cent fewer homes during that period. Some communities with hot, humid climates maintain twice-a-week service because of health and odour concerns.

At present, collection is arranged systematically. The waste is collected twice a day from every collection point.

A number of options exist for each of the first three components. Choice of which option to develop is dependent upon existing practices, new planned activities, and input from ISWM staff and stakeholders. From an inventory of existing municipal assets and equipment, the current waste management practices (primary collection, secondary collection and existing disposal practices), feedback from the stakeholders, and acknowledgement of the limitations of budget, a plan can be formulated that will address the goals established for environmentally sound ISWM.

10.3. Household/commercial production, storage and collection

This primary system is necessary to ensure waste stored at source is collected regularly and not discarded in streets, drains, water bodies, etc. It is important that this step is designed to synchronize with the secondary waste collection step to ensure complete system functionality.

Waste density is highly variable and for non-compacted waste in developing countries (with typical municipal waste characteristics) it can be as low as 150kg/m3 or as high as 350kg/m3 if auto-compacted during haulage due to travel vibration as well as walking over by jumper boys during collection and if the waste contains a high proportion of street sweepings (dirt and sand). Based on the density determinations conducted as part of the waste audit, the adopted density is therefore approximately 400kg/m^3.

Commercial premises can vary greatly depending upon their commerce. Their waste containers must be appropriate for their waste production, or they will need multiple containers.

10.4. Primary waste collection

There are a number of approaches to collection of waste from residences and commercial producers. Together these are illustrated together in the Figure below, and described in detail as follows. Presented here are some of the possibilities.

- Householder separates the organics and fines, composts them at the house, and then places residuals in a small household bin. Door-to-door collection of home bins with manually operated handcart by community worker.
- Door-to-door collection of home bins with manually operated handcart by community worker.
- Door-to-door collection of waste piles by community worker.
- Householder takes waste to community bins as it is produced.
- Householder places waste in indiscriminate piles, to be collected by community worker.

Since 18.3 – 71.4% of the waste (survey data during 2007 - 2014) has been measured as food scraps, it means that composting at the household level has the potential to have beneficial impacts on ISWM management from primary collection to final disposal.

Depending upon space available, there may not be enough room to compost on-site. However, a mini enterprise for private company could be developed, that could get paid a small amount to take the waste away, than can sell the final product to farmers.

Diversion of the organic waste also reduces the odour and vector attraction of waste stored at the household and subsequently in primary dumps if a community based system is adopted.

At present, many households and commercial establishments dump their wastes in relatively uncontrolled piles that may or may not be formally designated.

Piles are subject to animal scavenging and scattering of the waste and is the least preferable option. Although virtually no coordination is necessary between the household and the collector is required, uncontainerised waste requires collection crews to hand-collect loose waste from the street, which is a hazardous and time-consuming practice.

One of the key factors that requires a concerted effort and buy-in on the part of the community is proper use of waste drop sites. In many instances, a trash dam is not properly used, so the result is not dissimilar to having an open trash dump site with similar visual, odour and health concerns. This may require an aggressive education effort.

Changing to waste bins (Hook-lift or skip bins) also require some community engagement to ensure that the waste is placed in the bin by the householder or commercial institution, and not just dumped near the bin.

At this moment, the municipality is not interested in privatisation of waste collection because it can manage waste collection to a suitable standard.

A number of both formal and informal drop sites exist for community-level solid waste collection at present. This confirms that a certain level of flow from primary to secondary to final deposit already takes place and is accepted by the community.

With most of the options, the waste is collected through the primary collection system and temporarily stored at community collection drop points – “trash dams,” bins, or skips - prior to being transported in bulk to the waste treatment or disposal site, or possibly a transfer station. The function of this component is solely to provide an interim storage site to make operations more efficient. As such, it is very important that they are:

- capable of holding the entire amount of waste brought to them during a set period (for instance, to be able to hold a week’s worth of contributions from primary collection if that is adopted as the collection frequency),
- emptied prior to new cycle of waste being brought to them – that is they are synchronized with primary collection, and
- easily emptied and accessible for transport vehicles.

There are a number of alternatives for drop points (primary dumping locations), including:

- not using formal drop points – just allowing uncontrolled open dumping
- uncontainerised, open piles in agreed locations
- trash dams (permanent concrete or steel bunkers)
- hook-lift bins matched to the collection truck.
- skip bins matched to the collection truck

The open pile alternative is by far the least desirable; the hook-lift bins or skips are the most efficient and clean, but are by far the most expensive initial cost requiring specialized matched equipment. Concrete bins are the midway option.

Hook lift bin systems do not provide any compaction and even partially full hook-lift bins will sometimes need to be transported. Bins cannot be added to one another to fill one bin (to maximise haulage efficiencies) unless waste is manually shovelled from one to the other.

Skip bins are loaded into a compactor truck where not only is the partially full bin issue then overcome, but the compactor truck can then double or treble the waste density making haulage far more efficient.

Locating any of these containers is an important decision. It is important to consider:

- Containers are located strategically, taking into account where community workers or households have established past drop practices.
- There is adequate space to place one or more containers, and access by the collection vehicle.
- They do not obstruct the entrance of any building, or hinder traffic.
- Neighbours will not vandalise them if the waste become odorous or if feral animals spread the waste
- The walking distance from the edge of the bin catchment is sufficiently short so that residents will take waste to the primary dumping location and not fly dump or litter instead. Anything less than 250 metres is usually considered sufficiently close, but reducing this to a 100 metre maximum walk if possible has been found to reduce illegal dumping to very low levels.

The value of locating at existing informal waste disposal sites is that the community is used to these drop locations, and the change in appearance (when a bin, skip or trash dam is placed) is a noticeable visual improvement. Thus objections from the community should be minimal in that case.

- **Table 10-1 Selected alternatives for community waste collection**

	Open piles	**Trash dams/Bunkers**	**Hook-lift Bins**	**Skip bins**
				
Price/unit	- 0 -	US$400 to $600	US$600 to $1500	US$400 to $1200
Vehicle required	Non-specific	Non-specific	Hook-lift truck matched to bin	Forklift-type compactor truck matched to bin
Positives	• Low cost • Disposal points presumably established by community needs	• Static so residents have defined disposal point • Relatively inexpensive • Requires no special equipment • Fabricated locally	• Bins easier to relocate as they are not fixed • In an emergency, small bins can be lifted by crane trucks which are relatively abundant, known by mechanics & operators • Fabricated locally • Easily removed, cleaned, repaired and replaced • Bins replaced immediately by empty bin	• Bins easier to locate as they are not fixed • In an emergency, skip bins can be lifted by crane trucks which are relatively abundant, known by mechanics & operators • Fabricated locally • Easily removed, cleaned, repaired and replaced • Skip bins recycled immediately and waste is compacted in truck
Negatives	• Alternative that most results in waste being irresponsibly discarded on streets. • Requires collection crews to hand collect loose waste from the street, which is a hazardous and time-consuming practice. • Allows animal access to scatter waste • Difficult to locate as residents don't like them beside house	• Difficult and slow to access & awkward to empty • Manual labor required to empty exposing workers to health hazards • Difficult to locate as residents don't like them beside house • Often vandalized and any metal doors stolen	• Requires specific hook-lift truck matched to bin • Lifting and unloading can cause damage to containers. • Very low risk of container being stolen • Does not allow compaction in transit to landfill	• Works best with specific fork truck matched to bin • Lifting and unloading can cause damage to containers. • Low risk of container being stolen • Does allow compaction during transit to landfill

10.4.1. Adopted Primary Waste Collection System

Waste bins used in this municipality are made of plastic with different sizes: 100, 120, 200 and 250 Litres. Most of them are 100 Litres. There are also few metal bins (50 litre) and bins made of vehicle tyres. It was reported that sometimes the waste overflows from provided bins (Feasibility report, 2007)

In 2016, there are 13 haulage vehicles (two of these vehicles are used only for special requests). There are 1 driver and 3 workers allocated for one vehicle. Each vehicle is used once a day to collect and dispose waste to the landfill. In total, there are 13 drivers and 52 workers for waste collection. At the waste disposal site, there are 9 workers: 6 machine drivers and 3 general labors.

10.5. Secondary collection

Depending upon the particular system and configuration, the number of trucks or tractor-trailers required can be determined. This also depends upon how long it takes to load the waste and how far it is to a landfill/disposal site. For instance, shovelling out a concrete trash dam or a scattered pile takes much longer than it takes to pick up a skip or hook-lift bin. But it is also possible that a dump truck can hold more than the amount of waste in two trash dams, whereas it may be that the flatbed associated with a crane can only transport two skips/bins.

If non-compacting systems (tractor-trailer, dump truck or hook-lift bins)

- In many cases hooklift bins, and to a lesser extent also the compactor trucks, will not be full when hauling to the controlled landfill. It has been assumed that on average the loads are only 80 percent of capacity. This will certainly be the case with the hooklift bins and tip truck
- With increased mechanisation of the fleet, an allowance must be made for both breakdowns and programmed maintenance. It has been assumed that only 85% of the mechanical fleet capacity would be available at any one time

Table 10-2 Selected alternatives for community waste haulage

	Tractor/Trailer	Tip Truck	Hook-lift Bin Truck	Skip bin Truck
				
Price/unit	US$25,000	US$90,000	US$120,000	US150,000
Bin required	Non-specific	Non-specific	Hook-lift bin – various sizes	Bin matched to Forklift-type compactor truck – various sizes possible
Positives	• Equipment is relatively cheap with good availability. • Has a good short turning radius, so it is fairly easy to access tight spots, such as within communities. • Still has maintenance issues with hydraulics associated with the trailer lifting ram (and possibly the front bucket system)	• This system is very similar to the first alternative, but uses a truck with potentially much greater haulage capacity than a trailer pulled by tractor. • Dump trucks are moderately priced with good availability and mechanical support. • Is capable of good road speed when going to the landfill. • Can access replacement trucks easily as these vehicles are used for many other haulage purposes	• Truck has large haulage capacity • Fast to load, empty and replace • Can take up to 30 cubic metres in one bin as no real limit on lift capacity • Trucks are moderately priced with good availability and mechanical support. • Is capable of good road speed when going to the landfill. • Can lift many different bin sizes to suit location needs	• This system is a very quick and clean way to collect containerized waste. • Low labour requirements and costs. • Relatively high weekly waste capacity • Compacts waste up to 3 times the density • Good road speed
Negatives	• Fairly labour intensive to fill trailer by hand. • Shovelling waste is a hazardous and time-consuming practice. • A tractor is very slow on the way to the landfill. • Consider using a transfer station to overcome the tractor's slow speed. • No waste compaction	• Fairly labour intensive to clean out trash dams. • Shovelling waste is a hazardous and time-consuming practice. • A large truck has poor turning radius, so may not be able to negotiate some narrow roads, or turns. But can use a variety of truck sizes to suit road widths in the city • Truck has hydraulic systems for tipping requiring maintenance (same as tractor-trailer systems) • No waste compaction	• Requires specific hook-lift bin • A large truck has poor turning radius, so may not be able to negotiate some narrow roads, or turns. • Does not allow compaction in transit to landfill • Cannot be replaced with other truck types such as tip trucks • Truck has hydraulic systems for tipping requiring maintenance (same as tractor-trailer systems)	• The most expensive in terms of capital investment, and not generally available locally. • Requires significant room to turn, and bin must be aligned with truck. Smaller rear lift vehicles are available for narrow street areas • May require advanced training for mechanics.

10.5.1. Adopted Secondary Waste Collection System

The task is carried out by the Division of Public Health and Environment.

MSW is collected and transported to the landfill by using 13 haulage vehicles: 8 waste compactor trucks and 5 open tip trucks. Two of open tip trucks are used only for special requests (about 18 runs per months). One open tip truck is used only for garden waste. The rest of vehicles are used to collect MSW daily, once a day.

The Municipality is comfortable with the current collection system approach and equipment and has no interest in privatising the operation.

11. Review of Waste Processing and Disposal Options

Even with waste minimisation education and maximised recycling efforts, there will still be a need for a final disposal option. Alternative methods of waste disposal were investigated as below:

- Incineration;
- pit burners;
- baling;
- composting;
- “Zero Waste” fully-integrated approach and
- Waste to energy

The composting and waste to energy options are presented in separate chapters.

11.1. Incineration

Incineration of waste would considerably reduce the volume of waste for landfilling. A large facility would need to be constructed to burn waste material, thus converting carbon and hydrogen compounds to carbon dioxide, water and other residues. In the process of burning this waste it is possible to generate some energy. The proceeds from energy sale would not offset the entire running costs, let alone redemption on the capital investment.

The negative side of incineration is the need to sort the waste stream prior to burning as not all waste material can be burnt. The most significant disadvantage is the generation of exhaust gases (some potentially harmful gases) and the visual intrusion of the chimney stack. Specialist knowledge is required to operate and maintain an incineration facility which adds significantly to the life cycle costs.

Incineration as the sole disposal method was not considered a viable option due to the disadvantages and high capital and operating costs of such a facility. Costs of up to $100 a tonne for incineration would not be unusual, converting to about $90 per cubic metre at 900kg/cubic metre density. For example, the Perth Solid Waste Study reviewed incineration costs and determined that a new incinerator in Hawaii was operating at a cost of $105 per tonne. These costs have been reduced in the last decade with the move towards to waste to energy approaches.

Any long-term proposal to reuse greenwaste would significantly reduce the calorific value of the waste, necessitating fuel supplements, particularly in wet weather periods.

11.2. Pit Burners

Pit burners are used as a relatively low cost method of burning selected waste, building materials and timber. They are cheaper than incinerators, however the exhaust gases are less controllable. Pit burners can reduce the volume of waste requiring landfill significantly, however, not to the extent of incineration. Operation in protracted wet weather would be difficult. .

Due to the difficulties in meeting exhaust gases emission requirements and expected public objection to the odours and visible plumes which would result, a pit burner system was not considered viable for the total waste stream. It may be appropriate for large timber pieces and tree stumps, especially following any natural disasters.

11.3. Baling

Baling domestic waste is a technique similar to compaction and uses pressure to bind the waste into a tight mass ready for disposal. This process significantly reduces the volume of waste and makes handling and transportation easier. However, baling plants are costly to purchase and operate. They are also prone to mechanical breakdown due to the highly variable nature of the waste stream, including items such as large metal off-cuts and rocks. The baled contents of the landfill take longer to degrade and stabilise, thereby making the aftercare and utilisation of the site more difficult.

It was considered that baling of waste was not an economically viable option in the study area, especially given the relative closeness of the landfill to the city meaning haulage is already efficient.

11.4. Composting

See separate chapter above.

11.5. "Zero Waste" Integrated Approach

A number of such schemes are in various stages of operation or development globally. Such a scheme involves is a multitude of components to theoretically manage all waste streams resulting on no residual waste mass.

In summary the zero waste approach has the following components:

- Receivals area where large objects are removed;
- A system to break open any bags;
- A trommel screen to separate out small components which are usually the organics;
- Magnets and Eddy current systems to remove all metals;
- Manual segregation of the remaining waste into various recyclable components;
- An organics composting facility;
- A compost screening, drying and bagging process;
- An incineration system for plastics and other inorganic waste;
- A brick making facility to utilise the ash from the incinerator;
- A crusher to allow a recycling of construction and demolition waste; and
- Appurtenant works such as gas scrubbers and other odour control systems.

The aim of such facilities is very clear, that is, to have a zero waste operation. Such zero waste facilities are the ultimate aim for all Waste Management operations but to date have not succeeded in a sustainable way anywhere globally in a traditional community setting. There have been many pilot and short-term trials which have the theoretically achieved a zero waste position, but none in a sustainable real world application.

In reality however the long term expectations are not positive because of operating costs for energy alone as well as maintenance costs for all the mechanical equipment which is operating in a very harsh environment. Also high level of operator skills are required to operate the facility as well as maintain the equipment, especially items such as incinerators.

The key issues regarding sustainability are on-going funding and plant complexity. Experience indicates that such funding often tails away when higher priority local funding requests eventuate, usually associated with higher profile local authority activities.

In summary, it is simply impossible to recycle or reuse every component of a real-world mixed domestic waste and commercial/industrial waste stream. Even internally to the ISWM operation, composting is not a completely predictable activity. Compost facilities utilising more traditional waste streams like green waste or sewage sludges --always have some batches that do not meet specification for some reason either biological or due to contamination. These off-specification batches have to be dumped and there is no facility at this style of plant for such a large volume to be disposed of.

11.6. International Comparisons

There are no functioning full scale MSW compost schemes operating in developing countries in SE Asia which are self-funding. All have failed through a lack of a viable market for the product, lack of funds to continue operation (as they are not self-funding) or ultimately conversion to composting other more suitable material such as animal manure. A large scheme handling 1000t/d operates in Lahore but that is a PPP arrangement where compost contamination is not an issue (as one of the PPP partners is the adjacent farmer using the compost and he does not mind if the compost has foreign objects therein) and finally compost is applied to high value food crops.

Waste incineration is generally only practiced in locales where land costs are so high to preclude landfill development. They are banned in some counties like the Philippines because of concerns about the stack emission being environmentally damaging and even carcinogenic. The Government there does not believe that incinerator scrubber and filter systems will be maintained in the long term thereby allowing toxins to escape into the atmosphere.

The unfired bricks can only be used for local non-structural drainage projects which will eventually be fulfilled. Also incinerator ash can contain many contaminants such as heavy metals. Unless a pozzolanic material such as cement is added to the mix, then the heavy metals will be mobile and can leach out causing pollution.

11.7. Summary

Most of the above methods can be used for reduction of the volume of waste; however a landfill is still required for some part of the waste stream.

A typical zero waste approach is considered very unlikely to be sustainable for the many reasons listed above. The high capital and operating cost of such a process makes the process nonviable unless the provincial or national government is committed to subsidising the operation for the life of the operation.

Given the cost of the above methods, landfilling is considered the most appropriate method for disposal. Only the remnant wastes will be landfilled.

12. Waste to Energy

12.1. Technology Review

A range of waste to energy (WTE) technologies are reviewed for the purpose of this comparative assessment, including:

- Moving Grate Incineration
- Fluidised Bed Incineration
- Rotary Kiln Incineration
- Gasification
- Plasma Gasification
- Pyrolysis
- Refuse Derived Fuel (RDF) for Cement Kilns

12.1.1. Moving Grate Incineration

Moving Grate Incineration (see **Figure 12-1** and

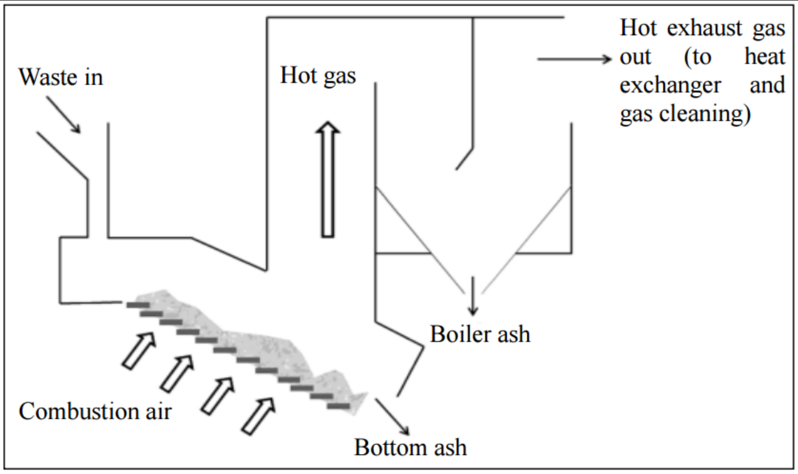
Table-12-1) is an incineration technology equipped with an inclined moving grate system which keeps the waste moving through the furnace during the combustion process. It is one of the most widely used MSW incineration technologies worldwide with an extensive commercial track record. The moving grate system has high efficiency to operate regardless of the composition, calorific value and moisture content of the MSW. Therefore the MSW feedstock does not require extensive pre-treatment before the incineration process.

In comparison with other thermal treatment technologies, the unit capacity and plant capacity of the moving grate incineration system is the highest, ranging from 10 to 1,125 tpd and 20 to 4,000 tpd of mixed MSW and/or RDF respectively. Moving grate incineration system is the only system which has been thoroughly proven to be capable of treating over 3,000 tpd of mixed MSW without requiring any pretreatment or preprocessing to achieve a homogeneous waste nature.

Process:

- Feeding hopper is filled with MSW, which seals the furnace from the outside and prevents backfire.
- MSW is fed via the chute into the grates. The grate is made up of moving parts, which push the waste through the combustion by grate movement.
- Primary air is injected through the grate from below and secondary air is injected above the grate into the flame region. MSW is first dried on the grate and then combusted at high temperatures (typically 850 – 950°C)
- Heated flue gasses are passed to a heat recovery boiler.
- Incineration bottom ash (IBA) is transferred from the discharge chute into a quench bath for cooling before further disposal.

- **Figure 12-1: Schematic Diagram of Moving Grate Incineration Process**



Source: Harrison, R.M. (2014).

- **Table-12-1: Technology Characteristics – Moving Grate Incineration**

PARAMETER	DESCRIPTION
Process Type	Thermal, Direct Combustion, Excess Oxygen
Typical Feedstock	Raw MSW
Track Record	Strong
Plant Capacity	200-4,000 tpd
Pros	• Large treatment capacities (up to 4,000 tpd). • Mature technology with worldwide application and with extensive commercial track record. • High reliability and comparatively low maintenance costs. • Little / no pre-treatment of MSW required, thus able to handle large variations in waste composition. • Flexibility regarding variations in calorific value and moisture content. • Low levels of particulates in flue gas. • Well-developed environmental/emissions controls systems widely available. • IBA is sterile, and recycling of metals from IBA is possible. • Possibility to control odour and wastewater from the process.
Cons	• Not suitable for liquids or powders. • Heat exchange may not be even, resulting in hot and cool spots within the waste stream. • Energy recovery efficiency is not as high as some other systems (e.g. fluidised bed filter). • Combustion residues may become melted to the grate, requiring periodic cleaning. • Waste gases produced when incinerating MSW typically include NO_x, dioxins and furans; therefore effective emissions control systems are required.

12.1.2. Fluidised Bed Incineration

Fluidised Bed Incineration (see **Figure 12-2 and Table 12-2**) is an alternative design to conventional combustion system in which the moving grate is replaced by a floating bed of granular materials, such as sand, which can understand high temperatures. There are two main types of fluidised bed: bubbling and circulating bed types.

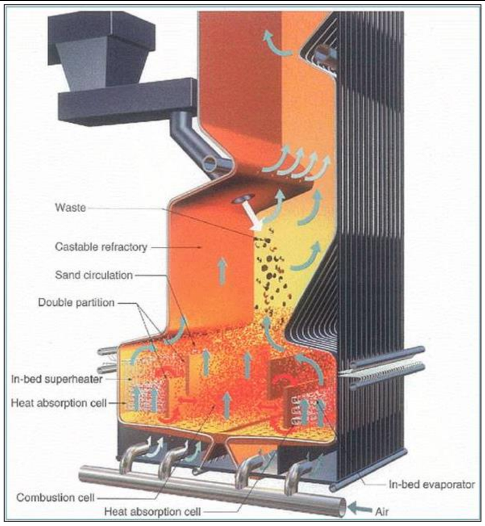
The pre-treatment of MSW is required in this system, usually by shredding, drying and pelletizing. The process efficiency may also be improved by co-combusting waste with other homogenous, high-calorific materials such as coal or woodchip.

The application for waste combustion using fluidised bed only began around 50 years ago. This included treatment of sewage sludge, as well as industrial and municipal wastes such as plastics, paper and tires (all of which had to first be processed and homogenised). Comparing to moving grate incineration, the fluidized-bed incineration system generally offers more uniform mixing, longer residence time (typically 4-5 seconds) and better residue burnout (typically less than 1% unburned carbon).

Process

- The MSW are shredded, dried and pelletized before introducing into the system
- An air distribution system forces large volumes of air through the media bed, causing it to circulate and become partially suspended, thereby acting in a fluid-like manner. The media can be sand, silica, limestone or ceramic material. However, sand media is the most popular.
- The processed MSW is introduced and combusted as a result of the elevated temperature and available oxygen (air temperature is typically 850-950°C, whilst sand bed temperature is typically 600°C)
- The incineration process is controlled by varying the waste feed rate and the air flow rate to the furnace.
- If combustion is interrupted for a short period of time, the sand bed temperature is typically maintained at 450-550°C which allows quick recovery to full operating temperatures.
- Ash is discharged through the base of the combustion chamber.

Figure 12-2 Typical Fluidized Bed Incineration Process



Source: SSWM Toolbox

Table 12-2 Technology Characteristics – Fluzidised Bed Incineration

PARAMETER	DESCRIPTION
Process Type	Thermal, Direct Combustion, Excess Oxygen
Track Record	Medium to Strong
Typical Feedstock	Treated RDF, sludge or other homogenous fuel such as wood chip or coal
Plant Capacity	200-1,600 tpd
Pros	• The waste is mixed and heated up evenly, allowing even incineration process • Particularly effective for incineration of high calorific value wastes. • Higher energy conversion efficiency when compared with moving grate systems. • Less NO_x production when compared to moving grate systems. • IBA produced is sterile. • Slightly higher thermal efficiency when comparting to the moving grate system.
Cons	• Requires extensive pre-treatment of wastes, usually by shredding, drying and pelletizing. • Might consider co-combusting waste with other fuel sources such as coal to improve efficiency. • Limited flexibility for managing variations in waste composition. • Larger volumes of fly-ash created when compared to moving grate. • High parasitic energy load. • High particulate load in flue gas. • Comparatively high maintenance requirements when compared to moving grate systems (due to wear of the internal cylinder caused by the circulated sand bed and waste feedstock.) and also regularly addition of media.

12.1.3. Rotary Kiln Incineration

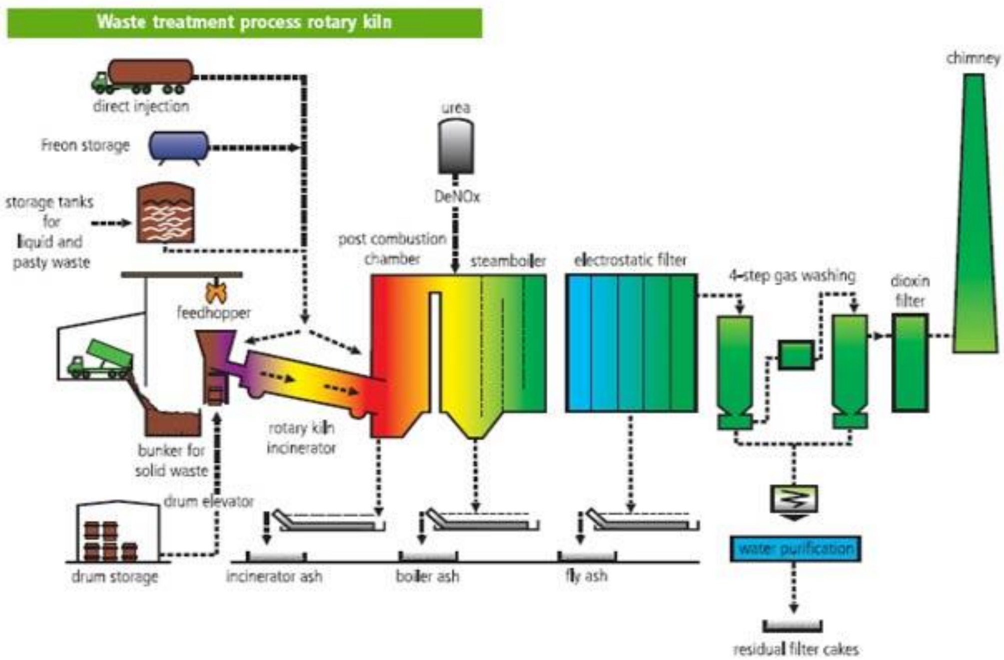
Rotary Kiln Incineration (see **Figure 12-3 and Table 12-3**) typically consists of two linked chambers – a primary chamber and secondary chamber. The primary chamber comprises of a rotating steel cylindrical shell lined with an abrasion-resistant refractive layer. The rotary system can achieve two objectives simultaneously using rotating motion: (i) moving wastes through the high-temperature combustion zone, and (ii) mixing and stoking the wastes during combustion. The secondary chamber is used to complete gas phase combustion reactions and burns the gaseous by-products from the primary chamber.

The rotary kiln incineration system provides good mixing and stoking of wastes, along with a high level of control of waste residence time; thereby resulting in more complete combustion. A significant advantage of rotary kiln is no waste pre-processing is required, and it is able to handle both liquids and solids. It is therefore commonly used to treat hazardous wastes, including high-energy liquids. However, it has higher maintenance requirements than moving grate systems, and capacity is restricted by limitations in drum size. Energy recovery efficiency is also lower as heat is lost through the metal shell of the rotating drum.

Process

- Wastes and air are injected into the heated rotating primary combustion chamber.
- Chamber rotates to mix/stoke wastes and move them through the combustion zone.
- Gaseous by-products are also formed through volatilization, destructive distillation and partial combustion reactions, and these are passed to a secondary "afterburner" chamber to allow combustion of gases
- Heated flue gasses are passed to a heat recovery boiler
- Ash is excavated from the lower end of the kiln

Figure 12-3 Typical Rotary Kiln Process



Source: Waste to Energy International

Table 12-3 Technology Characteristics – Rotary Kiln Incineration

PARAMETER	DESCRIPTION
Process Type	Thermal, Direct Combustion, Excess Oxygen
Track Record	Strong
Typical Feedstock	Solid or liquid wastes including hazardous wastes
Plant Capacity	20-144 tpd
Pros	• Little / no pre-sorting of wastes required. • Versatile, with the ability to deal with liquids and solids, as well as variations in moisture content and calorific value. • Ability to effectively control residence time, resulting in thorough burnout of waste • Particularly effective for treatment of hazardous waste streams, including high-energy liquids. • IBA is sterile.
Cons	• Regular maintenance of primary kiln is required, which increases OPEX. • Lower throughput in comparison to the moving grate system. • Low energy efficiency due to heat loss from the metal shell of the kiln. • Feeder end of kiln may be cooler than other portions, and may result in build-up of incompletely combusted residues such as melted plastic. • Limited capacity when compared with moving grate systems. • High particulate content in flue gas.

12.1.4. Gasification

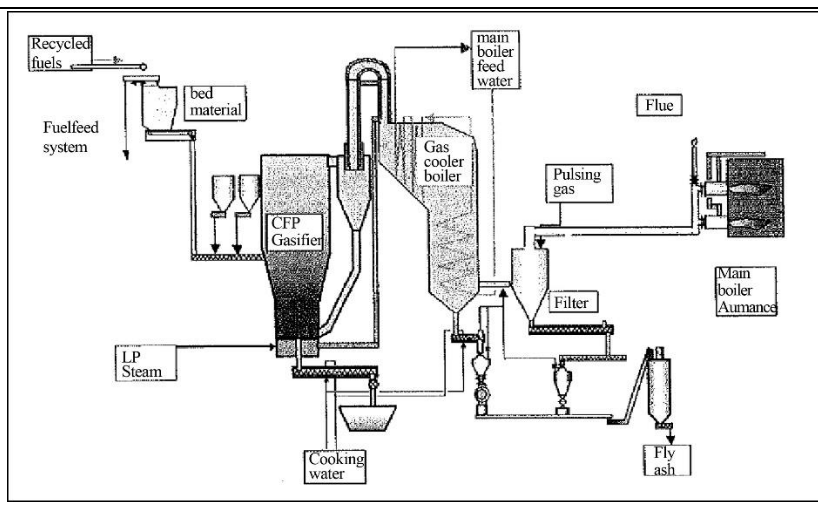
Gasification (see **Figure 12-4 and Table 12-4**) is an incomplete oxidation of organic compound and convert combustible waste to syngas or producer gas at temperature in the range of 500–1800 ^{o}C. Syngas comprises carbon monoxide, hydrogen, methane, carbon dioxide, water, nitrogen, argon, solid carbon and contaminated substances such as tar, particulate, chloride, alkali metals and sulfide.

The amount of air pollution substrates, particularly dioxins and furans, emitted from gasification typically reported to be less than incineration. Furthermore, the types of air pollution control devices may be similar, but smaller than incineration. This shows higher efficiency and energy recovery along with lower investment cost than that of incineration. Therefore, gasification technology has high potential to treat MSW in the future because of easy handling and burning of syngas, efficient conversion, low air pollution substrates, as well as the capability to scale-down the technology. However, the current gasification plants in operation have a much lower unit and plant capacity than the moving grate incineration plants for mixed MSW treatment in which their unit capacity and plant capacity generally range from 19 to 265 tpd and 38 to 530 tpd, respectively.

Process:

- The MSW is pre-processed first, sorting out the recyclables and organic fraction
- The MSW feedstock is then heated up in the reactor, with limited supply of oxygen/ air
- The Syngas is collected from the chamber and is typically passed to a combustion turbine where it is combusted to produce energy.
- Additional processes for further “cleaning” of the Syngas may be required to improve combustion efficiency and remove contaminants.

Figure 12-4 Typical Gasification Process



Source: Natural Science

Table 12-4 Technology Characterisitics - Gasification

PARAMETER	DESCRIPTION
Process Type	Thermal, By-Product Combustion, Low Oxygen
Track Record	Limited
Typical Feedstock	Shredded waste
Plant Capacity	100-450 tpd
Pros	• Little/no waste ash produced. • Suitable for the treatment of medical or hazardous wastes. • The End products of the process has a higher economic value and has the potential to be further processed into other products such as chemicals, fuels • Syngas can be stored and used for other industrial processes (e.g. production of gasoline) in addition to being combusted directly for energy. • No waste flue gas production.
Cons	• High parasitic energy load (i.e. the energy required to keep the process running). • Complex process to manage and difficulties in optimising (however can be very effective once optimised). • Requires pre-treatment of waste. • Limited capacity to cope with variations in waste composition. • Limited commercial track record for MSW treatment.

12.1.5. Plasma Gasification

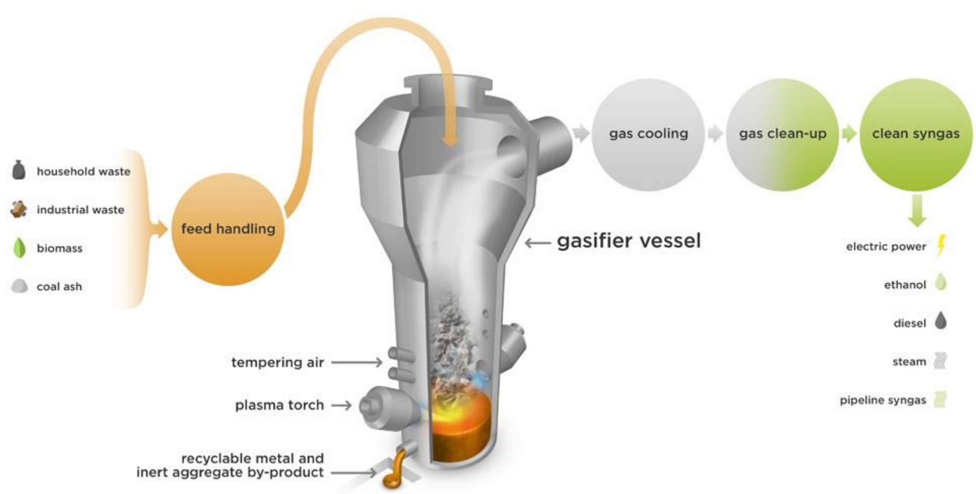
Plasma Gasification (see **Figure 12-5** and **Table 12-5**) is a more recent advent in waste treatment technology. It entails the chemical decomposition of waste in a low-oxygen environment, utilising a high-temperature plasma torch. The temperature of the plasma arc typically ranges from 2,700 to 4,400°C; however instances of temperatures up to 10,000°C have been reported. Plasma gasification plants have a comparatively low capacity range (between 20 and 500 tpd), and at present have not been widely-adopted for MSW treatment.

Little or no ash is produced since the carbon-based wastes are completely vaporised, and any non-carbon-based substances such as metals, glass or concrete are melted and turned into slag (for metallic components) or vitrified glass (for silica-based components). No flue gas is produced as the vapour by-products are captured as Syngas, which can be combusted to generate electricity or used as a reagent in other industrial processes.

Process:

- Pre-treated waste is fed into a vertical, cylindrical combustion chamber which has a low-oxygen atmosphere.
- The waste is passed through the arc of an electrically-driven plasma torch, within which it is vaporised to form Syngas.
- The Syngas is collected from the chamber and is typically passed to a combustion turbine where it is combusted to produce energy.
- Additional processes for further “cleaning” of the Syngas may be required to improve combustion efficiency and remove contaminants.
- The remaining slag is collected through an outlet at the base of the chamber.

Figure 12-5 Typical Plasma Gasification Process



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Source: Alliance Federated Energy

Table 12-5 Technology Characteristics – Plasma Gasification

PARAMETER	DESCRIPTION
Process Type	Thermal, By-Product Combustion, Low Oxygen
Track Record	Limited
Typical Feedstock:	Shredded waste
Plant Capacity	20-500 tpd
Pros:	• Little/no waste ash produced. • Suitable for the treatment of medical or hazardous wastes. • Good potential for metals recovery/recycling from slag/vitrified residues. • Syngas can be stored and used for other industrial processes (e.g. production of gasoline) in addition to being combusted directly for energy. • No waste flue gas production. • Vitrified slag is largely inert so there is little potential for contaminant leaching.
Cons:	• High parasitic energy load (i.e. the energy required to keep the process running). • Complex process to manage and difficulties in optimising (however can be very effective once optimised). • Requires pre-treatment of waste. • Limited capacity to cope with variations in waste composition. • Limited commercial track record for MSW treatment. • Process wastewater may be contaminated by carcinogenic or toxic compounds formed during the production of Syngas. • Syngas may require extensive contaminant removal before it can be combusted. • High CAPEX and OPEX costs when compared to direct combustion technologies. • Limited workforce with suitable skills available.

12.1.6. Pyrolysis

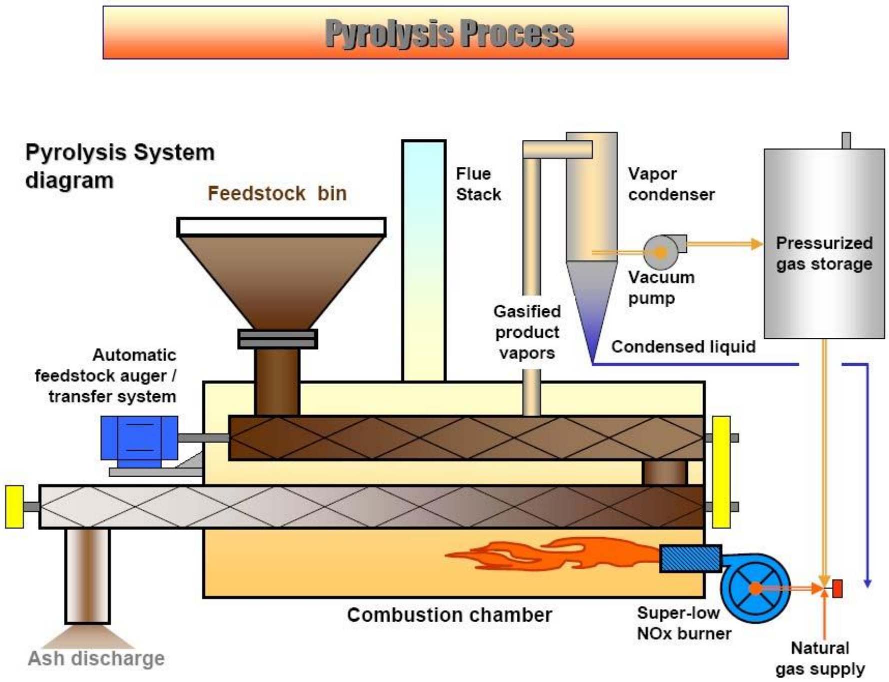
Pyrolysis (see **Figure 12-6** and **Table 12-6**) is an anaerobic indirect-heat process in which organic waste is decomposed to produce oil, carbonaceous char and combustible gases. These by-products are used as a fuel source and are burned to generate heat. Since no oxygen is required in the pyrolysis process, the volume of flue gas generated is lower than incineration and gasification processes. Unlike incineration and gasification systems, which are self-sustaining and use oxygen for waste combustion, an external source of heat is required to drive the pyrolysis reaction. Relatively low temperatures (in the range of 400 to 800°C) are required for pyrolysis. Pre-preparation of the MSW is also required.

Pyrolysis is not yet widely used as a treatment technology for MSW, and there is currently limited information available for review as many projects are still in the pilot stage. Challenges include low energy production (due to the amount of energy required to power the process), difficulties in process optimisation and safety concerns.

Process

- Processed MSW is placed into an airtight hopper.
- Waste is transferred from the hopper to a reaction chamber where it is heated in the absence of oxygen and is converted to char, pyrolysis oil and pyrolysis gas (lower temperatures favour formation char and pyrolysis oil, and higher temperatures encourage formation of pyrolysis gas).
- Pyrolysis oil is collected for combustion or for use in other processes, and solid residues are separated.
- Solid residues containing high carbon content may be subjected to an additional treatment.

▪ **Figure 12-6 Typical Pyrolysis Process**



Source: Waste to Energy International

Table 12-6 Technology Characteristics - Pyrolysis

PARAMETER	DESCRIPTION
Process Type	Thermal, By-product Combustion, No Oxygen
Track Record	Limited
Typical Feedstock	Processed MSW
Plant Capacity	100-500 tpd
Pros	• Pyrolysis oil can be stored and used in other potential industrial applications in addition to combustion for WTE (e.g. production of bio-diesel). • Lower flue gas emissions than conventional combustion technologies. • Particularly effective for volatile, high-energy waste fractions.
Cons	• Require pre-treatment of wastes. • Pyrolysis oil typically contains toxic and carcinogenic compounds. • Solid residue may not be completely combusted. • Low overall energy efficiency. • Limited track record for MSW management. • Solid residues may have high heavy metal content. • Additional treatment may be required to produce a sterile IBA.

12.1.7. Refuse Derived Fuel for Cement Kiln

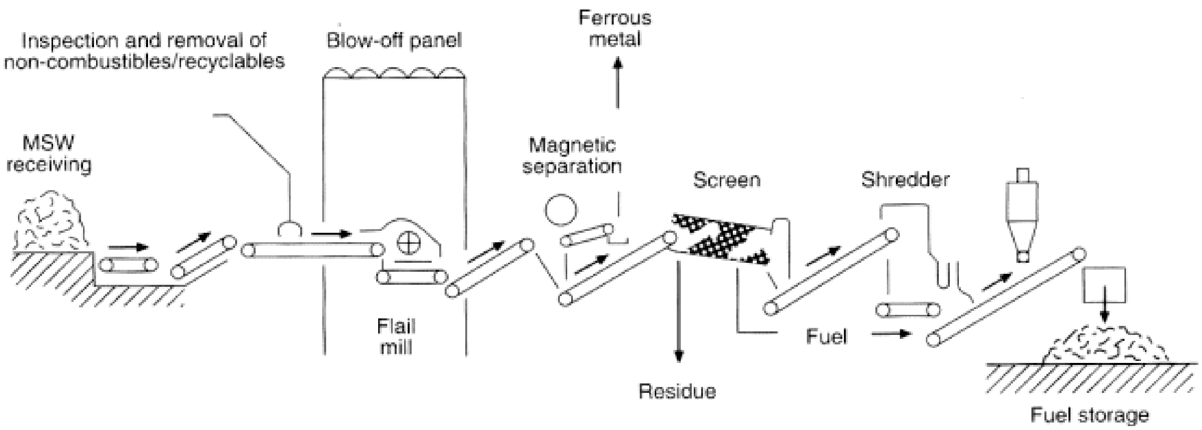
Refuse Derived Fuel (RDF) (see **Figure 12-7 and Table 12-7**) is a type of waste-derived fuels which are often used as a feedstock in WTE plants or industrial facilities, especially cement kilns. Comparing with "as-received MSW", RDF is usually of higher calorific value (due to its increased content of paper and plastics and stabilized organic waste), enabling higher efficiency of the WTE process, and is easier for handling, storage and transportation. Waste converter technology such as mechanical biological treatment (MBT) is commonly employed to produce RDF from fresh MSW. The manufacturing process of RDF usually include screening, shredding, size reduction, size reduction, classification, separation, drying, densification and storage.

Due to its operating condition with very high temperature (about 1450 ℃) and energy intensive nature, the cement kilns could use RDF as co-fired fuel without any modified process system, making RDF a favourable alternative fuel in cement kilns when co-fired. RDFs that are suitable for cement kilns should be at least 18.8 MJ/kg of calorific value, lower than 30% of moisture content, and less than 1% of chloride and sulphur. Research found that up to 15% of total energy in the cement industry could be substituted by RDF without much negative impact on the quality of clinker and air emissions. On the other hand, there are some key challenges of using RDF in cement kilns, including variation of input MSW characteristics, high transportation cost, need of sophisticated sorting technology and large storage. Also, cement kiln using RDF as co-fired fuel should be carefully modified to mitigate air emission and potential hazardous materials.

Process

- Non-combustible, organic fraction and recyclable materials of incoming MSW are removed with air knife or other density separation technique.
- MSW is comminuted by a flail mill.
- A magnetic separator is used to remove ferrous materials before screening out the larger particles.
- The remainder is shredded into small particles.
- The product is then dried and compacted at high temperature and pressure for cement kiln. This is required to save cost in storage and transportation, but the actual application may require de-compacting of RDF for easy feeding and attain high thermal efficiency during combustion.

- **Figure 12-7 Typical RDF Manufacturing Process**



Source: Murdoch University

- **Table 12-7 Technology Characteristics – RDF for Cement Kilns**

PARAMETER	DESCRIPTION
Process Type	Thermal, By-product Combustion, Excess Oxygen
Track Record	Strong
Typical Feedstock	Raw MSW
Plant Capacity	10-2,000 tpd
Pros	• RDF could be used as co-fired fuel by the cement kilns without modified process system due to its operating condition with very high temperature. • Energy consumption accounts for 30% of the production cost in cement industry. The cost of RDF is considerably lower than fossil fuels and is subject to the price volatility of fossil fuels. • Research found that cement industries in Thailand are willing to substitute 40% of energy by RDF. • Self-cleaning process of acid gas by lime reduced environmental control cost. • Little ash produced since ash will be melt and becomes part of final product. • RDF could be sorted out from fresh MSW or existing landfills.
Cons	• Product contamination has been a concern for cement factories, where standard setting for regulating the pollutant content of RDF may be required. • Need of sophisticated sorting technology and large storage. • Supply of MSW may face competition from nearby landfills. • Potentially high haulage cost due to long distance between cement kilns and RDF facility.

12.2. Comparative Summary of Selected Thermal WTE Technologies

Sections **12.3.1 - 12.4.1** provide a comparative review of the key characteristics of the selected thermal WTE processes and technologies, which is in turn summarised in **Table 12-8**.

- **Table 12-8 Comparison Summary of Selected Thermal of Treatment Technologies**

PARAMETER	MOVING GRATE INCINERATION	FLUIDIZED BED INCINERATION	ROTARY KILN INCINERATION	GASIFICATION	PLASMA GASIFICATION	PYROLYSIS	REFUSE DERIVED FUEL FOR CEMENT KILN
Plant Capacity Range	200-4,000 tpd	20-1,600 tpd	20-144 tpd	100-450 tpd	20-500 tpd	100-500 tpd	10-2,000 tpd
Waste Type	Solid only	Solid and sludge	Solid, sludge or liquid	Solid or liquid	Solid or liquid	Solid or liquid	Solid and sludge
Flexibility	High	Low	Medium	Low	Low	Low	High
Energy Gen. Efficiency	Medium	High	Medium	High	High	Low	High
Relative Facility Size	Large	Large	Large	Medium	Small	Small	Medium to small
Relative CAPEX	Medium	Low	Medium	Medium	High	High	Low
Reliability	High	High to medium	High to medium	Low	Low	Low	High
Relative OPEX	Medium	High	Medium	High	High	Medium	Low
Track Record for MSW	Strong	Moderate	Moderate to strong	Limited	Very limited	Very limited	Strong
Flue Gas Emissions	Medium	High	High	Low	Low	Low	Low
Requires Pre-Treatment	No	Yes	No	Yes	Yes	Yes	Yes

12.3. Engineering and Economic Factors

12.3.1. Flexibility in Waste Composition

Moving grate incineration technology possesses a high level of flexibility to deal with variations in waste quality and composition. It also does not require pre-processing of MSW, such as shredding or grinding, whereas this is a requirement for other systems apart from rotary kiln incinerators. Moving grate incineration is also flexible in terms of treatment capacity, with effective facility sizes ranging from 20 to 4,300 TPD.

A limitation to moving grate technology is that it can only handle solid, non-powdered waste. Rotary kiln incineration has the flexibility to deal with both liquid and solid waste; however its capacity efficiency is lower than that of the moving grate. Cement kilns are tolerant to waste composition, provided that the RDF produced could attain certain calorific value, moisture content particle size. The other technologies reviewed all require varying degrees of waste pre-treatment.

12.3.2. Electricity Production Efficiency

The greatest potential energy recovery efficiency is from plasma gasification as the chemical energy from MSW is converted into Syngas. This Syngas can be sent to a combustion turbine where the energy released during combustion directly powers turbines. This potential energy recovery efficiency is however offset by a relatively high parasitic energy load (i.e. the energy required by the process), meaning that in practice the comparative efficiency is much lower. On the other hand, a typical cement kiln can utilize up to 100% of the thermal and mineral (using the ashes as cement blending material) value of RDF during the co-fired process, given that the raw material mix is appropriately adapted by the cement operator.

For conventional incineration systems (moving grate, fluidised bed and rotary kiln), energy in the MSW is recovered through a near complete waste burning process and the heat energy is then diverted to waste heat boilers to generate steam for electricity generation using steam turbines. This process results in greater heat loss as the energy is exchanged between the various systems, and so has less efficiency potential than gasification.

The lowest energy recovery potential at present is from pyrolysis due to the large amount of carbon which is often not fully converted, as well as the high energy input requirements needed to sustain the process.

12.3.3. Reliability and Track Record

Broadly-speaking, the greatest operational reliability at present is provided by moving grate incineration systems. These are by far the most widely used technologies (over 900 installed worldwide) for both energy recovery from MSW, as well as incineration without energy recovery. The experience of application of the moving grate system in Thailand has not been so successful due to high variation of MSW moisture content between wet and dry season, Thai practice of putting bags in bags and no waste separation at the sources. They have been proven to be robust and easy to maintain in comparison to other technologies. Meanwhile, RDF also has a strong track record and relatively stable operation, where the utilization of RDF as alternative fuel in cement production has become a common practice in Europe since 1993.

Arguably, the lowest reliability and weakest track record for MSW treatment is currently provided by pyrolysis technologies as these are still in a development phase.

12.3.4. Land Requirements and System Complexity

The possible land requirements for the various technologies are subject to the number of units needed to treat the target waste load of MSW, as well as the footprint size of the various units.

The moving grate incineration plant occupies a large footprint; however each process unit has a large treatment capacity. Therefore a smaller number of units are required to deal with a large volume of waste. In contrast, gasification, pyrolysis and plasma gasification units occupy a relatively smaller footprint; however the unit of gasification, pyrolysis and plasma gasification has limited treatment capacity, thereby requiring a larger number of units to be installed. RDF for cement kiln does not require much land for its sorting technology but a large storage area may be needed.

As such, if incineration of large volumes (e.g. 500 or more tons per day) of MSW is required, moving grate facilities frequently provide an optimal combination of treatment capacity in comparison with the required facility footprint. On the other hand, both gasification and plasma gasification can also be considered if the volume of MSW is approximately around 500 tons per day, and RDF suits more for areas with less MSW generation.

12.3.5. Capital and Operating Costs

CAPEX and OPEX costs vary significantly across projects, countries and regions, and thus a relative ranking has been provided rather than absolute cost ranges. When considering cost efficiency (i.e. the treatment capacity in comparison with CAPEX and OPEX investment), the most efficient systems are often moving grate incineration. This is because of their large treatment capacity (reducing the number of treatment units required), relative operational simplicity, and widespread application. Additionally this technology does not require pre-treatment of wastes thereby further reducing OPEX costs. On the other hand, fuel cost saving has been a strong incentive for the energy-intensive cement industry to employ RDF as an alternative energy source, making RDF for cement kiln an appealing option in terms of cost effectiveness.

The lowest cost efficiency is typically realised with pyrolysis and plasma gasification systems as these are relatively recent innovations for MSW treatment, and many functioning units are prototypes. As such their development and maintenance is expensive when compared to conventional combustion technologies. Additionally the process units have limited capacity, thereby increasing the number of units required to manage a given volume of waste.

12.4. Environmental Factors

12.4.1. Air Emissions

Plasma gasification generally generates a lower volume of flue gas and associated pollutants than other incineration technologies since the vapours are largely captured in the Syngas. The low oxygen, high-temperature environment also significantly retards the production of dioxins and furans. Syngas often undergoes a “cleaning” process to remove toxic contaminants, and if this is done effectively it burns cleanly to produce CO_2 and water vapour. The lime and alkaline material presented in the raw material of cement production could be conveniently introduced into the kiln to absorb and neutralize acidic hazardous gases such as hydrogen chloride and sulphur dioxide released during RDF burning. It is also worth noting that cement manufacturing process consumes about ten times more energy than that of the average amount required by other manufacturing processes due to its requirement of extremely high temperatures, where the use of RDF for cement kilns serves as important means to reduce fossil fuel consumption of cement industry. Nonetheless, contamination of RDF applied in cement kilns shall be carefully investigated to avoid emissions of hazardous substances.

When comparing direct combustion technologies (namely moving grate, rotary kiln and fluidised bed), the lowest volume of flue gas emissions are produced by moving grate incineration. These emissions may contain various toxins and pollutants, and as such the application of appropriate air pollution control technologies are required to reduce these emissions.

12.5. Technology Recommendation and Implementation Schedule

12.5.1. Technology Recommended

After screening out the options of fluidized-bed incineration, rotary kiln incineration, plasma gasification and pyrolysis technologies, an evaluation of the moving grate incineration, gasification and RDF for cement kilns are carried out based on the criteria set out in **Table 12-8** with specific consideration of the feed-stock types, energy desired, end use requirement, pollution control standards, economic performance and other locally specific factors.

Incineration has been increasingly implemented for MSW treatment and energy recovery in Thailand. The existing capacity of MSW incineration plants in the whole country is about 96 MW of electricity and the expected capacity is 268 MW of electricity / 16,152 t/d MSW when the planned 15 plants are completed. Moving grate incineration is attractive for larger cities thanks to high subsidy from the government (approximately from USD 0.161 per kWh), and the capacity range of moving grate incineration plants in Thailand is 240-700 tpd. The high capital and operating costs and technological barriers for scaling down to suit small municipality is a major hurdle of this technology to be adopted in Buriram. While clustering of MSW from small cities to support a centralized WTE plant could potentially achieve feasible investment, the idea may be opposed by political motivation as each municipality may just desire to obtain revenue from WTE for themselves as soon as possible.

The existing capacity of gasification in Thailand is 7.2 MW of electricity generation with 602 t/d MSW consumed, and the technology has a potential to generate 28.04 MW of electricity using about 1,983 t/d of MSW. The syngas produced by gasification technology is easy to handle, has less air pollutant than that of incineration, and can be used to generate high-quality fuels or chemical. Also, unlike moving grate incineration, gasification technology can be designed for a small scale. Nonetheless, commercial operation record of gasification technology is still limited due to highly heterogeneous nature of MSW, and achieving the required syngas conditioning and cleaning are still costly.

The RDF used in Thailand for cement kiln alone is approximately 78.26 ktoe (kilotonne of oil equivalent), producing 0.36 Mt heat per year. The heat and material content of RDF could be highly utilized when it is co-fired with coal in the cement kiln. The pollution control of burning RDF in cement kiln is relatively handy, yet the receiving cement kiln should be carefully modified to mitigate air pollutants such as dioxins. Also, small sorting facility can be set up to accommodate the low MSW volume of Buriram. The key challenges faced by RDF include high transportation cost, upfront capital cost for sorting technology (although it is still cheaper than the other two technologies) and need of regulatory change, e.g. setting RDF standards and revising air emission standards.

After balancing the pros and cons of the three technologies, RDF for cement kilns appeals to be a more practical WTE option that could be further explored by the Buriram Municipality. The advantages of RDF for cement kilns over the moving grate incineration and gasification technologies in terms of reliability, operating experience, flexibility, capital and operating costs as well as environmental impacts are summarized as follows:

- Buriram Municipality is a small city with just around 30-40 tpd MSW produced currently plus a further 50 tons from neighbouring municipalities. RDF technology is flexible to accommodate small amount MSW, where the investment cost of moving grate incineration plant cannot be justified for treating such small amount of waste;

- The power generation potential per tonne of MSW of RDF is among the highest of the three technologies (over 300 kWh), yet the CAPEX and OPEX of RDF are normally the lowest.

- Due to warm climate and high moisture content of MSW in Thailand, pre-treatment of waste or RDF is required for most WTE technologies to generate energy, meaning that moving grate incineration may bear additional waste pre-treatment cost;

- RDF possesses less operation complexity in comparison with moving grate incineration and gasification technologies;

- Both RDF and moving grate incineration have a strong track record during the past decades, while there is a concern for operation failure of the gasification technology due to the unpleasant experience in Germany; and

- The emission control of RDF for cement kilns possesses less technological complexity and requires less investment comparing with moving grate incineration.

12.5.2. Next Step

The capital cost and operating cost of RDF are relatively reasonable, which range from about USD 22,000-53,000 per tonne (CAPEX) and USD 7-20 per tonne (OPEX) respectively. For instance, based on the source of Sci Eco Services Co., Ltd., an established company in waste management in cement pyro-processing, the modification cost of a cement plant in Thailand is about USD 1 million with the treatment capacity to treat 200 tonnes of waste per day (see **Figure 12-8**).

- **Figure 12-8 Conceptual diagram of the SCP cement plant with a 100 t/d RDF facility**

Source: Sci Eco Services Co., Ltd.

As for the market potential of RDF for cement kilns, cement industries in Thailand were found to be willing to substitute 40% of their energy source by RDF, i.e. around 2.7 Mt per year, and the estimated potential for RDF production in Thailand (2.46 Mt per year). At least three cement companies have invested in the sorting plants for RDF production in Thailand, namely TPI Polene Company (TPI), Siam City Cement Public Company (SCCC) and Siam Cement Group Company (SCG), where all three companies co-fire RDF in cement kilns with TPI also using RDF for electricity generation. Currently, MSW from a number of local authorities in ten provinces including Buriram are delivered to the RDF production plants developed by cement companies such as TPI, SCCC and SCG. The Consultant started to investigate major cement companies in Thailand to further understand their interest in RDF facility within the area. It is noted that TPI possess a dedicated incineration plant for RDF with the capacity of 2,000 tpd. The company is currently sourcing high quality RDF as far as Ubon Ratchathani

Nonetheless, it is worth noting that the implementation of RDF for cement kilns in the municipality could be facing the following technical and political problems in the short run:

- Based on the initial investigation from the Consultant, the nearest cement plants which can handle RDF are located in Saraburi which is about 150 km from Buriram, thus transportation of RDF could be costly;

- The tonnage of waste generated for Buriram is small, and the RDF production potential is about 10-15 tpd, which may not service the fuels required for co-processing of cement kiln, or does not justify the transportation cost;

- Cement plants in the serving area of the potential RDF facility may not be equipped with appropriate air pollution control equipment needed for RDF combustion. The upgrading cost for this aspect and possibly the cement kiln may not be justifiable if only 15 tdf of RDF is burnt;

- The waste quality if high in Chlorine (from plastic) or phosphate would contaminate the cement product quality. Normally the cement companies will reject RDF if the environmental standard is not met. The produced characteristic of produced RDF have to meet the required standard of each cement kiln to minimize the concerns of cement plants about the potential contamination to their product;

- Allocation of costs and earnings may be challenging as the project is not solely for waste management but also commercial production for private sector gains;

- The energy output benefit which is originally intended for the public is now being consumed by the cement companies;

- The public may be concerned about effectiveness of the environmental / safety controls as it is not a dedicated waste project and controlled by a party with low transparency; and
- While MSW excavated from existing landfill has a potential to produce RDF, factors such as expected low CV content, high moisture content, inhomogeneous nature of waste, need of more sophisticated sorting and potentially higher environmental and safety hazards make the actual implementation undesirable.

The existing MSW management strategy of Thailand still focuses on bulk collection and mass disposal, while promotion of integrated waste management system to reduce landfill burden and generate renewable energy has been enhanced. While the 11^{th} National Economic and Social Development Plan (NESDP, 2012-2016) proposed a MSW management plan targeting 50% proper disposal and 30% recovery, as of 2013, only 27% of MSW was properly disposed; 19.1% was recycled and composted (only 0.4% for WTE), and some 53.5% was disposed improperly. On the other hand, the Thai Ministry of Energy has announced the target of renewable energy contributing at least 25% of final energy consumption by 2012, where 400 MW of electricity and 200 ktoe of heat will be contributed by MSW.

Under the current situation, it is recommended to have a stepwise implementation of waste management for the municipality, which will allow for the establishment of required capacity and institutional arrangement. As the waste management hierarchy calls for forming a proper engineered landfill in the short term, WTE (i.e. RDF for cement kiln) shall be at least five years down the road for small municipalities like Buriram. In the long run (approximately a decade later), MSW incineration for clustered cities could be further investigated as the integrated solid waste management in Thailand becomes more mature. While the development of RDF in Buriram is subject to detailed feasibility study..

13. Review of Current Disposal Site

13.1. Background

The disposal site was constructed and started accepting waste in about year 2000.

The site is located in Phrakroo sub-district, Muang Buriram, Buriram province about 16 km from downtown. The total area is 16 hectares divided into 4 phases:

- Phase 1: 2.24 hectares, used during 2000 – 2007, waste amount 98,750 tons
- Phase 2: 3.2 hectares, used during 2009 – 2014, waste amount 100,750 tons
- Phase 3: 3.92 hectares, used during 2014 – recently, waste amount 42,468.31 tons
- Phase 4 (Secondary area): 1.4 hectares, used during 2007 – 2009 and 2011 - 2013, waste amount 55,200 tons

Currently, the operation is in the phase three area and the Municipality has estimated the lifetime remaining at 4 years, if using the present method of low mounds with flat tops into the future.

The operation is reasonably good overall. There is a control over where waste loads are dumped, as well as an attempt to provide some waste profiling and application of cover soil. There is no open burning of waste on the site. Overall, the collection and disposal of waste is to a reasonable standard.

Currently, the total quantity of solid waste that is disposed to the sanitary landfill is 86 tons/day (41 tons/day from Buriram municipality and 45 tons/day from other municipalities/cities).

Other important information about the sites:

- The landfill site is of flat type.
- Locally the soil profile is medium-hard clay over hard sandy clay and over hard clay.
- The water table depth is about one metre but varies seasonally.
- There is an external catchment in the area
- The municipality reports no fires. There is no active burning with flames visible nor opening burning of waste.
- Only one family of four is allowed to collect recyclable wastes on site.
- Everyday soil is used to cover new waste. Approximately 120 m3 of soil is reportedly used for 90 ton of waste disposed each day.
- At present there is some signs of leachate leaking out from the landfill
- The nearest groundwater user is approximately 1 km from the disposal site and the water depth in their well is unknown. The water is not used for drinking.
- There are 2 bulldozers, 2 excavators, 3 tip trucks, 1 water truck, and 2 pickup trucks on sites permanently. However, most of them are old and frequently require repairs. A new bulldozer had just been delivered at the time of inspection in April 2016.

13.2. Site overview and Surrounds

The site is reasonably flat with less than three metres fall over the natural surface across the site.

The site has been developed in four stages with the first, second and fourth stages being intermediately covered at the time of inspection in April 2016. These overall stage sizes are described above but in terms of future expansions, the base sizes are notionally 140 metres by 120 metres, 160 metres by 110 metres, 200 metres by 190 metres and 60 m by 160 m respectively and all are rectangular. The waste is approximately six metres above natural surface level on average.

The current operating area or stage three is approximately 200 m by 190 m wide on average. This is at the northern side of the site and has a boundary common with the eastern end of stage four and the western side of stages 1 and 2.

On the south western corner of the site, two leachate ponds are located.

There are no buildings established onsite, such as offices and equipment workshops and storage facilities.

In terms of neighbouring activities, there are no surrounding buildings directly adjacent to the landfill.

13.3. Hydrogeology

Hydrogeological information is presented earlier in this report and is notes that it is essentially clayey sand at the surface with increasing clay content until reaching a heavy plastic clay at a depth. This was confirmed by site inspection observations of the local soil excavations.

13.4. Site design and operations

The drainage systems throughout the site contained only small quantities of litter which would exit the site during rain or significant wind events. Litter was observed in small quantities on the access roads to and around the site during the inspection. However the quantities were small and reflect a reasonably high standard of operation at the site.

There are some very basic errors in the current design approach. The approach to cell development involves the construction of a perimeter earthen bund which has the potential form a large dam which at the time of inspection was partially full of large volumes of leachate. This is further exacerbated in the first lift where the perimeter bunds the covered with the artificial HDPE liner.

All stages, where completed or operational, have a very flat surface with the grade approaching 0%. Such a flat slope is resulting in excess leachate formation due to high rain water infiltration rates through the cover. Furthermore, such a flat slope allows the formation of local depressions due to differential settlement of the waste as it degrades. These local depressions which are present on all the mounds act as recharge points for rain water and again add to the formation of excess leachate volumes.

Along the southern side of stage two, some leachate expressions were observed flowing towards the central drainage system located beside the main access road.

The leachate springs were observed in the second lift meaning that the first lift which is contained by the artificial liner must be fully saturated. Continuation of the same approach to developing a series of enclosed bunds and then developing a plateau mound essentially with a flat top will merely exacerbate the problem even with the application of a suitable final cover on the top surface. Therefore excessive leachate generation will continue to occur resulting in potential contamination of local surface waters and also has the potential to contaminate local groundwater reserves. Whilst waste is being deposited and covered in stage three at the moment, there are some remaining areas in this stage where waste has been placed in an uncontrolled manner however these areas are relatively small.

At the time of inspection, intermediate and final soil cover was being placed on top of stage three even though it was being placed at the very flat slopes. Such flat slopes are inappropriate and will result in significant leachate generation and emissions.

The stage 3 mound also contains a number of areas where waste is not being compacted and covered and that have not been sensibly incorporated into the ongoing waste disposal activities. These then resulted in even further opportunities for rain water infiltration and leachate formation.

13.5. Leachate treatment and disposal

Two leachate treatment ponds are provided which were only partially full at the time of inspection (which was the driest part of the year) and the leachate was not flowing into the local watercourse and drains.

The operators advised that during the wet season there is significant leachate flow exiting the lagoons.

The leachate ponds are not provided with aeration equipment and would mainly act as large settling tanks and provide some limited facultative treatment. But the ponds would certainly not produce a leachate meeting the local discharge standards for effluent entering local water courses.

The HDPE liners in both lagoons are damaged and would obviously leak significant quantities of leachate when at top water level.

13.6. Site capacity

The Municipality staff and its site operators believe the site is almost at capacity.

In a later section of this Plan, landfill life predictions are made based on the site being operated as a controlled landfill and with external batter slopes of 1 vertical is to 2.5 horizontal, which is the international standard for such controlled landfills. In fact there are decades of life available on the site and the operation could be continued in parallel with a remediation process on the previously worked stages which would ultimately be incorporated into the overall final mound.

13.7. Site equipment and soil cover requirements

Two old bulldozers were working on site and the municipality advised that an excavator and tip truck are also available. A new bulldozer had been obtained at the time of inspection but was yet to be commissioned.

For the tonnage of approximately 90 tonnes per day entering the site, a D7 bulldozer together with an excavator should be sufficient to allow the site to be operated correctly, provided that a tip truck is available for hauling cover material and that a sufficient stockpile or source of cover material is provided.

The quantity of cover material required in a controlled landfill should be approximately 20 to 25% of the airspace consumed, assuming that the daily cover 150 mm thick is applied together with intermediate cover 300 mm thick on areas which will be later receiving additional waste, and 600mm final cover.

However the minimum operational requirement would be approximately 10% of the airspace being consumed by cover material.

13.8. Summary of operation

Overall, the site is reasonably well run but the fundamental operational and design errors cannot be attributed to the budget limitations.

To reiterate, there were basic operational errors which could be remedied through better planning and operation and would not impose any additional cost. For example the current cover on stages one and two involved placing soil at almost zero grade resulting in a flat plateau for the final mound shape. Such a flat slope will ensure that any heavy rainfall will significantly infiltrate into the refuse resulting in the formation of excess leachate. This leachate will eventually be expressed through the toe or the lower slopes on the external batters and migrate from the site resulting in environmental impact.

There is no additional cost in remediating the site to an appropriate standard by planning and profiling, and therefore additional expertise is required to operate the site as well as remediate previously worked areas to a suitable standard.

13.9. Remediation Priorities

The highest priority is always fire control. It is critical that all actively burning surface waste and smouldering buried waste is fully extinguished and cooled prior to the new landfill commencing operations. To the credit of the operators, there was no burning or even smoke plumes at the time of inspection. However there were signs of small fires in the past and therefore the following description allows for any future burning on site.

- Small surface-only areas of combustion in the existing dump can be controlled with water and subsequent application of soil cover material. But the only way to completely extinguish subsurface fires at dumps is to excavate waste until the combustion source is reached. Therefore, there is little choice in the remediation of this site but to adopt a cut and carry approach to remove all actively burning and smouldering material and wet it prior to replacing and covering in accordance with a final design. Some of this burning material could be incorporated into the Stage 1 borrow pile and covered until it can be used as daily cover for later stages of the landfill. Therefore, the extinguished waste pile will need to be well clear of initial landfill development stages to avoid double handling.

In parallel, urgent action is required to prevent new fires starting anywhere in the active dumping areas and to stop the fires in previously worked areas. Initially the surface fires should be extinguished and then deeper fires progressively excavated and extinguished as part of the initial activities leading to eventual full remediation. It is critical that no fires are allowed to start within the landfill proper either due to purposeful ignition or importation of already burning or hot waste from the previously worked areas or subsurface burning extending into the landfill cells.

As noted above, Buriram municipality reports no open burning nor fires on site. The site has therefore two different types of waste to be managed:

- Old waste in the landfill does not need special treatment but could be recovered for waste-to-energy system in order to reclaim land space if this is economically viable.
- Contemporary waste that needs appropriate planning for future disposal alternatives.

13.10. Inert Waste

Waste which is more than 15 to 20 years old or which has been completely burnt is essentially inert. Therefore the level of protection required for remediating inert waste is far less than that of contemporary or new waste.

The approach could be as follows to remediate any inert waste under the initial Stage 1 landfill development:

- Excavate all burning material within the stage one footprint;
- Continue excavation until the required cell development profile is achieved and the necessary quantity of cover material/inert waste has been achieved;
- Separate out all actively burning material and hot waste and place on a soil covered area outside Stage 1 adopted as the cover stockpile location for Stage 1 landfill operations;
- Wet the waste and allow to cool down;
- Profile the cooled waste to ensure a minimum of 5% slope;
- Compact the previously deposited waste using the bulldozer, with at least 5 passes;
- Cover with 600 mm of soil. The soil for this cover activity may be taken from the excavation works required to prepare the base of the first stage of the landfill.

For the other previously deposited waste areas outside the footprint required for the development of Stage One of the proposed landfill, the action would be to place the cooled waste on top of the previously deposited inert waste well away from the Stage 1 footprint area and cover stockpile area.

The biggest cost associated with remediation will be the excavation of burning/smouldering waste at depth, carting to a prepared area and spreading, extinguishing the fires, reloading the waste, returning it and finally compacting it. Minimising the quantity of waste that has to be extinguished will greatly reduce the overall remediation costs so fire control is needed at the site prior to any landfill earthworks activities.

Because the old inert waste will be profiled, compacted and covered, and the local soils are not highly permeable, it is unlikely that temporary liner systems or leachate collection and treatment plants will be required.

Similarly, because almost all of the organic material has either degraded or been combusted, there will be little landfill gas being produced. Therefore, there is no requirement to install a gas management or collection system for any remediated waste piles.

13.11. Contemporary Waste

Waste which may have been partially burnt but is still "active" will still be handled in a generally similar manner, but could not be used for cover and would need to be eventually incorporated into the landfill cell. The contemporary waste would be extinguished, cooled, profiled, compacted and covered in a location clear of the Stage 1 footprint, but sufficiently close to be able to be efficiently hauled for placement within the landfill proper for final disposal once the advancing landfill cells have been progressively developed.

It is expected that the "temporary" stockpiles of contemporary waste would be established in a number of locations to minimise haulage distances.

13.12. Parallel Operating Period

While the landfill is being constructed and commissioned, waste will continue to arrive at the site and will require management.

One option is to upgrade the current operation is by providing operational guidelines to improve the operation making it closer to a Controlled Landfill. Apart from banning all fires and extinguishing existing fires, the main differences would be as follows:

- Formalising the responsibility of the site staff to direct all trucks to only dump at the prepared dumping table;
- Profile the area to minimise rainwater infiltration;
- Improve compaction;
- Prepare cover stockpiles;
- Apply cover on at least a weekly basis, preferably daily.

These basic refinements would result in the site being sustainable until the landfill proper is ready to receive waste.

Most of the remediation can be done prior to landfill completion by using the new landfill equipment which could be purchased early in the project procurement process. The equipment can then be used to complete the remediation and as training for the new operators. The costs for the fuel consumed can just be drawn from the site's general operations budget.

The second and third stages of landfill development would then need to progressively incorporate this waste into the lined cells as they advance across the ultimate footprint. By the time the third landfill stage is being developed, most of the "contemporary waste" from say would be essentially inert and could be used as daily cover supplement anyway, avoiding utilisation of active landfill airspace.

14. Appropriate Standard for a Waste Disposal Facility

The selection of the design and operational standard for the disposal facility will be based on the table below, plus the addition of any local specific requirements by the PCD. This presents four options ranging from uncontrolled open dumping to a fully engineered sanitary landfill.

The first option of open dumping is essentially what is happening at present, or even somewhat worse, and cannot be supported in the future.

The second option is a controlled dump but this still does not have waste compaction and soil covering, leading to significant ongoing environmental impacts. This option also could not be supported.

The third option of a Controlled Landfill has most of the environmental and operational benefits of the final option (a fully engineered sanitary landfill) but without the technical complexities of leachate treatment plants for example, and social dislocation of banning all waste pickers form site. The Controlled Landfill option can be upgraded with scale-appropriate additional interventions for leachate and gas management, but not burdened with the additional constraints of the full sanitary landfill option which are undesirable for such relatively small operations as at Dili.

The fourth and most complex option is a fully engineered sanitary landfill. This compulsorily includes the following requirements in addition to those of a Controlled Landfill (the third level of complexity):

- a leachate treatment plant;
- mechanised material recovery facilities;
- mandated removal of all waste pickers from site; and
- full gas control and use.

This combination is considered too expensive for the relatively small city and far too complex to operate sustainably without ongoing external technical support at least for some years. Also the additional operating costs for items like the landfill are significant but yield little environmental gains at this scale. Furthermore the required removal of all waste scavenging and animal husbandry activities from the site would have significant social impacts at this time.

Given that there is little difference in cost or operational difficulty between a controlled dump and a Controlled Landfill, but the Controlled Landfill has significantly better environmental benefits, a Controlled Landfill is the most appropriate disposal system for the city.

Table 14-1 – Controlled Dump and Landfill Options

Type	Characteristics	Advantages	Disadvantages
Open Dump	• poorly sited • unknown capacity • no cell planning • little or no site preparation • no leachate management • no gas management • occasional or no cover • no waste compaction • no fence • waste burning • no record keeping • uncontrolled waste picking • no groundwater monitoring	• easy access • low initial cost • low operating cost • aerobic decomposition • access to waste pickers • materials recovery	• high environmental impacts • unsightly • groundwater contamination • surface water contamination • high risk of explosion, greenhouse gases • vectors/disease transmission • reduced lifetime of dump site • inefficient use of landfill area • breeds vermin - rodents, flies • no record of landfill content • air pollution
Controlled Dump	• sited with regard to hydro-geology • planned cell development • grading, drainage in site preparation • partial leachate management • no waste covering • no compaction • fence • basic record keeping • uncontrolled waste picking • waste burning • no gas management • no groundwater monitoring	• moderate environmental impacts • permits long term planning • improved stormwater control • less risk of leachate release • controlled access and use • access to waste pickers • materials recovery	• moderate environmental impacts • groundwater contamination • surface water contamination • moderate risk of explosion due to gas • vectors/disease transmission • reduced lifetime of dump site • inefficient use of landfill area • breeds vermin - rats, flies • no record of landfill content • air pollution • high health risk to waste pickers
Controlled Landfill	• sited with regard to hydro-geology • planned cell development • grading, drainage in site preparation • improved leachate and surface water management • regular (not usually daily) cover • waste compaction • fence • basic record keeping • controlled waste picking • gas management provisions • monitoring of groundwater	• low environmental impacts • permits long term planning • improved stormwater control • reduced risk of leachate release • controlled access and use • reduced risk to waste pickers • materials recovery • waste is covered by soil • efficient use of landfill area • reduced breeding of vermin - rodents, flies • extended lifetime of landfill site	• still reduced environmental impacts • still limited potential for groundwater contamination • still limited potential for surface water contamination • still low risk of explosion due to gas • still reduced risk of vectors/disease transmission • little or no record of landfill content • some air pollution
Sanitary Landfill	• site based on environmental risk assessment • planned cell development • extensive site preparation • full leachate and surface water management • full gas management • daily and final cover • daily waste compaction • fence and gate • record waste volume, type, source • no waste picking	• minimized environmental risk • permits long term planning • improved stormwater control • minimized risk of leachate release • reduced risk from gas • vector control • improved aesthetics • extended lifetime • controlled access and use • eliminate risk to waste pickers	• high initial cost • high operating costs • longer development time • slower waste decomposition • minimized risk of vectors/disease transmission • minimized risk of vermin – rodents, flies • displacement of waste pickers • loss of recyclable resources • optimum use of landfill site

Source*:* Adapted from Municipal Solid Waste Management. United Nations Environmental Program, 2002.

Based on the above, the proposed disposal system is a Controlled Landfill but with some aspects to suit local conditions. For example, the leachate management system will reflect the very arid conditions meaning that leachate pump stations will not be required and simple evaporation ponds used for leachate disposal instead.

15. Future Controlled Landfill Development

15.1. Introduction

Landfilling is the most cost-effective system of solid waste disposal for most urban areas in developing countries. Composting of solid waste costs 2-3 times more than controlled landfill, and incineration costs more than landfilling unless energy is recovered.

A landfill is a contained and engineered bioreactor and attenuation structure, designed to encourage anaerobic biodegradation and consolidation of compacted waste materials within confining layers of compacted soil. At a proper controlled landfill, there are no nuisance impacts of constant burning, smoke, flies, windblown litter, and unsightly rubbish heaps. Waste in a proper controlled landfill is not directly exposed to rainfall, surface runoff or groundwater. Leachate generation is derived only from a limited quantity of infiltration which reaches the waste deposit and captures the by-products of waste biodegradation. While little leachate is generated in a controlled landfill compared to an open dump, leachate concentrations are much higher -- organics are higher by a factor of more than 10 -- and thus leachate needs to be properly managed.

Controlled landfill design needs to provide for cover of fresh waste, incorporate mitigative measures to manage leachate and gas produced within the landfill cells, provide for a final soil and vegetative cover, and establish an environmental monitoring system of up-gradient and down-gradient groundwater monitoring wells and surface water sampling locations. Typically the daily cover material is soil; however, tarps or inert materials (i.e., construction debris or compost residuals) could be used.

15.2. Site selection

It is critical that a long-term view is taken when selecting the site such that initial small savings in cost or overcoming local socio-economic issues are weighed against the possible long-term benefits associated with accessing a much better site. This may simply be in terms of having better soil profiles which allow easier stormwater diversion drain construction as well as ongoing cell development and cover winning.

However the most critical aspect generally is having a reasonable site slope and soil suitable for excavation and using as cover. If the slope is too steep then it will be difficult to gain the required capacity even with deep excavations and diverting external stormwater runoff difficult. Conversely a site that is too flat will make leachate drainage systems more difficult and costly to develop.

The landfill design approach was staged as follows:

- Population and Waste Generation Spreadsheet was used initially to provide the waste mass and volume of landfill airspace required.
- Landfill Capacity and Size Spreadsheet was used to determine the footprint size required.

Landfill Design guidelines used to design the landfill are described below.

In this case, the design approach was to continue using the current site because it provided sufficient capacity and develop a parallel operating and remediation strategy to minimize the overall Waste Management costs.

15.3. Landfill Configuration

15.3.1. Initial Stage

Estimates have been made of the likely population growth and the waste quantities generated over the next 20 to 30 years. The 20 year time frame is often adopted for siting landfills because of the significant socio-environmental issues and delays involved with obtaining planning and engineering approval for a new facility. Furthermore, the local interest in perhaps utilizing RDF or other significant waste diversions will only further extend the life of the facility which will be receiving only residual waste with these upfront interventions should they occur.

A typical landfill development will involve a balanced cut-to-fill arrangement whereby soil is excavated prior to basal lining or amending the bottom soil to provide a suitable basal liner. Stages one, two and three cannot be excavated for soil recovery as the waste will be remaining in Situ and progressively remediated as part of ongoing operations.

A nominal width of 120m has been assumed and the first cell of Stage 1 will need to be 140 m long to provide a life of some 2-3 years, depending upon recycling and waste diversion initiatives. It will be approximately 20 m high and will require cover to be excavated from other sources when required. So there is no need to excavate the base of the landfill to such a depth as to obtain sufficient cover for the whole landfill life. In such cases of general soil availability around the site, the excavation works for the landfill base would be limited to just achieving the required shape and slopes at the minimum excavation depth, unless the site is very small and deeper excavation is essential to provide the landfill life required.

A three to five year life is common as the first main stage of a landfill development.

15.3.2. Subsequent stages

There is a general approach in developing countries to limit waste to very shallow mounds given a fear of waste collapses. However, this is a very inefficient approach as the expensive basal liner and associated leachate collection facilities are not utilized to their full extent with only a willow layer of waste being applied. This approach also maximizes the waste mound surface area and area of flatter slopes, and therefore the opportunity for rain water infiltration leading to excessive leachate generation. It is far better to place the highest possible amount of waste on the engineered system to maximize financial returns on that investment and minimise potential environmental impacts from leachate generation.

The second stage atop Phase 2 could provide a total life of some 5 years, and will be 110 m long by 160 m wide. It will be approximately 20 metres above the existing waste level.

Connecting and over-topping Phases 1 and 2 and filling to a height of 30 m will provide enough air space for over eight years in total.

The final landfill footprint will occupy the entire site (Stages 1, 2, 3 and 4 in one mound) and be effectively 500 metres long, 240 metres wide and 40 metres above the existing waste surface level.

Allowing for increasing population over time, as well as increasing per person waste generation rates, the existing site has the capacity to accept waste for over 30 years. Should other major waste diversions be implemented such as refuse derived fuels, composting or major recycling initiatives, the life of the landfill would be further increased proportionately.

The external batters will initially be at one vertical to 2 ½ horizontally which will settle to one vertical to three horizontal over time as the waste decomposes and auto-compacts. Municipal waste is generally stable at approximately a 45° slope or a one vertical to one horizontal batter. However, flatter slopes are provided to allow reasonable site access and to increase the ability of soil to remain on the batter slopes and not be washed or eroded away.

- **Table 15-1 Landfill Staging**

Landfill Stage	Length (m)	Width (m)	Height (m)	Life (yrs)
1	140	120	20	2 - 3
2	160	110	25	5
Total site	500	240	40	30

15.4. Landfill Gas

Other aspects can be incorporated into the landfill design such as landfill gas recovery systems.

Options include passive release, passive collection, gas flaring and productive gas reuse. The recommended scheme will depend upon the quantity of gas likely to be generated. This relates to the mass of waste deposited at the site as well as the organic content. If there is a strong push for composting food waste and diverting green waste into a chipping or mulching system, the quantity of landfill gas generated will be significantly reduced.

Given that the site is already relatively small in international terms, it may be difficult to justify power generation from the relatively small quantity of gas produced. However, there are opportunities for flaring the gas to reduce the greenhouse gas impacts by converting the methane to carbon dioxide. There is also an opportunity to collect the gas and provide it to nearby villages for cooking and heating purposes. The quantity will probably be too small to justify installing gas cleaning and scrubbing systems to make a gas that could be used to power the landfill equipment onsite.

Later stages may be attractive to reuse schemes that just burn the gas to heat brick kilns for example, but not for generating electricity. In summary;

- The controlled landfill is too small to be economic for productive gas reuse such as power generation or scrubbing to make CNG.
- A possible option is progressively installing a gas blanket under the middle third of the final cover cap to collect gas and vent through 6m high passive vents.
- If the methane is later required to be oxidised to reduce greenhouse impact, then a gas flaring system could be installed to convert the methane component to carbon dioxide. These units cost about $350,000 but are not required for at least a decade until the site has sufficient mass to generate enough gas to allow the flare to operate in a stable manner.
- Vertical gas wells can be retrofitted to maximise gas collection only if mandated in the future. The standard design for these vertical wells is to have them at a 50 metre grid pattern spaced over the site. The vents are slotted pipes 150 to 200 millimetres in diameter placed vertically in a 900 millimetre diameter gravel wick, but only extending 2/3 of the depth of the waste. These are usually only installed when there is sufficient waste on site to generate useful quantities of gas for commercial uses, and the earlier acid forming stages of the aerobic and anaerobic breakdown have finished and methane forming bacteria dominate.

Since any one or a combination of all of the above described treatments/controls can be implemented at a later date without detrimental effects, there is no need at this stage to make a final decision on this matter.

Initial comparisons would suggest it will also be too small to attract CDM consideration.

15.5. Surface Water Management

Managing both external and internal stormwater runoff is critical at landfills. Often the uncontaminated stormwater runoff is accidently mixed with the leachate to produce a large volume of very dilute leachate which is hard to manage.

A key element of site drainage will include management of stormwater impounded in the active cells following a significant rain event. While the waste will initially be deposited at the higher end of the cell and worked down slope, there is still a possibility that protracted rain will introduce enough rain water into the cell to allow the impounded water to contact the active waste face.

15.6. Leachate Management

Leachate is one of the biggest environmental issues at a controlled landfill and is traditionally treated and discharged. However, it is proposed to adopt a different approach where leachate generation is minimised and the leachate is either reinjected or irrigated at the site, obviating the need for a leachate treatment plant. The basics of the management strategy are as follows:

- eliminate seepage of leachate from beneath the site by utilising any low permeability soil on site or artificial liner such as GCL under the landfill
- eliminate lateral movement of leachate by grading the base of the site to the central area and intercepting this seepage in leachate interceptor/collector drains.
- reducing the volume of leachate generated by using filling, compaction, shaping and covering procedures which severely inhibit direct rainfall entry.
- reducing the volume of leachate generated by intercepting and by-passing all upstream surface water catchment areas around the fill area in surface drainage channels or bunds for floodwater.
- monitoring the groundwater quality hydrogeologically upslope and downslope of the site.

In this manner it is anticipated that there will be no excess leachate requiring treatment and then disposal to the local water environment.

With the available size of the site and the many years that will be associated with each stage of the development of the final landform, there is ample time available to modify the system if required, and monitoring programs will be sufficient to detect problems on site before they become a potential problem for downstream users.

Managing both external and internal stormwater runoff is critical at landfills. Often the uncontaminated stormwater runoff is allowed to mix with the leachate to produce a large volume of very dilute leachate which is exceedingly difficult to manage.

The best approach is to always ensure that leachate and uncontaminated stormwater remain separate. The drains will continue to run along the outside of the landfill perimeter road and immediately inside the landfill fence. A smaller internal drainage system will be provided on the inside of the landfill perimeter road to collect stormwater runoff from the landfill mound as it develops.

In summary, uncontaminated stormwater will be kept completely separate from the leachate interception and collection system to minimize the volume of contaminated water requiring management at the facility.

Leachate is one of, if not the biggest, environmental issue at a controlled landfill and is traditionally treated and discharged. However, it is proposed to adopt a more contemporary approach where leachate generation is minimised and the leachate is either reinjected or irrigated at the site, obviating the need for a leachate treatment plant. The basics of the management strategy are as follows:

- reducing the volume of leachate generated by using filling, compaction, shaping and covering procedures which severely inhibit direct rainfall entry;
- reducing the volume of leachate generated by intercepting and by-passing all upstream surface water catchment areas around the fill area in surface drainage channels or bunds;
- eliminating seepage of leachate from beneath the site by installing either an artificial liner or a compacted clay liner that can be reworked to provide the usually required permeability of less than 10^{-9} m/s
- eliminating lateral movement of leachate by grading the base of the site to the central area and intercepting this seepage in leachate interceptor/collector drains;
- monitoring the groundwater quality hydro-geologically upslope and downslope of the site.

With the available size of the site and the many years that will be associated with each stage of the development of the final landform, there is ample time available to modify the system if required, and monitoring programs will be sufficient to detect problems on site before they become a potential problem for downstream users.

The average moisture content of municipal waste ranges from about 20 to 45 per cent, with most of the moisture being held in foodstuffs and green waste. Commercial and industrial waste mixed with non-putrescible municipal waste has a moisture content of less than 20 per cent.

There is evidence that local waste streams are wetter because of elevated food waste content but this needs to be confirmed through detailed auditing of the mixed waste stream. In any case, the waste entering the site is unsaturated and therefore has the capacity to absorb moisture before leachate mobilization occurs. This means that by minimizing rainfall infiltration during the wet season that any leachate being collected at the base of the landfill can be reinjected at the top of the mound to allow ongoing absorption.

The degradation of the organic component of the waste mass produces a small quantity of liquid leachate and gaseous by -products. The leachate produced is partially absorbed into the dry waste mass and partially lost as vapour due to the heat of the biodegradation process. Under these conditions virtually no free liquid is produced.

Due to unavoidable direct rainfall entry over operational areas of the landfill, the volume of liquid within the waste mass increases. The direct entry of rain is expressed as a percentage of the rainfall on the site. Well run sites with excellent surface water controls have limited their annual leachate production to less than 5 per cent of annual rainfall. Poorly run sites where even external runoff water from adjoining catchments has not been excluded have an annual leachate production in excess of 100 per cent of annual rainfall.

Once the moisture content of the waste mass approaches 70 per cent or so, the waste becomes saturated and any water excess becomes free to move by gravity. Under these conditions, leachate collects at the base of the landfill or above low permeability soil layers within the waste mass and expresses itself in springs around the toe of the landfill or even up the sides of the perimeter batters.

15.7. Maximising Landfill Capacity

As far as is practicable, the capacity of the site to accept waste should be maximised. The utilisation of all the necessary environmental control measures and other infrastructure such as access roads can then be maximised economically.

The maximising of a site's capacity to accept waste usually involves the provision of relatively steep perimeter batters. Although compacted waste can be safely constructed on very steep batters (1H:1V) because of its inherent strength through a range of internal "reinforcing components" (plaster, timber, wire, metal, branches etc.), it has been found that final batter slopes are best designed at about 3H:1V so that a final soil and vegetative cover can be more easily established and maintained. An initial exterior slope of 2.5H:1V has been adopted which will settle over time to 3H:1V.

The upper level of the mounding is usually restricted to about the level of the surrounding topographic high points.

This upper area of the landform should have a minimum final gradient of 5 per cent to encourage surface water runoff, allowing for some inevitable differential settlement of the waste mass over the long term

15.8. Site equipment

An excavator is used to move waste around the site, clear waste out of drains, load soil to be used as daily cover, intermediate of final cover.

A bulldozer is used for both compaction and profiling activities.

In addition to these items, a body tip truck is required to be able to move soil around the site and assist with any drain clean-ups (litter removal) and other site haulage activities.

A desirable piece of equipment would be a dedicated landfill compactor for sites receiving more than a few hundred tons of waste a day. This will achieve much higher compaction densities than a bulldozer and therefore significantly increase the life of the site.

However, in addition to the benefits of increased site life, higher compaction densities also have other significant additional benefits such as reducing leachate generation, providing a more stable batter slope which then reduces the risk of rain water infiltration through differential settlement areas, reduces the likelihood of vermin infestations and also leachate expressions.

A further controversial benefit of having a landfill compactor, as opposed to larger bulldozers, is the landfill compactor is a specialist piece of plant that can only be used at landfills. There are many cases where large bulldozers purchased for landfill operations have been moved to other activities associated with higher profile benefits such as road improvements and never returned to the landfill for their original purpose.

15.9. Summary

The facilities to be provided for Stage 3A would be as follows:

- A 140m by 120 initial cell (Phase1) of the proposed ultimate four cell system required for the 30 year development, including associated bulk earthworks and liner system;
- Various building upgrades are required including a reception/gatekeepers hut, ablution blocks, meeting rooms, storage room, generator building, etc.;
- Access roads both internal and external to the site necessary to reach the first Stage in all weather conditions
- A new weighbridge;
- Areas to allow processing and stockpiling of recyclables. This will increase in importance over time as the community becomes wealthier and as a result the amount of packaging and therefore recycling opportunities increase;
- Leachate pipe collection systems and pump station;
- Stormwater drainage systems;
- Potable and non-potable water supply;
- Ancillary works such as landscaping, lighting and fencing;
- Operating equipment such as a bulldozer, excavator and tip truck.

16. Management of Specific Waste Types

Management of the waste entering the site will be critical for both environmental and personnel safety.

The presence of medical waste observed during the audit confirmed that management of incoming waste needs improvement and the following details set out a possible approach, to be refined during project implementation.

16.1. Summary of Waste Categories

The waste entering the Site may be categorised as follows, with some examples given;

- Acceptable Wastes (General) – general household and commercial waste;
- Acceptable Wastes (but Difficult) – tyres, mattresses;
- Special Wastes (Sometimes Acceptable) – asbestos, liquid waste;
- Prohibited Wastes – radioactive waste.

The first two categories are always accepted, but the second category requires some special management. The third category may be acceptable based on quantities involved, actual waste characteristics and so on, and is decided on a case by case basis. Prohibited wastes are never allowed into the Site.

It is critical that all loads are inspected when they arrive at the Site gate or any future transfer station in the collection system.

16.2. Acceptable Wastes (General)

The following general wastes will be accepted at the Site;

- domestic solid waste, as collected by city or private vehicles on a regular basis;
- acceptable commercial and industrial waste regularly collected by contractors;
- garden waste (i.e. green waste or yard waste) that may or may not be collected separately to municipal waste;
- inert waste, i.e. construction and demolition debris including concrete, timber, masonry, bricks, etc. These should be stored separately as they can be reused for gas collection blankets, etc.

16.3. Difficult Wastes (but always Acceptable)

Difficult wastes are those wastes that are allowed to be tipped at the Site, but require special treatment to ensure that the best compaction/disposal is achieved. This class does not include hazardous or dangerous wastes. See **Appendix I – Difficult Waste for details**.

- Tyres;
- Mattresses;
- Whitegoods (fridges, freezers or stoves);
- Car bodies;
- Drums.

16.4. Special Wastes (sometimes Acceptable)

These are other wastes that may be accepted on Site, but will have to be decided on a case-by-case basis, and would include some hazardous and dangerous waste. More details will be provided on how to manage these materials during project implementation, such as;

- Asbestos;
- medical waste, including "sharps";
- dead animals;
- pathogenic wastes;
- “dry” sludges, such as treatment plant sludges;
- low level radioactive waste;
- liquid waste, including paints and thinners;
- toxic substances, such as acids and biocides (pesticides and herbicides); and
- contaminated soil.

See **Appendix J – Special Wastes** for details.

16.5. Prohibited Wastes

Items always unacceptable in the Site will include;

- hot loads, greater than 50oC in temperature;
- pressure cylinders e.g. Condemned gas cylinders, fire extinguishers;
- recyclables, except to the recycling area, such as greenwaste, bulk metals or reusable demolition waste;
- large volumes of liquid waste;
- radioactive waste;
- large containers which cannot be crushed; and
- dangerous goods, such as reactive chemicals, explosives including unexploded bombs and so on.

Dangerous goods are those wastes that can affect a person’s health or the environment. Some wastes appear to be safe when delivered to the Site but when tipped can react with the air, water or other wastes to form a dangerous material. Typical dangerous goods include***;***

- Chemical wastes which can react to form dangerous gasses, liquids or solids. Chemical wastes can be either liquid or solid.
- Radioactive wastes. These can come from hospitals, universities, research institutes and private companies.
- Liquid wastes can be dangerous. These include oils, pesticides, solvents, paints, etc.
- Asbestos (can be safe if correctly packaged, but dangerous if dry and powdery).
- Medical waste (may be safe if autoclaved or pre-treated in some other manner, but very dangerous if containing untreated used sharps and syringes).

There are many dangerous goods that can be delivered to a Site, and Site staff must be trained to exercise extreme caution when dealing with these wastes. An Operations Manual will need to be developed prior to operating the new landfill.

16.6. Pathogenic and Medical Waste

This material represents a very small part of the total waste stream, but is particularly dangerous to workers and scavengers. Therefore it needs to be addressed in detail during project implementation.

Local hospitals have incinerators and reportedly have a waste segregation policy in place. The infectious material includes general domestic waste which has come in contact with infectious material such as cleaning equipment, as well as sharps. The simple, but effective segregation procedure should ensure that the most dangerous components, namely the sharps and infectious material, are sent to the incinerator on site rather than mixed with the domestic waste. This reported segregation activity has not been confirmed, but will be reviewed during the next stage of the project implementation.

Incinerators at the hospitals are reportedly not fully functional and the World Bank is attempting to assist the hospitals in upgrading these items. This will be reviewed during project implementation.

Various local small medical facilities, such as medical clinics, have inadequate facilities to correctly handle all their special waste. This has been confirmed by some medical wastes appearing in the waste dump locally.

The main issue of concern is sharps (needles, scalpels). Assuming that incineration is not available, these should be managed by either:

- placing in a puncture proof container, disinfected and co-disposed with waste in a dedicated cell at the Site, or
- destroying by burning in dedicated cardboard boxes fuelled by petrol or in special desk-top electric incinerators, for example. This is usually done at the Site of waste generation.

The key issue is that all medical facilities must segregate their waste at source prior to collection. That will ensure that only small quantities of the dangerous wastes are generated for special handling.

- Red bag for infectious waste,
- Black bag for general waste, and
- Yellow puncture proof containers for sharps
- Sometimes Orange for radioactive waste

The ultimate solution is to require medical waste incinerators at the various institutions. Ash residual could be safely co-disposed with the general waste at the landfill. The general requirements for a mediwaste incinerator are that the temperature should be over 1 200º Celsius and have a residence time of 2 seconds. However, the cost would be prohibitive for small facilities.

Due to local cost constraints, a dedicated disposal area at the Site for pre-treated medical and other special wastes will need to be considered at this stage. An alternative is autoclaving the hospital waste either at source or centrally at the ISWM site.

In summary, infectious waste should be disinfected at the hospital or medical clinic and then deposited in a dedicated location within the landfill cell, along with household and other hazardous waste.

More options will be developed and refined for managing these wastes. The exceptions are the larger hospitals which have their own waste incinerators and adequate segregation procedures in place.

16.7. Household Hazardous Waste

The waste inspections identified only a very small quantity of household hazardous waste in the waste streams, such as used fluorescent tubes. Following the Information and Education Campaign and possible implementation of basic waste segregation, all household hazardous waste should be deposited in a dedicated cell within the landfill.

This dedicated portion of the cell would also be used to accept other appropriate hazardous waste. The cell would usually have an operational life of only six months before it is then covered with clay soil, and an adjacent clay trench constructed within the overall cell.

17. Climate Change Issues

The time scales for climate change and waste management are similar. For instance, landfill sites can be operational for decades and still remain active for decades following their closure. Therefore, there is a need to consider potential changes in waste management over significant timescales and respond appropriately.

According to the study conducted by Thailand-EC Cooperation in 2013, the sea level change in the bays of Bangkok and Mekong delta was 0.5 to 0.6 cm/year, which was much faster than the global sea level rise[1]. The mean daily maximum temperature in Thailand is expected to increase by 1.2 to 1.9 °C by 2050. The number of rainy days and the level of precipitation in Thailand have decreased over the last 50 years. At the same time, scientists expect that precipitation events, while shorter in duration and net amount, will increase in intensity in the form of destructive storms, cyclones, floods and landslides[2].

Northeast Thailand is considered to be one of the driest regions in the country with an average rainfall of 120 cm per year. Most cases of severe droughts occur in the north and northeast regions, which account for over 80% of the country's drought-prone areas[3]. Together with few natural resources, many small holder farms and low soil fertility, it is the most vulnerable region to climate change[4].

The rainfall and temperature can cause critical impact in each stage of ISWM such as waste collection, transportation and final disposal. The summary of impact of climate change across various stages of ISWM is discussed in **Table 17-1.**

[1] http://eeas.europa.eu/delegations/thailand/documents/thailande_eu_coop/geo2tecdi/naeije_en.pdf
[2] https://www.academia.edu/2047244/Climate_Change_and_Thailand_Impact_and_Response
[3] http://unfccc.int/resource/docs/natc/thainc2.pdf
[4] http://oar.icrisat.org/6548/1/Policy%20Brief%2022.pdf

Table 17-1 Climate change impacts on ISWM

ISWM Activity	Climate change variable	Impact
Waste collection	Rainfall decrease	• Increases dust generation and outdoor air pollution.
	Temperature increase	• Increases decomposition rate of solid wastes, resulting in insect infections and bad odour. • Damages collection bins/facility. • Demands frequent waste collection from the collection centres. • Reduces productivity of the collection workers.
	Cyclones	• Increases incidences of windblown litter. • Causes injury to collection workers due to windblown flying objects.
Transport	Rainfall decrease	• Increases dust generation and outdoor air pollution during waste handling and transport.
	Temperature increase	• Increases frequency of waste collection to avoid rapid decomposition at the collection centre. • Increases heat stress to the staff.
	Landslides	• Causes destruction of access roads to waste collection sites and landfill sites. • Causes damages to collection vehicles, office buildings, site infrastructure, etc.
Thermal processing (Waste to Energy)	Rainfall decrease	• Alters feed's moisture composition. • Reduces water availability for the site management.
	Temperature increase	• Increases rate of decomposition of wastes kept in the storage bunkers leading to generation of odour, insect infestation and aerosols. • Alters feed's moisture composition. • Increases possibility of fire accidents. • Reduces productivity of workers.
	Cyclones	• Causes damage to site infrastructure leading to site closure
Final disposal	Rainfall decrease	• Alters the site hydrology. • Reduces water availability for site management. • Increases strength of leachates. • Increases shrinkage of clay linings and capping layers.
	Temperature increase	• Alters the waste decomposition rate. • Reduces productivity of outdoor workers. • Affects site infrastructures due to heat stress. • Increases stress on vegetation in site premises.
	Cyclones	• Damages the site infrastructure such as buildings, offices, etc. due to high wind speed. • Increases probability of dispersion of odour, infections, etc.

The consideration of adaption and mitigation measures at each stage of the ISWM system is an effective way to fight against the climate change impacts. The general climate change-related adaptation measures taken into consideration in planning the ISWM with the final controlled landfill disposal are provided in **Table 17-2**.

Table 17-2 Climate Change Adaptations/ mitigation steps

No.	Project stage	Climate change adaptation/mitigation steps
1	Definition of the project scope	Impacts of climate change variables on ISWM project taken into consideration
2	Assessment of project feasibility	• Climate threats, vulnerabilities, impacts to solid waste collection, transport and disposal facilities assessed • Alternate options and mitigation measures identified
3	Project design	• Waste to energy plant and residue landfill location sited away from floodplains, wetlands or areas with high water tables • Landfill site kept away from the drinking water supply sources • Design standards considered to strengthen the containment walls to accommodate future high winds • Water catchment systems designed that can keep pace with the projected rainfall patterns • Extreme event evacuation plan prepared
4	Construction, operation and maintenance	• Financial and technical resources considered assuming more frequent maintenance and repairs • Plans to prevent the erosion of landfill slopes, covers and roads into and around the landfills prepared • Storm water catchment systems designed to ensure proper function
5	Monitoring and control	• Regular inspection of the water catchment systems and the containment walls, particularly after extreme rains or storm events • Periodic monitoring of waste segregation, storage and feeding equipment and emission levels from waste to energy plants • Regular monitoring of the landfill site for its ground water table and possibility of contamination

Thus, the overall impacts of climate change on the ISWM infrastructure will be assessed and adaptation measures will be considered during the design and implementation phase of the proposed ISWM.

18. Privatisation Opportunities

18.1. Background

Expanding private sector involvement in the collection aspects is traditionally the most promising opportunity. It is critical to consider the length of contracts for privatisation success however. Short contracts of a year or two duration are insufficient to allow the investor enough time to recover Capex exposure. Any privatisation contracts requiring extensive capital injection by the operator must be at least 5 years in duration, but preferably a minimum of 10 years, to allow amortisation of the capital cost, such as providing a new waste compactor collection fleet. Alternatively, the recommended collection fleet to be purchased under the loan could be leased by the city to the private sector operator.

At present, either individuals, NGOs or commercial companies are undertaking recycling activities. So there is little PPP opportunity for traditional recycling, unless at a very large scale such as adopting centralised composting or development of a mechanised material recovery facility.

Regarding the landfill operation, the private sector may not be attracted because of the low potential for innovative technical or management solutions that will make the private sector price cheaper than the City operating cost.

Operation of the controlled landfill is probably not of great private sector interest given the relatively small size and low technology approach recommended for this project, although again this could also be tested in the market place on a non-committal basis. Payment would usually be on a per ton basis, with operational performance style specifications setting out recycling, environmental and operational criteria. In that case, the City would change to becoming a regulator rather than an operator.

Another option for private sector involvement may be a composting or mulching scheme for greenwaste. Whilst a full scale centralised composting scheme for food scraps recovered from comingled waste is unlikely to be recommended for reasons listed elsewhere in this report, a composting scheme could be established in partnership with local agricultural companies. Such a public private partnership would require a private agricultural company agreeing to take and pay for the compost generated. A different ownership model such as a PPP may be appropriate and will be considered in the future when appropriate.

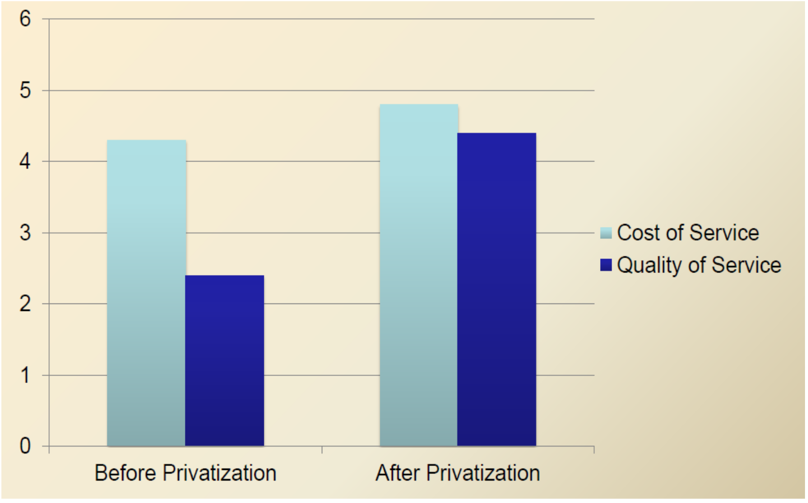
Even more critically than the payment agreement, there will be a need for the private company to agree to avoid any form of litigation against the City if the compost contains foreign objects such as glass, plastic or metal residues or other contaminants. Legal cases against the suppliers of contaminated compost have resulted in many plants closing in Europe and America.

These and other options for private sector involvement, particularly based on performance contracting, will be investigated during this project.

Overall, if the city is interested in seeking greater private sector involvement, it can be sought on a non-commitment basis. This means that the city can seek tenders for one or more components of their waste management services and compare the offers. In any case, it is likely that the collection, recycling, and disposal aspects will be undertaken under different arrangements, contractual or otherwise.

18.2. Value for Money Concept

A key aspect that must be presented to the community is that privatisation does not necessarily lead to lower up-front fees or prices. The key factor is the “Value for Money” assessment wherein the service quality improves but the cost increases, but the cost does not increase as much (to reach the better level of service) if the old cost structure was simply extrapolated. The cost per ton of waste of collected reduces but the overall cost increases for example.



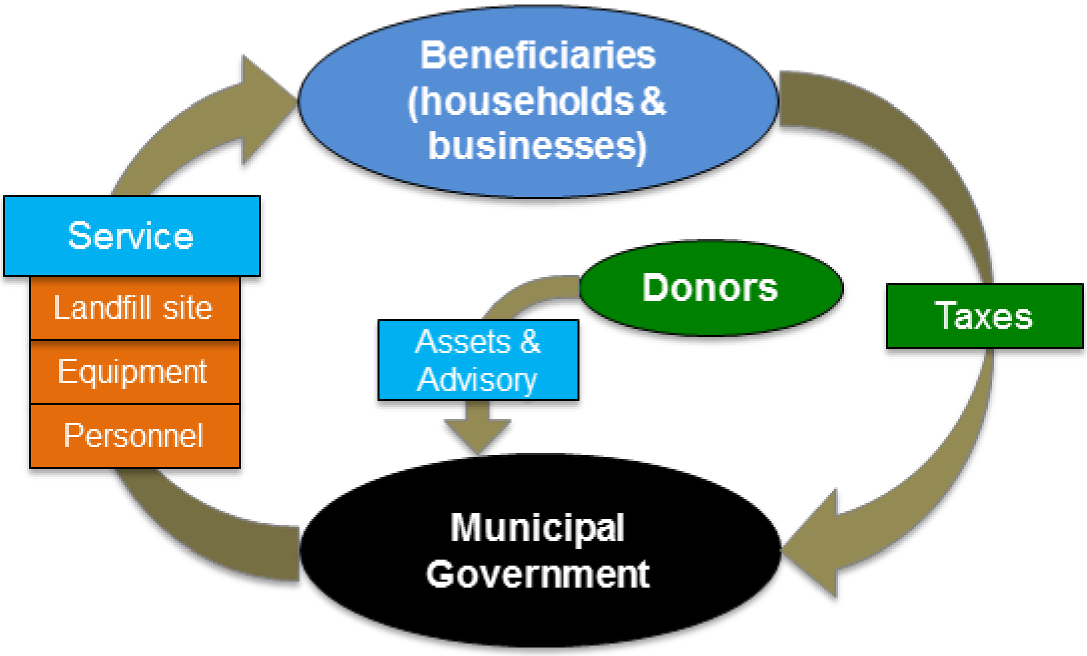
- **Figure 18-1 Quality of Service = Value for Money**

18.3. Modality Options for Privatisation

18.3.1. Background

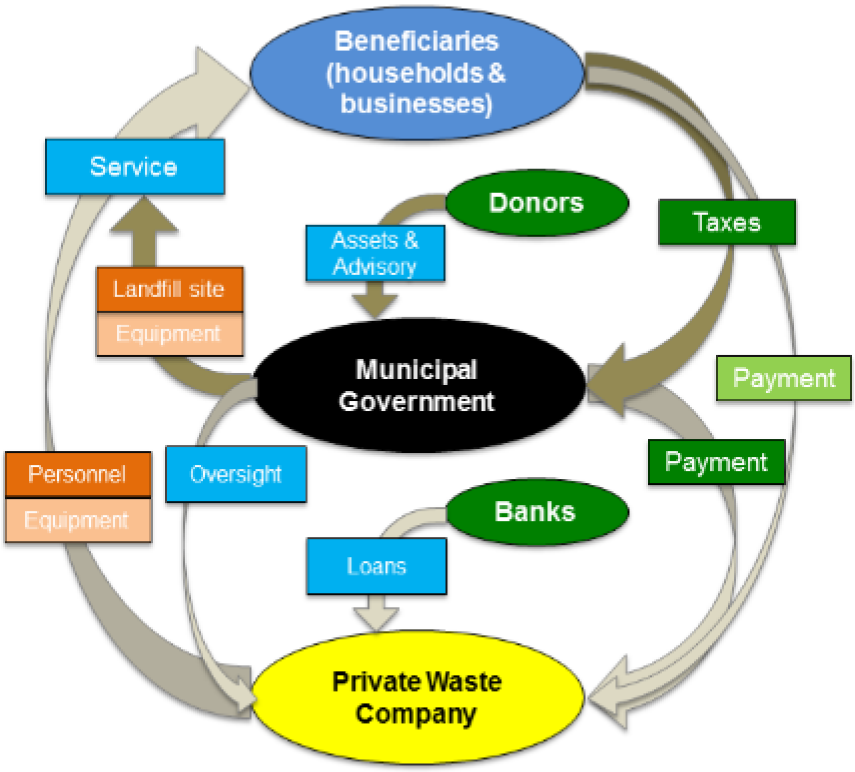
The present public-based structure for ISWM is presented below.

Further details of some options are presented in **Appendix K – Privatisation Options.**



- **Figure 18-2 Municipality-led institutional model for managing an ISWM plan**

There are a large number of options for private sector involvement in Solid Waste Management. These range from very simple short-term service contracts through complete Privatisation and asset sales. The options will vary depending upon numerous factors, such as the ownership of the equipment or the disposal site, such as a possible fleet of collection equipment including expensive compaction vehicles.



▪ **Figure 18-3 Public-private institutional model for managing an ISWM Plan**

Operations and maintenance financing can come from a number of sources: municipal taxes, private fees, and donor/central government funds. Eventually for a program to be sustainable, it needs to be self-funding. A potential scheme could have these components:

- Private collection fees providing funds for primary collection to a community based organization or municipality,
- Municipal taxes providing funds for secondary waste collection, landfill operation and ditch/street cleaning.
- Donors providing funds for capital improvement and equipment.

In order to achieve this state, the municipality must initiate/strengthen the collection of the cleaning tax from the population as part of the municipal budget reconciliation process. Payment of private fees must be encouraged through education, transparency and community communication and participation in the neighbourhood cleaning activities.

18.3.2. Service Contracts

These delegate particular operations and maintenance (O&M) functions to a private operator for a short period of time (one to two years) in return for a specified fee. These could be appropriate for operating a Controlled Landfill or collection services if the scale of the operation is sufficient.

18.3.3. Management Contracts

Service contracts allocate responsibility to a private operator for the full range of O&M decisions, typically for three to five years, or longer. The private operator is paid a fee, which may sometimes be linked to performance. It could be appropriate for operating a landfill if the scale of the operation is sufficient.

18.3.4. Lease Contracts

These are where a private company is granted the right to the revenue stream from the operation in return for full O&M responsibilities. Ownership of the asset remains in the public sector. These are also known as “contracts d’affermage” or service concessions.

The private operator collects revenues directly from the customer, and pays a percentage as a rental fee (or redevance) to cover the administrative and investment costs of the public entity, which exercises residual ownership of the assets. The responsibility of the public entity typically includes regulating the contract and managing the investment program. The leasee does not therefore invest in fixed assets, but does bear the full commercial risk of running the service.

This option would only apply if the City owns the land or collection vehicles, and the government agrees that the fee for service basis will be applied to the community. At present the community does not pay directly for waste management services by the Municipality.

18.3.5. Concession Contracts

These grant a private operator the right to exploit a given service for a fixed period of time (ranging from 5 to 30 years), assuming full commercial risks and responsibility for a specified program of new fixed investments. A formula is set for tariffs to be collected by the operator, to cover the full cost of running the service and capital expenditure.

As with lease contracts, provision is made to renegotiate the tariff formula to reflect changing circumstances throughout the long life of the contract.

These contracts are only appropriate for large landfill operations, a major collection service or perhaps for a very large mechanised MRF (Municipal Waste Facility). This is not the present situation in the city, but may become the case in the future.

18.3.6. Build Operate Transfer (BOT) contracts

BOT contracts give the responsibility to a private operator (or consortium) both to finance and construct an infrastructure facility and to operate and maintain it for a specified period of time. At the end of an agreed period, ownership of the facility is transferred to the government at a symbolic cost.

The private operator retains all the revenue from operating the facility for the period of the contract, to pay for the capital and operating expenditure. This revenue stream typically consists of fees paid by the public sector user and commercial operators.

These contracts are only appropriate for large landfill operations, a major landfill or perhaps for a very large mechanised MRF (Municipal Waste Facility). This is not the present situation in the city, but may become the case in the future.

18.3.7. Private Sale

This involves selling existing public facilities to a private operator, usually by means of an auction. Private sales may involve majority or minority stakes in the state owned enterprise, and certain restrictions on purchasers. The decision whether or not to participate can only be made on a return on investment basis.

Sale is usually only an option for very large facilities. At present, the facilities are too small to be an attractive sale option.

18.4. Summary Table of Options

- **Table 18-1Summay Table of Options for Privatisation Options**

Service Contracts	Management Contracts	Lease	Concession	BOT/BOOT	Divestiture
Promotes competition when contracts are bid. Contracts can be re-tendered every 1-5 years.	Promotes competition when contracts are bid. Contracts can be re-tendered every 3-7 years.	If the lessee is expected to inject capital, the lease term should allow time to earn return. (5 to 30 years)	Takes over management of operations from government, but concession term (15 to 30 years) must allow return on capital.	Takes over management of operations from government, but concession term must allow return on capital. (15 to 30 years)	A fast, but irreversible, option for improving solid waste manage-ment.
If contract fails, risk is relatively low.	Can improve service while retaining public ownership.	Reduced government risk management and investment goes to bulk assets transferred.	Relieves government of need to fund investment.	Full responsibility for operations, capital raising and investment goes to private sector.	Full responsibility for operations, capital raising and investment goes to private sector.
Duration - if problems with contract — can easily re-tender.	Potential first step to concession contract.	Proportion of management responsibility and commercial risk is transferred to lessee.	Full responsibility for operations, capital raising and investment goes to private sector.	Potentially large improvements in operating efficiency of assets.	Potentially large improvements in operating efficiency of utility.
Easy/Simple contractual form.	Potential for setting performance standards (with incentives to achieve standards).	Can increase efficiency of asset management – increases profits	Potentially large improvements in operating efficiency.	Mobilises private finance for new investments. Addresses funding shortfall	Mobilises private finance for new investments.
Potential starting point for private sector participation.	Reduced risks to government and contractor.		Full private sector incentives across utility.	Full private sector incentives across utility.	Full private sector incentives. Addresses funding shortfall.
Can increase utility's focus on core business	Can revert to in-house management or contract, may be re-tendered if problems arise.	Incentives for contractor to minimize costs, provide reliable services and maximize revenue.	Attractive to private financial institutions provided	Attractive to private financial institutions.	Private company would have clear incentives to achieve full cost recovery.
Potential for efficiency gains in the area covered by contract	Potential for utility to bring in competition.	Outcome depends on the terms of lease agreement. Foresight and advisory support needed to negotiate a balanced arrangement.	Contracts are complex. Need parity in negotiating strength to achieve fair outcome.	Contracts are complex. Need parity in negotiating strength to achieve fair outcome.	Could be successful where there is a good track record of private ownership. Needs strong regulatory oversight.

18.5. Suitable Aspects for Privatisation Locally

18.5.1. Waste Segregation and Recovery

Waste segregation is the sole purvey of the waste generator, be it a household, institution or a commercial operation. Therefore there is no role for privatisation in waste segregation, apart from perhaps an educational role in encouraging waste generator compliance or perhaps funding the provision of separate bins for the various waste streams.

Waste recovery is already happening in the Municipality at the household and waste generator level. In the household, recyclables are generally being recovered, particularly items such as aluminium and glass. There is no role for external privatisation of these roles apart from perhaps a private involvement in the necessary education campaigns to encourage segregation and materials recovery at source.

Overall, the possible role for the private sector in this phase of ISWM is opportunistic and not commercial.

18.5.2. Collection

The municipality has advised that it is not interested in Privatisation or even corporatisation of the collection activities.

18.5.3. Recycling/Composting

Traditionally Municipalities only support recycling companies and do not compete with these private entities such as corporations or NGOs.

The Municipality may provide assistance in kind, such as allowing access to vacant land at the landfill for recyclables stockpiles or providing a compactor or chipper. But the aim is always to support the private sector and not compete by establishing their own Municipal schemes.

The main issue will be formulation of a private agreement with a cement Company or other third party to facilitate waste diversion through refuse derived fuels.

18.5.4. Disposal

The landfill is reasonably well operated at present and assistance by the private sector in day to day operation is considered unnecessary at this time.

However a revised approach to profiling, compacting and covering as well as leachate management is required. This could be achieved through a new revised design approach and a short training program including on the job components.

18.6. Adopted Approach

The Municipality has decided that the present level of private sector involvement is appropriate and as such proposes to involve the private sector only in RDF aspects of ISWM.

19. Information, Education and Communication Campaign

19.1. Introduction

The ISWM Plan must address sustainability issues and not just engineering interventions. So an Information, Education and Communication (IEC) Campaign is essential to upskill and educate the community, city and agency staff and civil society on many aspects of ISWM, ranging from health and pollution impacts to waste minimisation and segregation benefits in the future.

To achieve the target of these two plan, Buriram has to promote information, education and communication campaign on integrated solid waste management. Plan of IEC can be categories into three aspects.

- Upstream integrated solid waste management
- Mainstream integrated solid waste management
- Downstream integrated solid waste management

19.2. Upstream integrated solid waste management:

There are several planned projects aimed at raising awareness and reduce waste at source.

19.2.1. Project Zero waste communities:

Three pilot community were selected to promote zero waste communities namely; Wat Isan community, Bulamduantai Community and Bulamduannua community. Zero waste communities is promoted by the central government to raise awareness of community in term of waste recycle and on site utilization. Education through seminar and training are disseminate to household, school, commercial area in the community. Evaluation and competition were done by the central government. These three communities in Buriram were awarded as the pilot zero waste community in 2013.

19.2.2. Waste recycling:

There are many schemes involving solid waste recycle campaigns in Buriram.

Thai people have a strong relationship to Buddha religion including monks and temples. The first scheme is to link recycle waste to the activities in the temple. Recycled waste is collected from households and schools such as plastic bottle, glass etc. and are then respectfully given to the monk where these waste can collected and sold to the recycle shops later on. These activities are popular in several communities in order to both raise awareness and reduce solid waste. The second scheme is solid waste trade. Recycle waste from household were a=carry to school and trade with diary goods or eggs. Usually this activity was done by student at school where they can bring recyclable waste from their home to trade with goods at the school.

19.2.3. Hazardous waste collection

Buribum community has plan to distribute hazardous waste collectors to community. This hazardous waste will be collected by the municipality and sent to relevant agency to be disposed of. Awareness of hazardous waste separation and handling are promoted before the collectors arrive in the certain area.

19.3. Mainstream integrated solid waste:

The main stream plans are to promote waste recycling and better waste collection. Several projects and plans are implemented including ‘clean city tricycle’, ‘waste separation on municipal collector’ and ‘waste separation to increase tricycle collector incomes.’

One of the local waste collector vehicles in Thailand is the tricycle that can move around in the village and small alley where trucks and cars cannot access. The project promotes tricycle for effective collection of recycled waste from households and to facilitate selling – project also include prizes for recycling waste.


- **Table 19-1 Price of recycle waste in three shops in Buriram (Baht/ kilogram)**

Type	Teitamrai Shop	Totong recycle	ChaitaweeBurirum
Plastic bag	-	2	-
Clear plastic	6	5	5
Common plastic	7	7	6
Plastic bottle	15	14	13
Newspaper	5	4	4.2
Black & white paper	6	4	5.5
Other paper	2	1	2

19.4. Downstream integrated solid waste management

This is the plan to reduce amount of waste that goes for final disposal by promoting separation at site.

Buriram has won several awards that indicate the success of integrated solid waste management such as:

1) Win Zero waste community in 2011,2013,2014,2015
2) 6 star level of certification of support and built capacity of Local Administrative in solid waste and hazardous waste management in 2012
3) Certificate in demonstration site of solid waste management 2012
4) Good performance award in management at provincial level
5) Third runner up of the sustainable livelihood municipality in 2010 for middle size municipality
6) Award in 100% no foam for food container

It is critical to engage with the community and civil society to bring about a better understanding of the key waste management issues relating to the environmental and health impacts of poor waste management, waste avoidance, minimisation, reuse, recycling, household composting and the increasing need in the future for waste segregation, especially green waste. In summary, it may involve items such as the following:

- Household, community and school meetings involved;
- Literature and pamphlet content to be developed based on existing sources;
- Organize activities integrated with programs in schools, cultural and other venues;
- Organize thematic seminars noting the current state of the environment so that there are specific activities designed to meet the IEC objectives;
- Training will eventually need to extend to the City residents generally and ISWM staff specifically.

In detail, the IEC will need to address stakeholders and issues such as the following as a minimum:

- The community on waste minimisation, reuse and recycling;
- The community on using food scraps for animal feed or home/commune composting;
- The community on the impacts of illegal dumping and littering;
- City staff, waste pickers, site workers, equipment operators and so on for general controlled landfill recycling and disposal operations;
- The community and city staff on segregating waste as it may be required in the future
- Any waste pickers educated on the risks and hazards of being exposed to waste and need for wearing suitable Personal Protective Equipment (PPE);
- Hospital and medical centre personnel on segregation of medical waste;
- The cost implications of providing a higher service standard for both collection and disposal activities.

There is plenty of ready-made literature, and training materials, that can be used and would be available through the multi-lateral donors and International nongovernment organizations (INGOs). For example, a specific education component would be household waste segregation and household based composting and a pilot scheme could be established in one commune. This will require protracted assistance from training organisations, such as a local NGO. Usually such schemes are run by a local NGO with local contacts and a vested interest in the sustainability of the outcome.

Some possible options are listed in the **Table 19-2** below:

- **Table 19-2 – Typical IEC Components**

Item	Issues	Approach
Environmental Management	Burning garbage causes air pollution and health risks	Explain the environmental damage caused by garbage fires
Environmental Management	Illegal disposal of garbage into creeks, rivers and vacant lots	Explain the environmental damage caused by illegal garbage dumping and littering, and the prosecution liability.
Waste segregation	Essential if mechanised recycling and composting schemes are to be efficient, but costly to have the necessary different receptacles and collection services.	Explain how to do this. Start at Household. level if segregation is desired.
Waste minimization	Purchasing products with the least amount of packaging	Education on benefits of less cost of collection and wasted materials and landfill space consumed
Waste Toxicity	Reduce toxicity of products purchased and segregate hazardous waste for separate collection and disposal	Education on alternatives to certain chemicals, e.g. natural toilet cleaners
Reuse	Reusing containers, such as bottles	Education on benefits as per packaging reduction and other sources
Recycling	Recycling containers, such as plastic bags for garbage containers	Education on benefits as per the above. Also need to market en masse for better prices (e.g. plastics and glass) and also obtain market access e.g. for sale of tin cans
Recycling	Drop off centres for selected items	Consider a centralized system for whitegoods, garden or green waste, hazardous waste, etc
Organic reuse composting	Do it at Household?	Training on methods and equipment required. Market development for local product. Also consider vermiculture? Encourage feeding of domestic animals
Greenwaste	How to manage yard and tree clippings	Chipper needed at the landfill in future. Chipping for mulch for composting is also an option
Privatisation	Community concerns abput cost and reliability/level of service	Community awareness on Value for Money concept, supported by success stories such as Herat.

The benefits will include:

- Compliance with local regulations;
- Community educated about the socio-environmental impacts of poor waste management;
- Community more willing to pay for better service;
- Enhanced recyclable recovery rates. This will be incremental initially and then a major increase when greenwaste and construction and demolition waste are recycled in future years;
- Educated community on waste minimisation and the 3Rs (Reduce, reuse and recycle) including household composting where appropriate.

It has been mentioned in previous studies that the successful implementation of any solid waste management strategy would rely both on an increase in awareness of solid waste management issues and the related firm commitment to resolve waste management issues among the key stakeholders.

These stakeholders include among others, non-government organisations involved in environmental concerns, junk dealers, professional organisations, local government officials (Neighbourhood and municipal/provincial) national government agencies and the industry sector.

Another equally important factor to the strategy is the training aspect for the identified stakeholders on the elements of a solid waste management system and the specific environmental concerns.

19.5. Possible Community Training Elements

The following items should be considered when developing the detailed training and education program on the ISWM program component.

Table 19-3 Typical Training Components –

Item	Issues	Household/Neighbourhood	Municipality/ Province
Environmental Management	Burning garbage causes air pollution and health risks	Explain the environmental damage caused by open garbage fires	Ordinances
Environmental Management	Illegal disposal of garbage into drains, rivers and vacant lots	Explain the environmental damage caused by garbage dumping	Ordinances
Waste segregation	Essential if recycling and composting schemes are to be efficient, but costly to have the necessary different receptacles and collection services.	How to do this. Start at Neighbourhood and Household. Possibly use Neighbourhood eco-aides to collect compostables and recyclables with only one Municipality pick-up service.	Legislation requires segregation
Waste minimisation	Purchasing products with least amount of packaging	Education on benefits of less cost of collection and wasted materials and landfill space consumed	Container Deposits
Waste Toxicity	Reduce toxicity of products purchased	Education on alternatives to certain chemicals, e.g. natural toilet cleaners	Legislation
Reuse	Reusing containers, such as bottles	Education on benefits as per packaging reduction and other sources	Legislation
Recycling	Recycling containers, such as plastic bags for garbage containers	Education on benefits as per the above. Also need to market en-masse for better prices (e.g. plastics and glass) and also obtain market access e.g. for sale of tin cans	National recycling market studies
Recycling	Drop off centres for selected items	Consider a centralised system for whitegoods, garden or green waste, hazardous waste, etc	

Composting	Do it at Household or Neighbourhood levels?	Training on methods and equipment required. Market development for Neighbourhood product. Start at Neighbourhood and then go to Household? Also consider vermiculture?	Establish sustainable markets for compost
Greenwaste	How to manage yard and tree clippings	Chippers at Neighbourhood level as input to composting perhaps. Chipping for mulch not composting is also an option	Can the chipper be funded?

Items required will include the following, but the full list of requirements will have to be developed in consultation with the training and education specialists, as well as the Municipality participants;

- primers (why bother segregating, recycling, etc),
- facts sheets (how to compost and what to look for when operating a compost)
- presentation material for our specialists to "train the trainers" such as NGO's, Neighbourhood officials, etc. to roll out the program to the community
- presentation material for the "trainers" to use at the actual training and education at the future Neighbourhood meetings or household meetings, NGO meetings, etc.

The recommended approach is the "train the trainers" methodology, in which nominated person swill be identified to roll out the full information and education program.

A second element will be introducing educational material into the school curriculum. This is a longer-term issue that will require support at Provincial or National level prior to implementation.

19.5.1. Operator Training

In addition to community training on awareness issues such as recycling and composting, there is a need to train the site operators in how to run a Controlled Landfill. This would usually be undertaken using the Operations Manual SOP and EMP SOP in a mixture of classroom and on-site classes. These SOPs would form the entire package of training materials required for this activity.

19.6. Possible Communications Strategy Elements

19.6.1. Institutional responsibility

The primary entity for a social marketing campaign should be the Municipality Administration as it has a direct link with solid waste management service delivery through the relevant department. Other organisations can play an important supporting role however solid waste is not their mainstream responsibility.

This department would be the information hub for everything to do with solid waste: they must know who the recyclers are, what they are doing, who to contact, not just so they can give advice to the community but so they can connect with recyclers, composters, community groups, and waste organisations to participate in key events.

Given that community awareness needs to take place at times which are suitable for the community, the Department and others implementing awareness activities need transport and other resources to get to the community and need support to work out of normal business hours – typically the weekend and evening.

Based on the analysis of behaviors, institutions and communication channels, the approach for improving waste behavior is through four main methods: television spots, community outreach, schools program, and general demand based awareness.

19.6.2. Mass media awareness through television spots

These would be prime time advertisements to increase sensitivity and change attitudes about socially unacceptable waste behavior such as littering and dumping. These spots will start people thinking about how their behavior is affecting others such as neighours, or people downstream (i.e. actions have consequences) and how rubbish does not go away just because it is thrown away.

A prominent local or National personality would be featured as a way to attract attention and importance. These spots would be a high priority and can be started early in the project. Although they are targeting residents through local media, the spill over into other urban centres and rural areas will not be wasted as the messages will be relevant for those living in other areas or for people who come to the Municipality from outside areas.

19.6.3. Community outreach through contracted NGOs

Depending on the formal recycling proposed, awareness would target residents to increase knowledge and skills in how to separate and sort waste and what waste should be recycled, as well as waste minimisation. An NGO could be contracted for this outreach and to work closely with local leaders. This would include demonstrations, advice and information together with materials such as posters in suco and aldeia offices, stickers, and leaflets explaining any waste separation required and how to do it.

Local offices should have posters on the wall for other issues so they could be a place where solid waste posters, and especially recycling posters or waste minimisation information is available. Local leaders could also have these materials for display (sometimes at their own home). Many of the existing posters are old and it is difficult to know the impact but new instructional posters e.g. how and what to recycle and possibly some motivational posters, should have an impact.

An informational video could also be developed to show how to separate waste – particularly if the separation is complicated. This video could be made available through DVDs and electronic file so it is playable on mobile phones in the suco office or at home.

19.6.4. Schools program

Given that youth are the future adults, they are already involved in rubbish disposal, they can be influenced by information and can carry that knowledge back to their homes, and they are a growing section of the urban population, schools and school children are targeted for a special program.

Children are expected to do some simple critical analysis in both natural sciences and social sciences. The curriculum should be continuous so even Grade 1 children learn about rubbish and this is carried through other grades at different levels.

For primary schools awareness would be through visits, talks, demonstrations, and action games by a contracted NGO, together with materials that support the new school curriculum e.g. posters, stickers, information packs.

For secondary schools, the emphasis would be on school talks and provision of reference material for student research and assignments.

Specific materials should be developed which are appropriate locally.

Additional activities could include school competitions within the urban areas e.g. art competitions which link art with rubbish themes (the artwork is then made into a calendar, providing 12 months of waste messages); sponsorship of a writing or poem competition about waste and the environment to support literacy; song competitions; video competitions (e.g. using a mobile phone camera); fashion event. Publicising of winners through mass media also brings attention to solid waste issues.

19.6.5. General awareness

General community awareness would be provided by the Department on a demand basis and could include talks to businesses and community groups, radio/TV shows and panels, newspaper articles etc. Special events could be added such as organising a show on recycled art; entertainment around World Environment Day (June 6); competitions around International Recycling Day (May 17). The Department could also develop special campaigns as needed such as plastic bag reduction (minimising at point of sale through awareness of both customer and teller, use of green/reusable bags). Where possible the Department should bring in the particular knowledge of specialists such as composters, recycling companies, collection service managers.

19.7. Communications Approach

As frontline staff interacting with the community on a daily basis, waste collectors (both contractors and staff) should also have basic training in waste: how waste breaks down, the collection service, what is recyclable, who is recycling etc. This could be combined with health and safety training.

A short course will need to be developed which should be delivered twice per year and updated accordingly.

Table 19-4 Communication Methods Options

	Behaviour change method	Informative method
Mass media	Television advertisements Short informational videos on key themes	Television interview, panels, news articles Radio talk back, radio panel Newspaper article
Community Outreach - Key informants	Training of community leaders (direct talk, informational video, leaflet, posters)	Other briefings e.g. government (direct talk, PowerPoint, informational video, leaflet)
Community meetings	community meetings (demonstration, informational video, leaflet, posters)	Interest group meetings e.g. businesses; women's groups (PowerPoint, demonstration, informational video, leaflet, poster)
Schools	Primary school talks, demonstrations, games (video, poster, leaflets, guide) Secondary school talks, information pack (video, posters, fact sheets) Teacher training	Competitions School magazine
Other	Training of waste collectors (video, demonstration)	

19.8. Delivery

A professional approach is important for effective communications, and using a local company also provides opportunity for employment and skills development, while at the same time developing content which is relatable to the majority of the target audience.

New materials must be developed and old ones updated to be tailored to the local situation and the use of materials and approaches simply copied from other countries avoided. There is a risk that the messages miss their target and are ineffective unless they are carefully researched and developed.

School materials may be developed by NGOs and specialist education staff or by a communications company. This will require Regional or National inputs.

Change champions and respected leaders can be effective at influencing attitudes and behaviour Leste however there is a need to choose carefully those who model good behaviour, not those that are promoting a certain cause then demonstrate the opposite behaviour. A spokesperson should be chosen not just for their fame but also for their personal commitment to the environment.

Change champions should also be selected closer to the time of implementation and service change, as popular public figures may change. It is critical to have a popular figure, even if that person wishes to charge for their services, to attract people to various events and bring attention to the campaign.

19.9. Coordination

It is critical that the relevant staff coordinate with other agencies involved broadly in solid waste management, and one such opportunity is through a new ISWM Committee and Working Group. This would be a way to coordinate with other departments and ministries.

19.10. Monitoring

How community awareness is carried out has a potential wider implication for further awareness in other Municipalities. Therefore it is important that both the method and impact of the awareness is monitored. A few simple key indicators should be developed which could be used on annual basis to monitor changes in waste behaviour. These could include recycling volumes, littering and problem dumping area observations (photographed annually), surveys on attitudes to waste and disposal behaviour, attendance at public events, recall on littering/dumping/recycling messages.

19.11. Proposed IEC Content and Delivery

The above sections provide an overview of the possible content and delivery approaches,

It is proposed locally to deliver the IEC by:

- Educate and advocate at all level using various means. Easy understanding flyer maybe effective for household. Radio broadcasting, internet connection, mass media are the effective means if contentiously and actively launched with high frequency.
- Initiate incentive scheme for recycle activities particular recycle business.
- Conduct recycle activities at school include learning centre and good practice example.
- Introduce public private partnership to launch the pilot project in awareness raising in the community which can be CSR from the private company.

20. Landfill Upgrade Cost Estimates

20.1. Background

The project identified for the city relates to refuse derived fuels. However to support the implementation of refuse derived fuels, a long term landfill site must be available. Therefore costings have been developed for this landfill upgrade just for city consideration.

Costings were developed to include all works and equipment required as part of the overall project development.

The costing for the landfill site is for what may be considered the overall first stage which includes the full development of Stage 1, as well as the purchase of all required equipment. It also includes the construction ancillary works described above such as access roads, buildings, lighting, leachate control systems and water supply and sanitation facilities.

20.2. First Stage Capital Costs

20.2.1. Landfill Construction Cost

The landfill construction cost consists of four components namely:

- earthworks,
- buildings,
- roads, hard stand, etc and
- site infrastructure.

As mentioned above, the basic cell design has been developed in the absence of detailed geotechnical information for the site.

The unit rates for civil works and buildings were taken from for the local government approved costing rates, or recent contracts where rates were unavailable in the government costing schedules.

Some items have been included as PC unit rates for minor works such as those associated with water supply and sanitation.

20.2.2. Earthworks

The earthworks costs are predominantly associated with preparing the base of the first cell, and also the costs associated with trimming and compaction to ensure a stable base is available within the old waste for the subsequent landfill cell development.

20.2.3. Buildings

The small cost is associated with providing a relocated gatehouse to allow inspections of loads and also recording of vehicle tonnage.

Also a standby generator building is to be provided to ensure constant power availability to pumps for lifting leachate.

20.2.4. Road works

Given the potential life of the site exceeding 20 years, costings have allowed for providing a main access road for a distance of over 300 m to facilitate all weather access for the protracted site life.

The new road is south of the Stage 1 repurposed cell.

This cost could be substantially reduced if only a gravel road was provided instead.

20.2.5. Site infrastructure

Assuming that clay synthetic liner is required (or a HDPE liner), the 300 millimetre protective layer of selected soil would be placed on top of the old waste prior to placing the artificial liner. A further 300 mm thick protective soil layer would be placed on top of the liner to protect it from penetrations and other damage when waste is placed in the new cell. The total cost of this liner installation exceeds 490,000 U.S. dollars. Whilst this is a significant cost, it is9a lot cheaper than removing all waste deposited to date and placing the liner at the base of the previously deposited material.

Relatively minor costs are associated with installing the leachate collection grid which consists of 200 millimetre diameter slotted PVC pipe work within a gravel bed.

A leachate pump station is provided to irrigate the raw leachate on previously worked areas or for dust suppression in dry weather, or reinjected during protracted wet periods into the top of the mound thereby avoiding any direct discharge of leachate from the site.

The other large item is for purchase of a landfill gas flaring system which costs in excess of 350,000 U.S. dollars. For such a relatively small landfill it may be argued that the quantity of methane produced does not justify this cost.

A new weighbridge has also been allowed for as the operators indicate that the present one is becoming unreliable. The new weighbridge would be located within the direct access road to ensure that all trucks vehicles were weighed as they enter the site.

20.2.6. Landfill equipment

A new D7 or equivalent size bulldozer, CAT320 or equivalent excavator, 10 wheel tipping truck and water tank have been allowed for.

Some or all of these may be provided by the central government but the costs are presented here to allow the feasibility study to be prepared.

The landfill equipment prices are based on indicative prices obtained from local suppliers. For the bulldozer and excavator, prices were obtained from Caterpillar which is one of the recognized suppliers of such equipment. Similarly for the truck, prices were obtained from recognised suppliers such as Hino. There are many other suppliers of high quality equipment in these categories which are equally appropriate.

The prices adopted represent high quality equipment which should last for at least 15 to 20 years if properly maintained. Much cheaper equipment is available from many other suppliers but the expected operating life would be substantially less, even with the recommended programmed maintenance.

20.2.7. Site remediation

The costs only allow for remediating stages 2 and 4. These are presently covered with soil but the design is incorrect and will result in excessive leachate formation into the future. Stage 1 will be converted into the new landfill operation will stage three continues to operate as at present during the construction and commissioning of stage 1.

Over 135,000 U.S. dollars has been allowed for bulk excavation work to reprofile the top of the mounds to achieve the desired minimum of 5% fall and compaction to ensure that the initial 5% slope continues to provide sufficient runoff after allowing for differential settlement within the waste mound over time.

The total remediation cost of approximately 350,000 U.S. dollars could be incorporated into the overall site operational budget if stages 2, 3 and 4 were progressively remediated as part of ongoing operations. This would entail diverting fresh waste to the closed stages and compacting the waste as per normal operations to provide the correct profile and shaping. However this will take many years and will result in ongoing leachate problems in the interim. Therefore it has been assumed that the dormant stages will be actively remediated in parallel with the ongoing operation on stage 3.

The intermediate cover cost is only some $120,000 which would provide a 300 mm deep soil cover to remain in place until the landfill footprint extends back over all four stages to achieve the ultimate site development.

- **Table 20-1 2016 Capital Costs**[5]

Item	USD
LANDFILL	**1,621,000**
Earthworks	213,000
Buildings	29,000
Roads, Hardstand and Tree Screen	273,000
Site Infrastructure	1,106,000
LANDFILL EQUIPMENT	**287,000**
INITIAL REMEDIATION	**353,000**
TOTAL	**$2,262,000**

5 Any opinion expressed by AECOM concerning the revenue, capex and opex is based on the generally accepted engineering practice in effect at the time of the assignment and information that has been supplied to AECOM by the Client and others in connection with the assignment. Any indication of cost would be in the form of an 'order of magnitude estimate', which should only be considered as an early indication of cost and in no case be considered as the actual costs. Such opinions are subject to risks and uncertainties that are beyond the control of AECOM. The passage of time may result in changes in technology, economic & market conditions, competitive factors, site variations, new products, company's policy or regulatory provisions which would render the opinions inaccurate. Thus AECOM makes no representations or warranties with respect to such opinion or recommendation and disclaim any responsibility for the accuracy and completeness of any opinion or estimates.

20.3. Operating Costs

The operating costs have been determined based on using actual local rates for the landfill staff. A suitable staffing mix has been proposed including some senior management through to a number of general hands on site to ensure litter collection and other essential activities are carried out onsite.

20.3.1. Salaries

The salary costs per year are approximately 130,000 U.S. dollars. This is for 15 staff plus one part time engineer. Such a team would be able to run the site to the standard required for a controlled landfill and satisfy local operational standards and requirements.

If the operation was outsourced to a private sector provider, then the costs may increase but the standard of operation would improve substantially based on performance criteria and KPIs specified in the contract which would be linked to payment terms.

20.3.2. Equipment

The equipment operating costs are approximately $110,000 per year.

This is based on real world data and not just fuel consumption costs. The operating costs listed include an allowance for regular and programmed maintenance as well as replacement parts as the age of the fleet increases. Obviously the operating cost increases over time as the motors become less efficient and more extensive repairs are required.

The equipment operating costs do not include a sinking fund contribution to allow for replacing the equipment at the end of its useful life.

20.3.3. Cover material

In the initial years of operation, a borrow pit may not be locally available to allow the municipality to access cover material free of charge. Therefore an operational allowance has been made for the purchase and haulage of 4,150 cubic meters of cover material in the first year, costing approximately 50,000 U.S. dollars.

If a borrow pit can be located quickly, then this cost would substantially reduce.

20.3.4. Miscellaneous

These costs include items such as survey and basic running costs such as power, water testing and other basic consumables which totalled approximately 25,000 U.S. dollars a year.

20.3.5. Summary

- **Table 20-2 2016 Operating Costs**[6]

Item	USD/yr
Staff Salaries	132,000
Equipment	107,000
Materials	50,000
Miscellaneous	23,000
TOTAL	**$312,000**

The operating costs are much more than the current OPEX budget. Implementing the upgraded scheme will require community support which will be initiated at least through the information and education campaign, a progressive increase in tariff over a number of years and central or provincial government support in the early years.

20.4. IEC Campaign

The information and education campaign described above would cost approximately USD50, 000 a year.

[6] *Any opinion expressed by AECOM concerning the revenue, capex and opex is based on the generally accepted engineering practice in effect at the time of the assignment and information that has been supplied to AECOM by the Client and others in connection with the assignment. Any indication of cost would be in the form of an 'order of magnitude estimate', which should only be considered as an early indication of cost and in no case be considered as the actual costs. Such opinions are subject to risks and uncertainties that are beyond the control of AECOM. The passage of time may result in changes in technology, economic & market conditions, competitive factors, site variations, new products, company's policy or regulatory provisions which would render the opinions inaccurate. Thus AECOM makes no representations or warranties with respect to such opinion or recommendation and disclaim any responsibility for the accuracy and completeness of any opinion or estimates.*

21. RDF Costings

Cost estimates, both capital and operational, will be developed as part of the pre-feasibility study.

Unlike the landfill costings presented above, costs for a RDF plant are difficult to estimate at this stage because various purchasers of RDF have different specifications and quantity requirements which significantly impact upon the RDF pre-processing required.

Also the decision is yet to be made on how and where the RDF would be processed and by whom. For example, the city could provide some the pre-processing equipment required or just the land at the landfill. Alternatively, the processing equipment could be provided by the purchaser of the RDF, or finally, the third option is a third party would process the municipal waste to produce the refuse derived fuel to then be on sold to a consumer such as a cement factory or purpose built RDF energy plant.

Given the complexity and number of combinations of processing and purchase options, RDF will be assessed in the PFS.

22. Resources and Funding

22.1. Identify Project Costs

The present cost of ISWM for the Municipality is very hard to isolate from within the general accounts of the Municipality.

Attempts have been made to review the general ledgers and obtain available costs from Municipality records, such as;

- transport costs
- composting or recycling costs
- dump operating costs

A typical review of the ISWM costs would have to include items such as the following;

- Fuel
- Direct labour costs, including vacation and leave provisions
- Equipment repairs and maintenance
- Overhead costs, such as senior Municipality staff management and support staff
- External costs, such as non-Municipality staff costs for legal advice, etc.
- Any promotional and education costs, and
- Miscellaneous costs

The above costs are not listed under a specific vote for ISWM within the general ledger, or logged in a manner that allows the above costs associated with the ISWM operations to be identified.

The future costs can only be reliably estimated once the present costs are determined. These can then be used a base for extrapolating the future costs as various waste management programs are instituted, such as the new collection vehicles or landfill is commissioned.

22.2. Internal Funding Opportunities

The preferred overall approach is to institute methods of Municipality charging which are;

- Direct – the people generating the waste actually pay for their waste,
- Enforceable – non-payment means termination of service
- Adequate for future provisioning – sufficient funds to not only operate day-to-day, but also to invest in a sinking fund for future Capex obligations, such as a new landfill dozer or collection vehicles

The Municipality presently charges a tax to cover, inter alia, cleansing costs but this is inadequate for the present operation and will be even more inadequate if an improved collection and disposal service is provided using the same economic model.

Alternative funding streams must be identified or the tax amount increased and the collection efficiency also improved. Alternative models such as outsourcing collection at no cost to the Municipality must be considered. (In developing countries, the collection costs are typically many times that of landfill operation)

22.3. External Funding Opportunities

The municipality has an ongoing need to finance capital projects.There is a number of possible external funding mechanisms available to the Municipality as follows;

- Grants
- Subsidies
- National Funds (include both ordinary grants for capital works and Special project funds, such as demonstration projects possibly)
- Local funds from operating surpluses
- Donations – cash or in-kind, such as land
- Incentives

The absence of resources for investment in solid waste management facilities has been identified as a major constraint to improved solid waste management. This is heightened by the fact that in Thailand, municipal governments do not borrowing power to fund a major projects.

This is related to the objective of providing finance to Municipalities for capital investment in ISWM infrastructure and cost sharing basis with National government accepting its share of the responsibility of upgrading an essential public health service, alongside Municipalities and the private sector. The purpose of the financing program is to assist in the achievement of an improved environmental method of managing municipal solid waste. The financing program will complement the strategy by providing supplementary financial resources necessary to achieve the strategy objectives in a properly coordinated manner within a reasonable time frame.

The most realistic and largest source of funding for solid waste project remains national government funding.The principal purposes of the financing program are:

- to provide Municipality access to the kinds of investment finance required for any large capital works project; and
- to provide viability gap funding for private sector projects that could not be implemented otherwise.

23. Evaluation and Diagnosis

23.1. Background

The monitoring and evaluation of the solid waste management program include detailed recording and assessments of the day-to-day operations. It is important to consider all costs incurred, and what category they fall in to. This is important to assess where resources need to be allocated, or conversely, where program changes might be able to reduce costs.

Secondly, both qualitative and quantitative evaluations of the working of the system need to be made. The assessment of the success of the ISWMP depends upon records of the amount of solid waste collected, frequency of collections of both secondary and primary secondary waste points, cleanliness of the various parts of the systems, and general effectiveness of the program.

Monitoring and Evaluation spreadsheets required would include as a minimum:

- Monthly Landfill Operations: Costs and Evaluation
- Monthly Secondary System: Costs and Evaluation
- Monthly Primary Collection: Costs and Evaluation
- Monthly Primary Storage: Costs and Evaluation

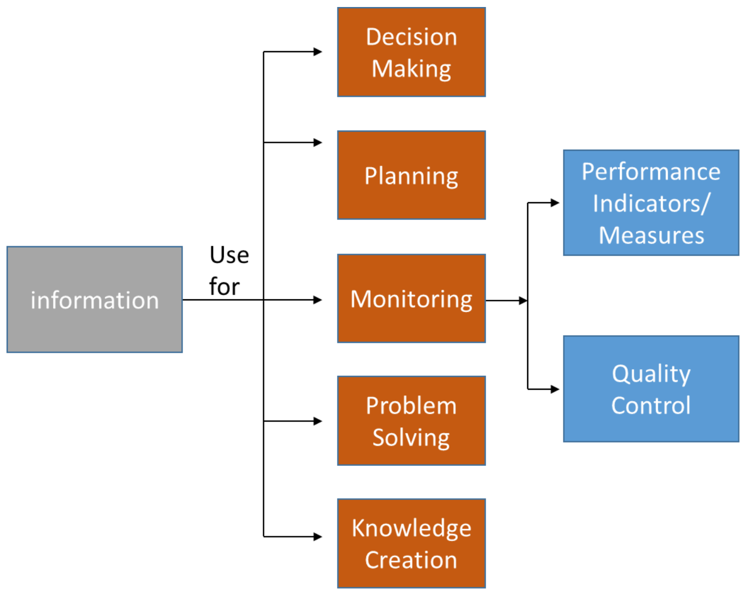
The costs and evaluations information needs to be recorded on a daily basis and turned in to the MSW manager on a weekly basis. The manager should summarize the monthly information and prepare a report to the Mayor on a monthly basis.

More details are provided in Appendix L – Evaluation and Diagnosis

The process of ISWM action plan implementation must be monitored and regularly reviewed in order to identify weaknesses in the program and to identify actions to update the process. The following sections discusses this aspect of plan evaluation using indicators and measures of ISWM performance and with reference to specific worked examples of implementation monitoring.

23.2. Performance Monitoring For Solid Waste Management Services

Throughout this Plan the need for collecting and utilising information has been stressed. Large amounts of data are being collected and processed into useable information. But it has to be kept in mind that information *per se* is only valuable when it is focused and being used to a specific end. The diagram below shows the various possible uses of information.



▪ **Figure 23-1 Use of Information**

23.2.1. Why Improve Performance Monitoring?

The monitoring tools frequently used to assess performance of the ISWM system are, among others,

- visual observations;
- general feed-back from the work force; or
- customer complaints.

Such observations can lead to inaccurate and unquantifiable results and present an insufficient basis for making planning decision for system improvement. Additionally, at first sight seemingly obvious reasons for an unsatisfactory performance of a ISWM function, may, through a more detailed and formal analysis, turn out to not be the reasons at all for the problems.

Monitoring the performance of a municipal ISWM system has a number of goals:

- To closely observe the quality of the ISWM service provided in order to maintain or improve service quality;
- To encourage the efficient use of available resources;
- To relate the outputs of a service to inputs (and ultimately their cost);
- To improve service quality overall and relative to cost;
- To enforce accountability of service providers;
- To put downward pressure on cost of service provision;
- To compare and assess services provided against the targets set out in municipal ISWM plan;
- To provide information on which management can make policy and management decision about the service;

- To compare the service provided between two or more sub-municipalities or municipalities in a regional association;

1) How effective is the ISWM service that is being provided? Meaning: To what extend does the system presently in place satisfy the need for a ISWM service and where is improvement required?

2) How efficient is the ISWM service provided? Meaning: Are we using the available resources in the best possible way and how can we improve their use?

- To compare the quality of service provision in a Municipality with a previous month or year;
- To monitor and evaluate the quality of services provided by private service contractors.

The two central questions of ISWM performance monitoring are:

Effectiveness and efficiency are closely related, increases in efficiency lead in most scenarios to increases in effectiveness, provided resources are not cut simultaneously.

23.2.2. Definitions of Performance Indicators and Measures

In order to determine the performance of a municipal solid waste management system in general, and its individual components in specific, data and information called "performance indicators" and "performance measures" of ISWM are used.

Performance Indicators - are quantitative data related to ISWM services such as:

- Number of businesses to be served,
- Kilometres of streets to collect from, or
- Number of employees in service.

Performance Measures - are the result of processing indicators, by relating them to either time or cost, and are the principle tool for assessing the performance of the system under review. For example:

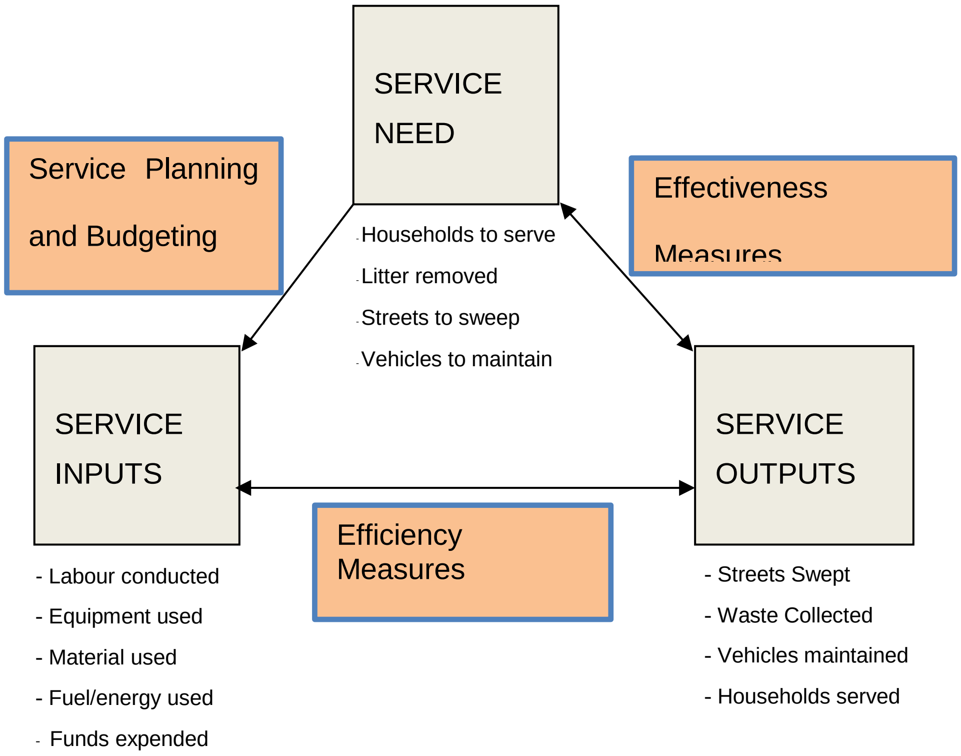
- Cost per ton disposed;
- Number of streets swept per hour etc.

In order to obtain reliable performance measures, the following is needed:

- Accurate, reliable and regular data collection;
- Accurate and reliable cost accounting procedures;
- Weighing of wastes, or estimates based on waste volumes as a substitute;
- Availability of service operating detail;

- Units to which the performance indicators can be related (e.g. costs per 1000 of population served, costs per household served, time per tonne of waste collected etc.)

■ **Figure 23-2 Indicators and Performance Measures**



23.3. Revising and Updating the ISWM Plan

The process of ISWM plan review should be regularly undertaken in a planned and scheduled fashion. A regular review of the progress with implementation of the action program is necessary to ensure that targets are being met in terms of service delivery, financial performance et.

The action plan needs to be flexible and there may be a need for the implementation program to adapt to changing circumstances and conditions, such as, for example, changes in the waste stream (e.g. through increased affluence), development of new technologies to treat and dispose of waste, or institutional changes.

A program of regular review can help to increase the Municipality's knowledge and understanding of the ISWM system through a process of interactive review, problem diagnosis and development of remedial action programs.

23.4. Proposed Evaluation and Diagnosis Program

Based on the above, it is proposed to implement an Evaluation and Diagnosis Program based on the following.

Modified evaluation and diagnosis tables will be developed based on the appendix samples, and simplified as required after selecting only those parameters which are relevant locally.

24. SWM Plan Summary Output

The outputs from the Solid Waste Management planning exercise are summarized as below:

- **Table 24-1 SWM Plan Summary Output**

GOALS	
To develop and implement solid waste management strategies and Pre-Feasibility Studies	
To prepare for the Action Plans	
To deliver PPP contracts to facilitate SWM action	
PURPOSE	**INDICATORS**
A reliable and sustainable solid waste management action in agreeable to municipality	• Deliverable plan of improvement on time. • Well managed systems for collection • Maximise recyclable waste recovery • Well operated landfill site • Quantity of waste in place (increase) • Numbers of participating municipalities (increase) • Numbers of complaints (decrease)
Outputs /results	**Activities**
Feasibility study and action plans are set up	Year 1: Fiscal year budget to include FS of SWM plan.
Recycling and reuse of waste is promoted	Year 1: Overall waste stream is reduced. Recovery centres established as a group, and more detailed investigation of options such as centralised or neighbourhood organics composting initiated
Official document submission to request budget	Year 1 :Process of annual budgeting plan with integrated SWM proposal and action plans
Management and bidding process : formulate bidding committee, Call for bidding, team set up and assign task	Year 1 : PPP process established Award of operation using the competitive bidding system Functional organization established with clear delineation of tasks, roles and responsibilities as well as sufficient operational budget
Stage 1 operate	Year 1- 3: First year rehabilitation of existing disposal facility. Second year and third year operate waste disposal in existing phase 1 landfill.
Stage 2 operate	Year 4-6: Year 4 rehabilitation of existing disposal facility. Year 5-6 operate waste disposal in existing phase 2 landfill.
Over topping stage 1 and 2	Year 7-9: Year 7 rehabilitate merging phase 1 and 2 after 6th year operation finish. Year 8 and 9 waste filling in the new merging area.
Stage 3 operate	Year 10-21: Year 10 rehabilitate phase 3 .Year 11-21 dispose waste in the rehabilitated and prepared area.
Merge all stage	Year 21-31: year 21 rehabilitate merging area of phase 1-4. Year 22-31 filling waste in the prepared area
Revisit WtE	This can be done when the amount of collected and received by Buriram municipality reach the amount that is feasible to invest. A new Feasibility Study will then have to be initiated.

Appendix A - Glossary of Terms

Aerobic process. Biological treatment process that occurs in the presence of oxygen. Certain bacteria that can survive only in the presence of any dissolved oxygen are known as obligate anaerobes.

Anaerobic process. Biological treatment process that occur in the absence of oxygen. Bacteria that can survive only in the absence of any dissolved oxygen are known as obligate anaerobes.

Amenity. The current existence of healthy, pleasant and agreeable (community) surrounding.

Aquifer. A saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

Avoidance/reduction. Reducing the quantity of waste produced and the quantity of resources consumed during the manufacture and life-time of the product.

Batch. Samples taken from one site in one day.

Beneficial use. The environmentally benign and useful application or use of a resource which is of public benefit, including welfare, safety, health and aesthetic enjoyment.

Bioremediation. The remediation or decontamination of any contaminated matter by the use of processes involving biological organisms.

Biosolids. The particulate matter, mainly organic, removed during the treatment of sewage.

Building and demolition waste. Solid and inert waste materials, arising from the demolition, erection, construction, refurbishment and alteration of buildings and construction, repair and alteration of infrastructure including roads, bridges, dams, tunnels, railways and airports.

Buffer distance. The distance between the tipping area of a landfill site and a segment of the environment to be protected.

Cell. A section of a landfill.

Clean excavated natural material. Material consisting of clay, soil and crushed rock which is not contaminated or mixed with any other material.

Clinical waste - (also called Medical waste). Any cytotoxic or contaminated solid waste which includes:

- **Sharps:** Any object capable of inflicting a penetrating injury contaminated with blood and/or body fluids. This includes needles, needle or syringe combinations and any other sharp objects or instruments designed to perform invasive procedures.
- **Bulk body fluids, blood and blood products**: Including any vessel, bag or tubing containing body fluids, blood or blood products.
- **Disposable and dressings linen:** Heavily soiled with blood and/or body fluid.
- **Microbiological and pathological waste:** Including discarded laboratory specimens, cultures and materials that have contact with such, and biological reagents.
- **Tissue:** Human tissue, organs, body parts, placentas and products of autopsy and animal tissue.

Commercial and industrial waste. Solid and inert waste generated by businesses and industries (including shopping centres, restaurants and offices) and institutions (such as schools, hospitals and government offices), excluding building and demolition waste and municipal waste.

Composting. The process of the conversion of organic materials by micro-organisms into soil conditioners, compost or humus. By definition, it is a process which must be carried out under controlled conditions yielding cured products.

Construction waste - see Building and demolition waste

Cover material. Approved material for use to cover dumped waste at landfills.

Decomposition. The breakdown of organic waste material by micro-organisms.

Degradation. An environmentally significant natural, physical, chemical or biological transformation to a lower state.

Demolition waste - see Building and Demolition waste.

DENR. Dept. of Environment and Natural Resources

EMB. Environment Management Bureau

EIS. Environmental Impact Statement.

EMP. Environmental Management Plan

EPWMD. Environment Protection and Waste Management Department

GFI. Government Financial Institution

Greenhouse Gases. Gases, such as methane and carbon dioxide, which in turn contribute to global warming.

Groundwater. Water saturating the voids in soil and rock; water in the zone of saturation in the Earth's crust.

Hazardous Waste. Waste which, through toxicity, carcinogenicity, mutagenicity, flammability, explosivity, chemical reactivity, corrosivity, infectiousness or order biologically damaging properties, which may present danger to the life or health of living organisms when released into the environment, excluding:

- municipal waste (other than chemical waste specially collected); and
- legal discharge to sewer, subject to trade waste or customer contract.

HHW. Household Hazardous Waste

IEE. Initial Environmental Examination

Industrial waste - see Commercial waste

Inert waste. Wastes which do not undergo environmentally significant physical, chemical or biological transformation and have no potentially hazardous content once landfilled. This waste from building and demolition includes bricks, concrete, glass, plastics, metal and timber. They must not be contaminated or mixed with any other material.

Inert waste landfill. Any landfill that accepts only inert wastes (*see* definition above). Inert waste landfills are usually subdivided into two class:

- **Class 1** - all inert waste including stabilised asbestos cement and physically, chemically or biologically fixed, treated or processed waste.
- **Class 2** - all inert waste except stabilised asbestos cement or physically, chemically or biologically fixed, treated or processed waste.

Landfill Environmental Management Plan (LEMP). A detailed plan for the operations of a landfill site from a greenfield state to a fully rehabilitated state including after-care.

Landfill gas. Gaseous emissions from the decomposition of waste. Also called biogas.

Landfill site. A waste facility used for the purposes of disposing of waste to land.

Leachate. Liquid released by, or water that has percolated through, waste and which contains dissolved and/or suspended liquids and/or solids and/or gases.

City. Local Government Unit

Litter. Solid waste that is outside the tipping area of the landfill site and is not part of the formal waste collection system.

Material recovery. A form of resource recovery of wastes otherwise destined for disposal in which the emphasis is on separating and processing waste materials.

Medical waste - see Clinical and related waste and Contaminated waste

Methane (CH_4). An explosive, odourless and colourless gas produced in a landfill by organic waste undergoing anaerobic decomposition. It is lighter than air.

MRF. Materials Recovery Facility

Mulching. The size-reduction of organic materials using one or more of the following processes: cutting, milling, shredding, grinding and other means.

Municipal waste. Solid and inert wastes arising from the three waste sub-streams:

- **Domestic waste** - household solid and inert wastes placed out for kerbside collection
- **Other domestic waste** - residential solid and inert wastes arising from domestic clean-up and garden waste
- **Other City waste –** municipal generated solid and inert wastes arising from street sweepings, litter bins, parks and garden clean-ups, tree loggings and council engineering work.

NSWMC. National Solid Waste Management Commission

Organic waste. One or more of the following types of waste: garden, untreated wood, fibrous, vegetables, fruits, cereals, biosolids, manures, fatty foods, meat, fish and fatty sludges.

PMO. Project Management Office

Poorly stabilised material. A treated material which is prone to further degradation or decomposition.

Public authority. A public or local authority constituted by or under an Act and includes:

- a Waste Board, or
- a department of the public sector, or

- a member of staff or other person who exercises functions on behalf of a public authority , or
- a nationally owned corporation or a subsidiary of such a corporation.

Putrescible waste. Waste being food or animal matter (including dead animals or animal parts), or unstable or untreated biosolids.

Recycling. The process by which waste otherwise destined for disposal is collected, reprocessed or re-manufactured and used to make a product.

Remediation. Work for the remediation, rehabilitation and monitoring of premises the subject of a licence and that is required by the conditions of a licence to be carried out:

- While the premises are being used for the purpose to which the licence relates, or
- after the premises cease being used for the purpose to which the licence relates, or both.

Reprocessing. Physical, chemical and biological processing used to transform waste, otherwise destined for disposal, into a raw material used to make a product.

Resource recovery. The extraction and utilisation of materials from mixed waste. Material recovered can be used in the manufacture of new products. Recovery of value includes energy by utilising components of waste as a fuel, production of compost using solid waste a medium, and reclamation of land.

Re-use. A process by which waste otherwise destined for disposal is cleaned or repaired for use, for the purposes of prolonging the original product lifetime prior to treatment or reprocessing.

Run-off. The portion of precipitation that drains from an area as surface flow.

Run-on. Where surface water runs off one site and flows onto the site in question (i.e. the landfill site).

Sludge. Semi-liquid waste produced as a by-product of an industrial process.

Solid waste. Any non-hazardous, solid, degradable waste. This includes putrescible wastes; garden wastes; uncontaminated biosolids; and clinical and related waste. All solid waste will have an angle of repose of greater than five degree (5^0) and have no free liquids.

Stabilised material. Material not prone to further degradation or decomposition.

Surface water. Surface water includes all natural and constructed waterways or channels whether flow is intermittent or not; all lakes and impoundments (except lined dams associated with landfilling activities); and other marshes, lagoons and swamps.

SWM. Solid Waste Management

SWMB. Solid Waste Management Committee

SWMP. Solid Waste Management Plan

Toxins. Substances which are harmful to humans, animals or plants.

TS. - *Transfer station*. A waste facility used to transfer waste from collection vehicles to a bulk haul vehicle, generally in order to achieve long distance transportation efficiency.

Treatment. Physical, chemical or biological processing of a waste for disposal.

Waste. Waste includes:

- any substance (whether solid, liquid or gaseous) that is discharged, emitted or deposited in the environment in such a volume, constituency or manner as to cause an alteration in the environment, or
- any discarded, rejected, unwanted, surplus or abandoned substance, or
- any otherwise discarded, rejected, unwanted surplus, or abandoned substance intended for sale or for recycling, reprocessing, recovery or purification by a separate operation from that which produced the substance, or
- any substance prescribed by the regulation to be waste for the purposes of this Act.
- A substance is not precluded from being waste merely because it can be reprocessed, re-used or recycled.

Waste facility. Any premises used for the storage, treatment, reprocessing, sorting or disposal of waste.

Water table. The top level of groundwater lenses

Appendix B - Waste Characterisation Audit and Density Determination Procedures

Introduction

Understanding the materials constituting a waste load is essential in developing any waste reduction, reuse and recycling programs, as well as identifying any materials that would require special management during transport, treatment or disposal.

There are many ways to determine the quantity of waste being delivered to a landfill ranging from desktop studies to making estimates of volumes entering a landfill. However all such methods are at best semi-quantitative as a mass estimate is required as opposed to a volume. Landfill management decisions are always based upon mass and not volume. A second component of waste audits is therefore determining waste density. This then allows the actual mass of waste being delivered to the site to be determined. Because most municipalities do not have access to a weighbridge, then these waste density measurements are necessary.

Aims

The aims of the audit are twofold:

- To segregate and weigh a representative quantity of the mixed waste stream to determine the percentage of various waste components, with a view to improving waste recovery and recycling.
- To determine average waste density and therefore weight of waste in the haulage trucks by weighing measured volumes of waste from selected truck loads, thereby allowing the actual mass per day entering the disposal site to be determined.

Approach to Waste Characterisation

In reality, because most vehicles carry a mixture of waste from different sources (households, market, street cleaning/sweeping, institutions, restaurants, commercial area, etc), there is no opportunity for undertaking audits of individual waste stream types and then recombining the individual waste characteristics. Even if the various waste streams could be segregated into different trucks, such an approach of auditing individual waste streams would not provide statistically valid overall waste data as there is no quantitative manner for combining the audit results of the individual waste streams. This would only be possible if a weighbridge was available to determine the relative mass contributions of the various waste stream types and they could be completely segregated. Because there is no weighbridge available and complete source segregation is not possible, the attempted aggregation of the individual waste stream data would therefore result in major errors.

Therefore the approach is to ensure that a fully mixed waste sample is characterised instead. Audits will therefore be undertaken on a well-mixed sample of the combined waste stream based on selecting representative waste collection days.

In addition, because weighbridges are unavailable, the need to determine the mass of waste entering the disposal site by other means is essential. Various methods are available for estimating the waste mass being hauled but these are only indicative in reality. Therefore the density of selected waste loads will be determined and applied to the total waste volume hauled to site. This will provide a good indication of the daily waste mass hauled to site, which is critical in determining many aspects of the collection, 3RS, waste treatment and finally disposal phases.

There will be different waste sampling procedures depending upon the size of the City, but the actual waste characterisation audit and density determination process is the same at all Municipalities.

Procedure Overview

An audit will be undertaken at an agreed site on the mixed waste being delivered to the disposal site. The audit will take place over 3 days as follows:

- On Day One, the actual audit site will be agreed and the overall procedures discussed with lead labourers, Municipal staff and advisors. The volume of waste in every truck entering the disposal site is to be measured while in the truck body and recorded. Selected typical trucks will then be diverted and the volume of waste in the truck re-measured accurately in-situ. Then the entire load of waste will be weighed to determine the density of waste. This would be done by repeatedly filling rubbish bins with the dumped waste and weighing the bins until the full load has been weighed. The density can then be determined for these specific loads. Samples of waste will be collected from every waste truck (the method depends on the size of the City as described below) and carried to the agreed waste characterisation location.

- On Day Two, samples of waste will continue to be collected from every waste truck (the method depends on the size of the City as described below) and carried to the agreed waste characterisation location. The waste pile is then to be mixed by local labourers hired for the audit. The volume of every truck load entering the site continues to be measured and recorded. Density determinations to continue by weighing selected full truckloads of waste. Waste characterisation will be done by taking waste from the mixed pile prepared over the two days and characterised by segregating the mixed waste into the 14 components for individual weighing.

- On Day Three, both the density and waste characterisation determinations to continue. The amount of waste to be characterised should total about 3 tons and also about 6 tons of waste to be measured and weighed for density determinations.

On all days, the volume of waste in **every truck** entering the site must be measured when in the truck body and the waste volume and truck details recorded.

Procedure Details – Waste Characterisation

1. Prior to the audit, determine if the waste stream is the same every day or are some areas of the City only serviced on certain days. For example, is market waste collected every day or only on certain days. Similarly confirm the collection timing for any commercial, institutional or industrial areas. These discussions will be held with Municipal representatives prior to the audit commencing.

2. Decide which collection days are the most representative of the overall waste stream. Note for example that if waste from say the market is only collected one day a week, but household waste is collected daily, then the auditing must not be biased by this difference - only 1/7 of the market waste pile should be included in the audit for example.

3. The Advisors will confirm with the City to decide the best days for the waste diversion and audit to occur

4. The Advisors will also confirm with the Municipal representatives how many trucks come to site each day on average based on as long a period of records as possible. This will be used to determine the volume of waste delivered on an average day, and ultimately the mass of waste disposed per day.

5. If it is small City, then the Small City procedure described below will be followed. Mid-size and Large municipalities have different procedures as noted below.

6. In all cases, place the waste diverted for characterisation in a separate area and do not mix with other waste being delivered to site.

7. Keep all animals and scavengers away from the audit waste pile

8. Place a plastic sheet on a flat section of ground at least 6 metres square for the characterisation audit.

9. Ensure that the waste is fully separated during the characterisation audit process. For example, a bag full of kitchen waste which is mainly food scraps must be opened and the waste separated. Food stuck to paper or plastic must be shaken off and the food and paper or plastic recorded separately. This is critical or else the results will show too large a fraction of organic waste.

10. Completely separate and weigh all waste each time in the characterisation audit pile before adding any more waste from the stockpile. No residual waste should be left before adding more waste for auditing.

11. Often there is an amount of small mixed material remaining on the plastic sheet after characterising a pile of waste. The Labourers should be encouraged to continue hand separating the waste components in the residuals pile until it is very difficult to proceed as the pieces are becoming too small to separate.

    Only then place the material in the sieve so the larger material are retained and can then be hand sorted into the usual 14 components.

    The finer material passing through the sieve then needs to be closely examined and proportions allocated to the relevant components, such as 50% "Soil and Dirt", 30% "Food Waste" and 20% "Garden Waste". These proportions are then applied to the total mass of the fines passing through the sieve and then the various proportioned weights allocated to the appropriate waste type.

    For example if there was 50 kg of fines remaining after sieving, with the proportions as listed in the example in the paragraph above, then 25kg would be allocated to "Soil and Dirt", 15kg to "Food Waste" and 10kg to "Garden Waste".

12. Notes must be kept of any unusual waste such as the presence of medical waste. Do not audit dangerous waste but just record its presence and approximate quantity

13. Note any hazardous waste such as pesticides, solvents or poisons

14. Record the main components of the Miscellaneous Waste category on the data sheet, such as soiled nappies, coconut fibres, etc

To reiterate, it is critical that as much waste as possible is hand sorted and placed into the relevant waste category pile as the highest priority. Only then can the residuals be sieved with the larger retained particles still hand sorted and the fines passing through the sieve weighed and then proportionally allocated to the observed waste categories. The waste types and relative proportions in the sieved fines will vary every time the sieve is used. A finer sieve than that shown in the photograph is preferred at say 10mm aperture.

SOLID WASTE CHARACTERISATION AUDIT SHEET.

City/City_________________________ Date____/_____/____ Sheet _____ of _____

Material	Kilograms	Comments
Paper/cardboard		
Glass (bottles, broken glass)		
Plastic bags		
Other Plastic (Drink bottles and containers)		
Aluminium		
Other Metal		
Food waste		
Green/Garden waste (Leaves, branches, grass, etc)		
Building/Demolition Waste (Tiles, concrete, bricks, etc)		
Timber/Lumber		
Soil and dirt		
Hazardous Waste (Describe in comments)		
Leather and Fabric		
Miscellaneous (Describe in comments)		

Procedure Details – Density and Mass Determinations

1. Prior to the audit commencing, determine the average number of trucks coming to site every day based on the best available Municipal records. The number of trips made by each truck each day must be determined if different sized vehicles are used.

2. Measure the volume of waste in-situ in all trucks entering the site on all three days. Make general observations on the waste type. These data will be used to determine the mass of waste delivered each day. (Do not just measure the external truck body dimensions as each waste load may only fill a fraction of the total capacity of the truck body.)

3. Divert selected trucks (which appear to contain waste typical of the overall waste stream being delivered to site) to a second dumping area, when labour resources allow, where the volume of the full load is accurately remeasured while still in the truck.

4. The entire waste load is then dumped onto a plastic sheet and then weighed bin by bin, noting that it does not need to be segregated. It is just the total weight of the load that has to be determined. (This combination of in-situ volume and mass will then allow the in-situ density to be determined for these representative loads.)

Note: *A team of 12 labourers (plus support from TA supervisors) should be able to weigh at least 6 tons of waste for the density determinations and a further 3 tons of waste as part of the waste characterisation audit in a three day period.*

Equipment Required

1. 3 x Plastic sheets, each at least 5 metres square – to put under audit waste piles

2. 6 X 100 litre plastic rubbish bins or similar – for carrying waste to the scale. No lid needed but good handles or grips are necessary.

3. Electronic weighing platform scales – for weighing waste when placed in plastic rubbish bins. Capacity of at least 100 kg

4. Sieve – about 10mm for separating out the smaller particles and dirt

5. Data recording sheets – to keep the results of weighing and note any issues (Included at the end of this guide)

6. Personal Protective Equipment – gloves, masks, eye protectors and rubber boots for labourers.

7. First aid kit – in case of cuts or abrasions

8. Water – for drinking and washing

9. 5 shovels and metal rakes, and some barrows – for mixing waste piles and/or loading waste for auditing. Borrow from City

10. 12 labourers (minimum). A budget of USD15 per labourer per day has been allowed previously to compensate for the hazardous nature of the work, as well as compensation for travel out of town to the dumpsite and purchasing meals in such remote locations.

Small Municipalities (Hauling Less Than 5 Truckloads A Day)

Waste Characterization

All collection trucks deliver waste to an agreed separate part of the site on the agreed day/s.

Waste being unloaded into a separate dumping area which is kept free from scavengers and animals until audit is finished

Waste piles from the loads being mixed together. Plastic buckets filled waste from one pile are mixed with the waste in other piles. Waste from the edges of various piles are collected and dumped onto the top of the pile. Aim is to make the overall waste pile one homogenous mixture of waste from the separate truck loads. (An excavator or end loader can be used instead if available of course)

Once the total waste pile is well mixed, separate out one quarter (Sector slice) of the overall waste pile for auditing. The quarter must extend from the edges of the pile to the middle of the pile and to very base of the waste pile.

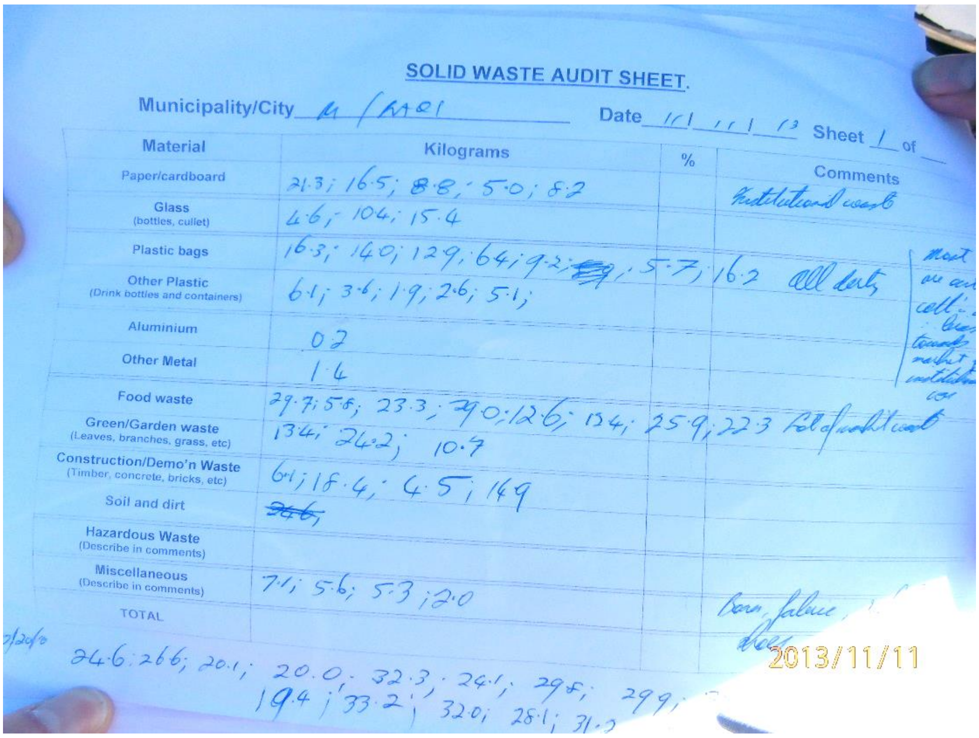
The quartered waste should then be further mixed. Then take waste from the mixed and quartered area (to the right of the pile here) to the audit area as required

Prepare the waste characterization area with signs and plastic sheet

Bring the waste from the preparation area to the audit sheet. Separate the waste into the 14 various components and place near the appropriate sign on the plastic sheet.

Note the plastic sheet under the waste audit pile to prevent contamination and losses. Note use of signs for each waste type. The waste in the audit area must be fully sorted, weighed and removed before any further waste is brought from the quartered pile. Whenever collecting waste from the quartered pile for auditing, take it from a different location with the quartered pile. This reduces sampling bias.

Weigh the various waste components progressively during the audit.



Continuously record the weights for each waste type and make copies of the record sheet in case it is lost or damaged during the day. Taking photos of the record sheet every hour during the audit is strongly recommended.

Waste Density Determination

Inspect and then measure with a tape measure **all** loads entering the disposal site to determine the total waste volume entering the site each day

Select a typical waste load and have the full load dumped after accurate measurement of waste volume in the truck. The waste will then be weighed (but not sorted) to determine waste density

For these density determinations, waste from a full load (the volume of which has been accurately measured in the truck body prior to dumping in a selected area) is being weighed bin by bin. No waste segregation into components is required as only total overall weight of the full truck load is recorded for this activity. The total weight of the truck load is to be determined and then used to calculate the truck waste density.

Midsize Municipalities (Hauling 5 To 20 Truckloads A Day)

Divert every truck to dump in a designated area but keep each individual pile as separate as possible. No scavenging allowed prior to auditing and keep animals away. The plastic sheets may be used to cover the waste piles until ready for auditing

Select two drums of waste randomly from each individual stockpile for taking to the audit area. Only 1 drum if a small load.

Waste from the individual stockpiles is then carried to the characterization audit area. Once the audit pile is fully sorted, weighed and removed, more waste is carried from the individual stockpiles by again taking drums of waste at random from every stockpile to the audit area. (There should be no residual waste in the actual audit area after every pile is audited, to avoid any sample bias, prior to getting more waste from the stockpiles ready to audit.) The 100L drums must be filled from a different part of the individual waste piles at each filling during the audit.

Note plastic sheet under audit pile to prevent contamination and losses. Note use of signs for waste type.

The actual waste characterisation and density determination processes, as well as measuring every truckloads entering the site, is then the same as for the Small Municipality procedures described above. It is only the waste sampling process that is different.

Still measure the volume of every truck entering the site and select a few trucks for weighing their entire load just for density determination.

The aim should still be 3 tons of waste for full audit characterisation and 6 tons of waste for just weighing (no segregation required) for density determinations.

Large Municipalities (Hauling More Than 20 Truckloads A Day)

1. Collect two (2) plastic bin samples for each 3-5 cubic metres of waste in every truckload entering the site on the agreed day/s
2. Stockpile the waste samples
3. If the resulting sample stockpile is approximately equal to the volume that will be characterised by auditing, then just carry the waste to audit area as required during the actual characterisation.
4. If the sample stockpile is too large to audit, then mix and quarter prior to auditing as described for Small Municipalities.
5. Then just follow the actual characterisation audit and density determination procedures for Small Municipalities

Collecting a waste sample from **every** truck load on the agreed audit days

Must ensure that samples are representative. For example part of the large palm frond was included in the sample

Do the sampling from the trucks near where the audit is to be undertaken, to reduce having to carry the selected waste too far from every truck to the audit area.

Appendix C – Waste Audit Comparisons

Results of International Waste Audits

The Sialkot Solid Waste Management Strategy and Action Plan, Punjab, Pakistan (GHK, 2010) includes data on waste characterisation for three levels of household income as below.

- **Waste Composition of Sialkot, Pakistan**

Waste Type	High Income (Percentage)	Medium Income (Percentage)	Low Income (Percentage)
Paper/cardboard	13	11	12
Food/Organic Waste	40	40	35
Plastic	13	12	12
Glass	5	6	7
Rubber/leather	4	3	2
Metals	2	3	4
Wood	4	4	3
Miscellaneous	19	21	24

The tables below indicate the typical waste components in these countries.

- **Waste Composition of Philippine Cities**

Waste Type	Bamban (Percentage)	Magalang (Percentage)	Mabalacat (Percentage)	Angeles (Percentage)
Paper/cardboard	4.7	6.5	4.4	7.8
Food Waste	9.3	13.7	12.0	18.9
Plastic	16.9	15.3	17.2	17.4
Glass	1.4	2.6	2.4	1.8
Rubber/leather	0.6	1.4	2.0	0.9
Metals	3.1	2.9	1.9	2.1
Textile	0.6	3.2	1.2	3.4
Wood	0.1	1.0	1.9	0.9
Green Waste	54.4	41.7	52.2	40.3
Hazardous Waste	0.0	0.0	0.0	0.0
Miscellaneous	8.9	11.7	4.8	6.6

- **Waste Composition of Vietnam Cities**

Waste Type	Hanoi (Percentage)	Haiphong (Percentage)	Hue (Percentage)	Danang (Percentage)	Bac Ninh (Percentage)
Organics	60.7	57.5	77.1	68.4	56.9
Papers	5.3	5.4	1.9	5.0	3.7
Fabrics	1.7	5.1	2.8	1.5	1.0
Wood	6.6	3.7	0.5	2.7	-
Plastics	8.3	11.8	12.4	11.6	9.6
Rubber& Leather	0.2	1.9	0.2	0.2	0.2
Metals	0.2	0.2	0.4	1.4	-
Glass	5.0	1.3	0.3	0.1	0.5
Ceramics	1.2	0.4	0.7	0.7	-
Soil, sand	5.4	2.9	1.7	6.7	27.8
Ash	2.3	6.0	-	0.00	-
Hazardous	0.8	0.05	-	0.02	0.07
Sludge	1.6	2.7	1.4	1.3	-
Other	0.05	1.1	-	0.03	-
Total	100	100	100	100	100

Appendix D - Source Reduction Policy Options

Source reduction or waste minimisation is a necessary component of a waste management strategy. The benefits of waste minimisation include pollution prevention, reduced need for waste treatment and disposal facilities, and cost savings. The following sections review the major strategies employed to encourage waste minimisation, and are in compliance with the legal framework discussed in the previous chapter.

A primary step in determining the levels of source reduction strategies that can be implemented by generators is to get information on their current waste generation status and disposal practices. The Municipal Solid Waste Management Committee can pass an ordinance that will require high-volume generators, to provide this information for consolidation. This will determine the need for training and/or appropriate technology to promote in order to facilitate source reduction.

The following are examples of policy statements to facilitate source reduction of waste at household level, and are to be incorporated into waste management education and awareness campaigns:

Avoid Non-Recyclables

> Policy 1: Any item or product, which cannot be reused or recycled efficiently, must be avoided or not promoted.

A product, which cannot be ecologically processed or disposed of, becomes a burden to the environment and to the local government. As long as the technology or process to appropriately dispose of these products is not accessible or feasible, then the marketing and promotion of such products should be discouraged. Without infringing on the policies of free trade, the City should make it clear to the public that these items, even if they are cheap, are wasting taxpayers' money.

Items like cellophane, composite materials like doy packs and polystyrene can be actually reused or recycled but the technology may not be economically viable at this time.

"One-time-use" products like disposable razors, utensils, plates, cups, toothbrush, wipes, etc. must be avoided, whenever possible, but obviously higher concerns, such as the potential impact on health, must be considered in deciding the use of these items.

Use Re-Useable Products

> Policy 2: Products that are packaged for longer use, as in litres, must be given preference over sachets or small packs. Products that are refillable must be given preference over those that are singly packed.

These preferences are related to the impact that these types of packaging have on the ecological manner of their disposal. The practice of packaging in sachets and smaller containers may mean better marketing results, but at greater cost to proper disposal. Using refillable containers may be better if the refills are also packaged in recyclable containers. More often than not, the refills are packed in composite materials, which are in themselves not recyclable.

Various programs can be implemented in order to facilitate source reduction for industries and commercial establishments as well.

The Preventive Principle.

> Policy 3: All industries must adopt the "preventive principle" of clean processing and production whereby the majority, if not all, of the components of the production process are recyclable or compostable.

It is cheaper and more effective to prevent environmental damage than to attempt to manage or "cure" it. Prevention requires examining the entire product life cycle, from raw material extraction to ultimate disposal. It encourages the exploration of safer alternatives and the development of cleaner products and technologies.

For example, prevention requires changes in processes and products – designing non-toxic products from materials that can be safely recycled and composted – in order to avoid the generation of waste that needs to be landfilled.

The Democratic Principle

> Policy 4: The public must be given access to information and be involved in the deliberations for the approval of industries to be permitted to operate within the City, through the Municipal Solid Waste Management Committee.

Clean production involves all those affected by industrial activities, including workers, consumers, and communities. Access to information and involvement in decision-making, coupled with power and resources, will help to ensure democratic control. Clean production can only be implemented with the full involvement of workers and consumers within the product chain.

The Holistic Principle

> Policy 5: Decision on environmental resource use and consumption should not give way to new problems. An holistic approach should be used.

Society must adopt an integrated approach to environmental resource use and consumption. We need to think in terms of systems. For each product we buy, we need to have access to information about the materials, energy, and people involved in making it. Access to this information would help build alliances for sustainable production and consumption. We must also take a holistic approach so that we do not create new problems while addressing old one or shift the risk from one sector to another.

Adoption of Eco-technology

> Policy 6: Adoption of "Eco-technology" whenever possible to reduce the use of non-recyclables.

Ecotechnology is the concept of embedding technologies or manufacturing tin the natural cycles of the ecosphere, with its capacity to produce renewable materials. Ecotechnologies are biodegradable and may use a range of biological process in a holistic and non-invasive way, with the aid of efficient engineering.

Shifting Management Costs

Policy 7: The responsibility for disposal of used products should be shared with the producer.

Extended Producer Responsibility can be a way to shift waste management costs from the public sector to the private sector. Today, responsibility for the disposal of used products rests ultimately on local government and the general taxpayer, not on the producer. As solid waste burdens have increased and more stringent disposal regulations have made waste management more expensive, the budgets of local governments have been stretched thin, and local taxes have increased. The sitting of solid waste facilities has become a major issue. Local government have been saddled with the responsibility for a problem that is not of their own making and which they can do little to prevent.

Legislation

Policy 8: Legislate ordinances to apply “Extended Producer Responsibility”, like buy back mechanisms and avoidance of packaging waste.

Even since the Ordinance on Avoidance of Packaging Waste was enacted in Germany in 1991, product take-back and related forms of EPR have spread across industrialised countries, industry sectors, product categories, and waste streams. Although some of the applications of EPR may be new, the idea is not. After all, deposit refund systems on refillable glass bottled are some of the earliest forms of EPR.

The range of products and waste streams targeted under these emerging EPR policies includes packaging, paper goods, consumer electronics, office machinery, cars, tires, furniture, electric appliances, buildings and construction materials, mercury, batteries and household hazardous wastes.

In industrialised countries, product take-back programs have been enacted for the following product categories: packaging, batteries (particularly small consumer batteries), electric and electronic products, and end-of-life vehicles.

Appendix E – Waste Minimisation for Special Wastes

Tyres

The minimisation of tyres going for final disposal can be reduced by greater use of retreading, and reuse of tyres, but little else, as they are fundamental requirement in society.

The management of waste tyres has been highlighted as a major environmental problem over the last decades. When disposed of in landfills, tyres tend to 'float' up to the surface of the fill causing significant landfill closure problems. The adoption of shredding internationally as a prerequisite for landfill disposal of tyres has necessitated an increase in tyre disposal costs, creating an alternative market for disposal in tyre dumps. These dumps frequently catch fire, causing significant environmental damage. The creation of tyre dumps usually occurs in response to increased disposal charges at landfills, which have been raised in line with problems of dealing with tyres in landfill systems.

Clearly, there is a need to regulate discarded tyres as a prescribed waste and direct tyre disposal to either recyclable uses or at least require tyre shredding prior to landfill disposal. Those regulations must also prohibit the creation of tyre stockpiles for some undefined opportunity, without at least the provision of significant fire control systems.

A number of re-use and recycling technologies have been developed and implemented or proposed for waste tyres. Almost exclusively though, they require a significant gate charge to cover costs.

Potential recycling applications for tyres include:

- Incineration for energy recovery. A plant is currently being proposed for Perth and two operate in Manila.
- Chip rubber as a compost bulking agent, or use as a permeable layer for leachate or landfill gas collection.
- Sports field improvements (crumb rubber), which improves turf quality and uses about 12 000 tyres per football field.
- Road pavement: rubber modified asphaltic concrete uses about 10 000 tyres per kilometre of 10 m wide pavement.
- Road sub-base: whole and sliced tyre road mat system can be used similarly to geotextile membranes for stabilising poor ground.
- Finely milled rubber can be incorporated into a wide range of rubber or composite products.
- At a lower technology scale, old tyres are converted into sandals in Afghanistan.

- Alternatively they can be given back to households, stacked on edge to form a cylindrical container some 1.3 metres high, and used as an above-ground compost facility.

The discussion above illustrates that a number of solutions can be identified for the waste tyre problem, most of them offering commercial development opportunities. But these will only be viable if;

- tyres become a regulated waste, and (subsequently)
- co-operation between landfill operators and the commercial sector ensures landfills do not become a cheap legal dumping alternative.

Contaminated Soil

In general, landfills can accept any resulting low level contaminated soil if they;

- are clay lined or have an impervious base and walls
- have a leachate collection system and a leachate-monitoring program
- have a groundwater surveillance program.

Low level contaminated soil can generally be used as daily cover, provided that the contaminated soil is not used on any external batters. There is generally no need to mix the contaminated soil with general waste for co-disposal.

Acceptance criteria are available in international publications.

Asbestos

In most countries, asbestos is deemed a prescribed waste. As such it can only be disposed of at landfills according to the relevant national Standard or Act. These landfills should have designated areas marked by grid and depth references. The date and location of disposal is recorded for each load of asbestos.

Therefore there is no real opportunity for reducing the quantity disposed of without incurring a community health risk.

Food Processing Waste

The reduction of food processing waste is usually only successful where there is some financial benefit to the processor, and is therefore very much site specific.

Due to the putrescible nature of the waste, immediately transporting to the Landfill and then covering with other waste will reduce fly and rodent intrusion and odour problems.

Medical Wastes

Biomedical wastes include infectious substances and pharmaceutical substances. The onus is on the waste producer to ensure that wastes are segregated, packaged, labelled, stored, transported and disposed of in accordance with government regulations. Proper segregation of waste at the point of generation (using the internationally recommended colour coding and identification system) will substantially reduce the amount of waste that requires incineration or other approved treatment.

The categories of biomedical waste include;

- infectious substances

- pharmaceutical substances
- laboratory chemical waste

Infectious substances include all waste which is known to be, or could potentially be contaminated with pathogenic micro-organisms (e.g. bacteria, viruses, parasites) and which presents a recognised infectious hazard to personnel handling it, to waste disposal workers and to the environment if appropriate precautions are not used.

Similarly, medications, sharps packages, containers and equipment are often included in their description of pharmaceutical wastes. Cytotoxic chemicals are the most hazardous of pharmaceutical wastes and are substances used in chemotherapy, capable of impairing, injuring or killing cells.

There is no real way to minimise these wastes, apart from careful segregation to reduce cross-contamination of less hazardous waste.

Wood and Agricultural Wastes

Wood wastes, which are too large to shred, should be placed in a designated area prior to pit burning or disposal into the landfill face. This allows scavenging of the stockpiled material in an effort to reduce the quantity to be further treated, burnt or landfilled. Open burning on the landfill should be prohibited as this could cause the landfill to catch fire. Landfill fires can burn continuously for many years causing smoke, heat and explosions.

In the event of a fire in the landfill the affected areas must be excavated and smouldering material saturated with water to ensure the fire has been stopped prior to reburial.

Hazardous Wastes

The study area does not currently have a formal management plan for hazardous wastes. This should be remedied by auditing premises using or generating hazardous waste.

Industrial Waste Minimisation

At present there is no industrial waste in the City. However this may change and the following guideline may then be appropriate.

At the commercial and industrial level of waste production, which typically accounts for some 30% of all waste going to a landfill, the practice of waste minimisation can be assessed on a cost-benefit basis as well as on the basis of an environmental ethic for industry.

Industrial waste minimisation policy has traditionally been targeted at hazardous industrial waste streams. However, the principle can be extended to more than hazardous wastes, including such wastes as poultry processing residues and food processing effluent.

The most important prerequisite for an effective industrial waste minimisation policy is active enforcement of air and water pollution control and hazardous waste management regulations. Even without specific regulations requiring waste minimisation and utilisation of low waste technologies, increased charges for waste disposal and limitations on certain unacceptable disposal practices will provide some incentives for waste minimisation.

Planning controls could be considered for new industry, which make waste minimisation a development consent condition for new industry, or for expansion of existing industries. This would require a waste minimisation audit on the proposed process.

Appendix F – Minimising Plastic Bags and PET Drink Bottles

Plastic bags

Recycling

Plastic bags are only recycled in a few countries where:

- labour costs are very low
- plastic bags are not dirty with organic waste such as food scraps
- there are large quantities of such bags available, and
- where there is recycling facility very close by to overcome the high transport costs for such low density material.

Plastic bags which have not been cleaned can be sold internationally for USD0.07/kg whereas cleaned plastic bags attract a price of USD0.25/kg. Raw polyethylene pellets cost over USD 1.30/kg.

The option of recycling plastic bags, and in particular cleaning soiled bags, must be considered in the whole of life environmental context.

A somewhat similar scheme operates in Manila on laminated plastic and foil juice containers where these are recovered from the landfill and washed prior to being sewn into handbags and other carry bags.

Superficially the scheme is highly successful and has attracted international recycling markets and achieves a very high sale premium. However the washing processing is causing significant local water pollution as obviously the soiled containers are highly contaminated with organics.

So if a similar scheme to wash an ever higher percentage of the total mixed waste stream is proposed locally, then a recirculation system will have to be installed for the plastic bag wash-water with only the bleed off being directed into the leachate management system.

At this stage, recycling plastic bags will first require a waste segregation scheme where clean bags are kept separate from the dirty bags and other contaminants such as food waste. Alternatively the dirty bags need to be scraped and then washed. This will result in significant pollution and makes the whole-of-life considerations for recycling dirty plastic bags unattractive at this stage.

Locally there is very little opportunity for recycling plastic bags apart from burning as a fuel source or bringing in shredding equipment and moulds to make plastic items such as plastic seats. However given that most plastic bags are soiled in terms of either inorganic soil or organic material attachment, the overall environmental cost associated with having to clean and dry these bags, not to mention the higher transport content, would make such a scheme generally unattractive at the present time.

Burning plastic bags

In some countries plastic bags are burnt as a fuel source.

There are many technical papers investigating the health aspects of burning plastics and the general conclusion is that burning any plastic containing Chlorine atoms is dangerous. Burning these plastics, such as PVC (Poly-Vinyl Chloride)) can lead to the formation of carcinogenic compounds such as dioxins.

However almost all thin “grocery” bags are made from High Density Poly Ethylene (HDPE) or Low Density Poly Ethylene (LDPE) which do not produce toxic gases when burnt at normal temperatures. Therefore use of these bags as fuel is a valid recycling/reuse activity provide that the community is educated to only burn bags and not other plastics which may contain chlorine compounds, such as PVC.

Plastic bag ban

Some cities have taken the step of simply banning the use of plastic bags. An example would be cities with in Metro Manila. This ban applies to both the large supermarket outlets and also smaller corner stores where all purchases have to be placed within paper bags or cartons. This plastics ban has also been extended as far as drinking straws which have to be waxed paper rather than more traditional plastics straws.

This is not been universally supported and there is significant consumer resentment because in the often raining environment with in Manila, the paper bags become wet and grocery items can fall through the weakened wet bags.

This aggressive approach has been taken by the City already.

Plastic bag tax

As mentioned in the chapter above, some countries introduced a charge for the supplying of supermarket plastic bags. In Fiji for example, approximately 2¢ for each shopping bag was previously being charged at supermarkets to discourage people from taking excessive numbers of plastic bags and as a corollary, encouraging people to provide their own reusable fabric bags.

Such a scheme has recently been introduced into the European Union. However to make implementation more streamlined, only those supermarket chains employing more than 250 persons have to charge the tax. Therefore, a similar approach would be just that the larger supermarkets are required to pay the tax as opposed to the markets and the small stores.

Bio/Degradable bags

There a number of degradable plastic bags now available, generally termed:

- Degradable – where the matrix biodegrades leaving numerous small pieces of plastic
- Biodegradable (Oxodegradable) – special additives in the plastic allow the plastic to fully biodegrade over a specified period (Costs 7c to 10cents/bag approximately)
- Compostable – made of organic material such as corn-starch and are not really plastic as such and fully biodegrade (Costs about 21c/bag)

A normal grocery non-degradable bag costs about 3c/bag – range of 2 to 5 cents.

Degradable plastic bags break down primarily through the action of a chemical additive to oxygen, light or heat. The first generation involved just the degradation of the matrix holding the plastic molecules together such that the plastic bag merely broke down into a large number of very small pieces of plastic which then would take many decades to biodegrade. For plastics, degradability refers to change in chemical structure and loss in mechanical properties caused by a specific environment, resulting in the plastic breaking down into small fragments. Such bags are not really environmentally beneficial.

The second generation of biodegradable plastics are also known as 'oxodegradable' bags. These benefit from having chemical additives that can ensure that the entire bag breaks down over a specified time period into the base compounds (Carbon dioxide etc) and not just intermediate resins.

In the first stage, TDPA® accelerates the plastic degradation process by several orders of magnitude, whereby the long polymer molecules are reduced to shorter and shorter lengths and undergo oxidation (oxygen groups attach themselves to the polymer molecules). This process is triggered by heat (elevated temperatures found in landfills or composting), UV light (a component of sunlight) and mechanical stress (e.g. wind or compaction in a landfill). Oxidation causes the molecules to become hydrophilic (water- attracting) and small enough to be ingestible by micro-organisms, setting the stage for biodegradation to begin.

In the second stage, biodegradation occurs in the presence of moisture and micro-organisms typically found in the environment. The plastic material is completely broken down into the residual products of the biodegradation process. As micro-organisms consume the degraded plastic, carbon dioxide, water, and biomass are produced and returned to nature by way of the biocycle.

This time period can be set to vary from weeks up to a number of years as required by the purchaser. In the Pacific Island and many other nations, this has been the preferred approach and the consumer tax for purchasing non-biodegradable bags has been abandoned. The central government in Fiji for example has mandated that all plastic bags must be of the degradable type and this applies not only to shopping bags but also storage bags such as for hot bread, etc.

Compostable plastic bags are often made from farmed products like corn-starch, which, in the right conditions, will break down into elements like carbon dioxide, water and methane. These bags are generally best suited to composting and may contribute to methane emissions if sent to landfill. To meet international standards, bags need to compost within 12 weeks and fully biodegrade within 6 months. These bags are not suited to recycling and are only appropriate for large cities where the bag turnover is very high. However if the bags are stored for protracted periods due to slow sales or distribution issues, the bags will start to biodegrade prior to use. Therefore it is considered that the fully compostable “plastic” bags are inappropriate at this time

Summary

Therefore the recommended approach for plastic bag management is to legislate that all plastic bags have to be biodegradable using the second generation chemistry wherein the bags break down entirely into their prime elements, and not a multitude of small plastic remnants. This approach would also be supplemented through the information and education campaign which would encourage use of reusable fabric bags and the general minimisation the use of plastic bags, even though they would be degradable.

If this is not possible or practical, then a small tax will be applied at the point of sale to encourage people to reuse fabric bags instead of using plastic bags. In parallel, the public could be advised to use the plastic bags as fuel. This has the added benefit of reducing tree felling

Regardless of the option adopted, the community should be educated to minimise the use of plastic bags and encouraged to use reusable (multi-use) fabric bags wherever possible.

PET Bottles

Background

As noted above, these bottles only represent a small percentage of the total waste mass entering the dumpsite. However a large proportion of the bottles are not collected and represent a major component of the local litter concerns, especially given their propensity to be washed into local drain systems and ultimately be washed into the local rivers.

There are a number of options for waste minimisation/source reduction of these containers including taxes, charging policies, container deposit legislation and ultimately, extended producer responsibility.

Charging policies

These are alternatively termed pay as you throw schemes, meaning that any material sent for disposal attracts a specific charge. The idea is that a price signal is then sent to the waste generator to encourage waste Minimisation. However such schemes will only work within an institutional and enforcement environment where illegal dumping or littering is policed.

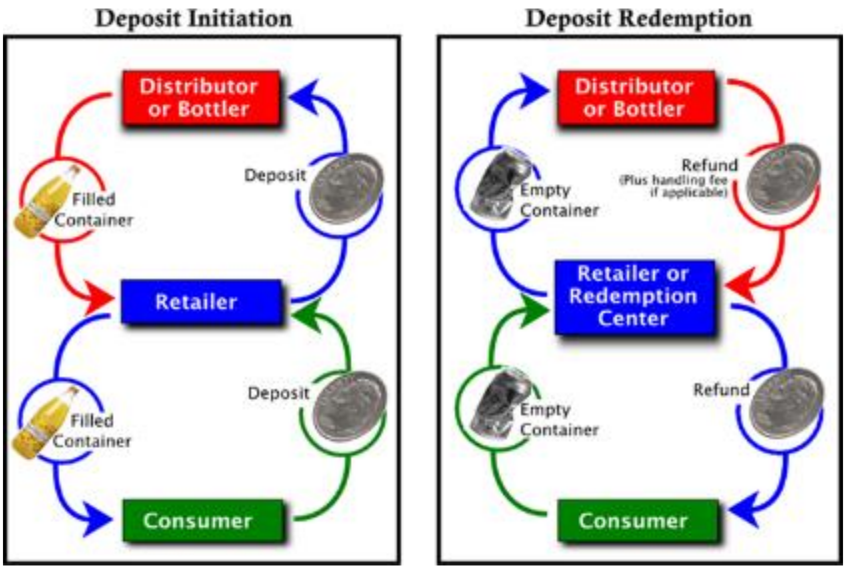
Therefore the basic charging policy should only be applied within a regime of close institutional control but is considered inappropriate at this time.

Container deposit legislation

It was first started in Germany over 35 years ago.

It works when a deposit is charged at the point-of-sale for the container. Traditionally this is mainly been for glass bottles to ensure their recovery and reuse and to a lesser extent aluminium cans. Given the very high recycle rates associated with aluminium globally, there is little merit in applying a container deposit to such a high value recyclable.

When the containers return to the shop, the deposit is then refunded to the person returning the item. This works well in larger shops where there is sufficient storage space to keep the containers awaiting collection by the beverage manufacturer. However for smaller shops, storage space will be at a premium and is particularly the case for small shops that have essentially no spare space for storage.



The other issue is that unless specific legislation is introduced to the contrary, any shop is obliged to refund deposits on an unlimited number of bottles. Some states within the USA have prescribed limits on the number of bottles that can be returned any one time or in fact the hours during which refunds will be paid out. There is no requirement to return the bottles to the same store from which the bottles were purchased for the refund.

The shopkeeper then claims back the deposit from the beverage manufacturer upon collection of the stockpiled containers.

Such a system works in an environment where the beverage manufacturers want the containers returned. However it would be far cheaper for the bottled water manufacturers to simply use new PET bottles rather than having to freight them back from the City to their manufacturing hubs.

To make the return of used PET bottles more financially viable, the bottles would either have to be pressed and baled or shredded prior to exporting. This negates the overall ideal of reusing the original container and morphs more into a recycling program rather than a reuse program which is the usual are aim of container deposit legislation. Furthermore traditionally the container deposit legislation was more focused on durable goods such as glass bottles.

Specialised chippers and granulators are available to reduce the volume required and therefore increase the attraction of recycling plastics, both bottles and bags.

There is always a percentage of unclaimed deposits that are usually retained just as profit by the various beverage companies. In some countries, such as the USA and parts of the European Union, the central government takes an active role in the management of the container deposit funds and actually retains the unclaimed deposits as part of government revenue. This is another level of complexity that is considered inappropriate at present.

There are real concerns with this approach because:

- Small shops will need to provide large secure storage areas.
- The storage areas must be secure as the bottles can be stolen and resubmitted for deposit funds again, or the bottles can be set on fire as they are highly flammable.
- There is no real incentive for the beverage manufacturer to pick up the returned bottles as they would be more expensive to collect, ship and return to their manufacturing bases internationally than simply using new bottles within the international bottling facilities. This is particularly the case with the current slump in oil prices where reprocessed plastic has become far more expensive than virgin plastic leading to the closure a number of very large plastics recycling companies in Europe.
- Therefore there is a real risk of large stockpiles will be generated without any market forces dictating that they would be reused or recycled.

In summary, container deposit legislation for PET bottles may achieve good collection but not necessarily facilitate a sustainable recycling protocol at the current PET prices and export costs.

Extended producer responsibility

This is the next possible step after container deposit legislation which makes the manufacturer of products responsible for the material's entire life cycle. This means the manufacturers are responsible for the take-back, recycling and final reuse for disposal of the products manufactured.

This responsibility is normally applied for larger items and lately particularly for materials such as eWaste internationally.

If extended producer responsibility was applied to these bottles, a very significant cost impact could be expected in the product sale price to the consumer.

Overall it is considered an inappropriate mechanism at this time for PET bottles.

PET tax

Another option is to apply a tax to either the PET bottles or the pellets used for bottle making. A notional charge equivalent to say a few cents a bottle could be applied.

The tax would work in the following manner:

- Government collects the tax on either PET bottles or virgin pellets from the manufacturers;
- The private sector or NGOs could then offer to pay a reasonable amount for used PET bottles for recycling. Such an amount would need to make it attractive for people to collect bottles for sale, especially those from the lower Socio-Economic groups;
- The bottles would then be cleaned, sorted and chipped and perhaps baled to maximize the quantity that could be transported efficiently;
- Once the recycling company has processed the material, the company would present their manifest to the government and receive payment for each ton of PET recycled.

There are approximately 18,000 two (2) litre PET water bottles per tonne making $360 a tonne tax revenue at a notional USD2¢ a bottle. Assuming 75% tax processing efficiency within the government, this translates to approximately $270 a tonne available to support PET recycling. This would be more than sufficient to make the recycling economically feasible even for remote parts of the Municipality.

Such a tax needs to be considered in terms of whether it is progressive or regressive, and whether it has significant impacts on the less advantaged communities. In fact such a tax would be pro-poor too as usually only about 50% of low to middle income earners buy bottled water. It is generally the middle to upper income bands that purchase bottled water. So the tax would not impact upon the less advantaged communities in terms of access to water.

However the significant increase in recycling would be beneficial to the disadvantaged community groups who would most likely become more involved in bottle collection and sale.

Implementing the scheme will obviously require government support and appropriate legislation.

Overall the purpose of the tax is to make the recycling scheme financially viable for such light material as PET. At the present time, it is only slightly better than marginal. Payment of the collected tax money back to the recyclers would greatly encourage both collection and recycling of this material, leading to a significant reduction in the amount of PET litter and general material waste at present.

Also if haulage costs still remain a constraint, the City could consider providing a small chipper to reduce the volume of the plastic and make transport more economical.

This tax will require the drafting and approval of National legislation.

Appendix G – Larger Scale Composting

Neighbourhood Schemes

The Social Action Centre of Tarlac (SACOT) operates a composting scheme in Dapdap, Philippines.

The scheme uses a hammermill and four motorised compost drums from Happy Soil. Raw product is essentially dry cow manure, mixed with additives such as odour suppressants, Happy Soil enzymes, coco-dust, burnt rice hulls and a small amount of composted municipal solid waste to act as a drying agent in the mix. Each drum is operated for 5 to 7 days, and produces 300 to 500 kg of compost or 12 to 15 bags.

The compost is sold for P150 (US$4) /sack to farmers operating organically-grown rice fields, endorsed and sponsored by SACOT.

The facility tried composting municipal solid waste previously, but the fertiliser content (NPK) was too low for rice agriculture, without needing artificial fertiliser supplements. This caused the permanent changeover to cow manure as the primary input, which provides compost with higher NPK content that is more suitable as a fertiliser replacement than composted solid waste.

The NGO may be suitable as a vehicle for energising the public in terms of solid waste management issues generally. However, the NGO is more focused on assisting farmers with their natural farming methods, rather than solid waste management.

Other issues to be addressed include;

- Vector control: There are existing non-pesticide fly catchers that can be used (i.e. trap-a-fly technology, where flies are attracted by natural means to a trap)
- Odour Control: There are many local deodorisers available that can be utilised by the facility. However, deodorisers are not necessary if the carbon-nitrogen ratio in the compost is maintained, such that no methane is produced beyond tolerable levels. Regular turning and aeration of compost heaps will reduce foul odour. (The composting process will definitely emit a specific earthy odour.)
- Dust control: When compost facility is set-up in windy area, a way of enclosing the area, such as roofing and boundaries, is necessary to control litter and dust.

Another operating compost scheme near the old Smoky Mountain dumpsite has a 1000kg/day capacity, and treats only hand-selected kitchen waste. It is mixed with equal parts of sawdust, plus some thermophilic aerobic bacteria. These bacteria are added every 2 weeks or so and cost P10/kg. The bacteria are added to equal about 10% of the daily

throughput of compost. The compost is sold for P3/kg, about 5 cents a kilogram. Because it is partially funded by University research funds, and the equipment costs are not being annualised, the economics of the system cannot be determined.

It had not operated for many weeks prior to inspection.

The Sun Valley composting system has been developed over a number of years to the present system of basic composting. The previous use of mechanised equipment especially motorised composters has now declined because of the costs involved. The present scheme theoretically operates as follows;

- Waste segregation is mandatory into wet and dry waste.
- Wet waste is collected daily by eco-aides from the households. It is mixed with coco dust in the field to assist in drying the waste.
- The impoverished areas do not enjoy a door-to-door collection service for wet waste, because they cannot afford to pay for this. These households deposit their waste into a centralised bin that contains coco dust to limit wetness and the associated odour. The central bins are then collected weekly.
- The bio-waste is then mixed in an old concrete mixer, and blended with chipped greenwaste to provide the carbon rich material and drier material to provide the correct carbon to nitrogen ratio and the optimum moisture content.
- The waste is then placed in open weave bags for 2 to 3 weeks.
- It is then sieved and milled, and re-bagged for another 1 to 2 weeks for maturation prior to marketing.

- The compost is not selling that well, apart from some small scale purchases by locals and some visitors. The application of this compost on purpose-built vegetable gardens has also reduced recently. In essence, it is not operating.
-

Centralised Schemes

Battambang, Cambodia. This small plant accepts only selected wet market waste which is hand sorted twice prior to composting. It is no longer hammer-milled prior to composting because of glass injuries. Hammer-mill not used as injuries from glass shattering kept occurring, even after 2 lots of hand sorting on selected market waste. This confirms the great difficulty in keeping compost feed pure, even when starting with selected and having two lots of hand sorting. The facility only survives because of ongoing equipment updates and daily operating funds provided by a local NGO. It is far from self-funding.

Baguio in the Philippines only runs their plant intermittently and has some old compost on display for demonstration but no new compost is being produced regularly.

Another example of the centralised composting scheme in San Fernando, Northern Luzon, Philippines. It reportedly sells compost at about P3 per kilogram, to the value of P12,000 per month, with production costs estimated at P34,000. The production costs include all labour costs. The scheme is located near to lahar affected areas which would be a prime candidate for using compost on lahar affected soil. Sales are questionable as during three separate visits to the site, the plant was never working and there were no piles of partially aged compost to see, only some very aged product which seemed very dry and possible many month sold.

Aceh, Indonesia has a central plant wh9ich reportedly keeps blocking with coconut husks. It appears to only run very intermittently, mainly for demonstrations. One operator confirmed that the plant is only run intermittently when visitors arrive. Compost is just used for planting a few demonstration seedlings as there is no market for selling outside.

Figure 7 Application of unutilized compost as regular cover in Gampong Jawa Landfill, Banda Aceh, Indonesia.

The large Ha Tinh facility in Viet Nam is designed for 200t/d and is highly mechanised with bag breakers, elevating belts, primary trommel, hammer mill, aerator, secondary trommel, motorised screens and then finally bagging. It has never operated sustainably and also is just started for demonstration. Note the impurities in compost after trommels.

Photo shows the second trommel and screening system after composting

The Lahore compost scheme is 1,000 t/d scheme and is as a result of a PPP with a local farmer who takes all the compost.

Compost quality is potentially poor and unsafe (glass, sharps) at times

Private component is a local farmer who accepts poor compost quality and unconcerned about worker safety issues

Risks

One issue to be considered is the risk management required. For example, Municipalities have been sued for damages due to poor compost causing crop damage due to excessive microbial activity, or personal injury from sharps accidentally included in the compost product in some countries. Even if the compost is given away, there is an inferred warranty that the material is fit for purpose.

Waste must be fully segregated at source to make this option sustainable as centralised waste segregation of mixed waste is unreliable and costly. This means that centralised schemes are possible only for long term consideration locally, not for immediate introduction.

The main risk is not having a sustainable market for the compost, especially where the net costs for the compost operation exceed returns which is usually the case.

If there was a larger fraction of greenwaste that could be separated out at source, then that may be viable to compost as it is many other countries, provided that there is a sustainable market and that there is a supplementary source of Nitrogen such as dried sewage sludge (biosolids) from a sewage treatment plant.

Appendix H - Background to Waste Containers, Segregation and Collection Systems

Introduction

The chapters on waste minimisation, reduction and recycling provide an overview of contemporary schemes worldwide. Some are more aligned with developed countries but are presented as an aspirational guide to the long term options.

This is critical so any medium to long term approaches preferred by the Municipalities are not restricted or prevented by the decisions taken for the short term approaches.

Present Waste Receptacles

Door to door collection involves a mix of hard bins and plastic bags, depending on the location and community wealth.

For community based schemes, some people use plastic bags or other flexible containers such as woven bags, and others just throw the waste unpackaged into the formal or informal primary dumping locations or fly dump their waste onto the nearest local vacant land, drain or river.

Relationship between Receptacles and Waste Segregation Approach

To decide what containers are required, waste segregation and collection must be addressed in parallel.

If waste is required to be sustainably segregated, there must be some downstream benefit realised and supported by the community. Segregation takes time and costs money for the householder, as additional bags or bins are required. Many schemes have subsequently failed because the community does not see any benefit in waste segregation, such as a result of witnessing:

- the segregated waste just being remixed in the haulage truck or at the landfill
- no decrease in their waste management charges/taxes although this may be expected as a result of waste being recovered because of their segregation efforts
- no environmental improvement with demonstrably less litter or uncollected waste apparent in the community
-

A common starting point for waste segregation is having one colour for wet biodegradables (essentially kitchen waste plus any dirt-free greenwaste) and one for all dry matter including all recyclables and other non-biodegradables.

Usually waste is segregated differentiating biodegradable from non-biodegradable waste to allow mechanised sorting of the recyclables centrally. Based on the waste audits, the high value recyclables are already being adequately recovered and could benefit just from some fine tuning. Therefore the amount of high-value recyclables entering the local waste stream for final disposal is minimal, and would not justify a highly mechanised MRF and therefore traditional biodegradable/non-biodegradable segregation.

However the separation of organics to facilitate animal feeding and composting at a communal or central installation supports this segregation option. Therefore this will require the use of two bins and a commitment to undertake composting at one or more of the institutional levels such as a householder, local commune/neighbourhood or a centralised scheme based at the landfill. The schemes could be located on other municipal land or on private land if a local farmer commits to productively using the compost produced.

The only waste streams of significant mass are the dirt/soil and the organics (green waste and food scraps).

Therefore the appropriate segregation option initially may be to adopt a two-bag approach to segregation of the organics (clean greenwaste and putrescibles) from other waste, and include waste segregation training into the IEC. The greenwaste is only small branches, roots plus leaves suitable for direct composting, and does not generally contain branches large enough to warrant chipping and then composting or direct reuse as erosion or dust protection.

Also the local greenwaste can come from sweepings and contain dirt. This percentage of dirt cannot be composted as the dirt will limit oxygen transfer into the compost windrows severely limiting the aerobic composting process. If there is sufficient dirt, then the compost process will become anaerobic which is much slower and odorous. Given that the dirt is often comingled with the greenwaste during the collection (sweeping) process, the greenwaste/dirt mix would require separation either at the household/street sweeper level or centrally. It is extremely unlikely that householders will be willing, on a sustained basis, to screen their greenwaste using a mesh sieve to separate the dirt from the organics. However householders with suitable large compounds could, as an alternative, simply bury the greenwaste /dirt mixture or place it around plants.

This allows greenwaste to eventually be chipped and reused at the landfill site and this is likely to be appropriate for many years as the City has extensive parklands and gardens and residents have house compounds with extensive greenery.

The ultimate ISWM approach must consider what the waste stream will look like after household wealth increases over time. Ultimately with additional parks and gardens there will be significant quantities of greenwaste that will not be used for fuel. This greenwaste and construction and demolition waste could be separately chipped/crushed and reused as landfill access road cover in wet weather, erosion protection on external mound batters. Alternatively the greenwaste can be used as a compost feed if some future composting scheme is adopted, such as with animal manure or biological sludges from treatment plants.

Waste Containers

Waste containers need to be selected to satisfy segregation needs as well as sensibly integrate with the proposed collection system, either community bins or door to door based.

If waste is to be segregated, there must be some downstream benefit realised and recognised by the community. Segregation usually involves having one container for wet biodegradables (essentially kitchen waste) and one for dry matter including all non-biodegradables. Usually waste is segregated differentiating biodegradable from non-biodegradable waste to allow mechanised sorting of the recyclables centrally. No mechanised sorting such as a Materials Recovery Facility (MRF) is being proposed at this time.

Developed countries have up to 5 separate containers, but three is more common for recyclables, green waste and residuals (both organic and inorganic).

Depending upon any move towards composting, the more traditional waste segregation of organics and non-putrescibles may be more appropriate.

If it is eventually proposed to segregate organics (food scraps and possibly clean greenwaste) from comingled inorganics, the appropriate approach would be to initially continue with using bags with different colours or coloured ties if being collected door to door or just dump segregated waste in the appropriate bins of a community collection scheme still applied.

One additional perspective for this option to reduce plastic bag content in the final waste is to use reusable woven plastic bags for carrying the waste to the appropriate primary dumping location.

The next step would be to have householders use hard plastic or metal bins so that the waste is deposited at the primary dumping location and the bins reused. This will require consideration of methods to manage vermin and flies such as:

- having informal primary dumping locations phased out to avoid putrescible waste simply being dumped in open areas
- moving towards enclosed bins (not the open sided concrete bins) to limit vermin and animal access
- ultimately having skip or hook-lift bins at all primary dumping locations

The next evolution would be to then eventually require hard bins (plastic or metal) to be collected from the household door to door where practicable. Generally door to door collection is only offered for houses along readily accessible streets. The more difficult to access areas often have a community based collection service using hand carts or barrows to bring the individual householders' waste to a primary dumping location, preferably a skip or hook-lift bin. Door to door collection is usually roughly twice the operating cost of community systems.

Daily house to house collection is resource intensive and therefore expensive, and should not be the initial aim of the Municipalities. If waste is to be segregated for commune-based or centralized composting, then a separate collection run will be required for the organics in a different container.

If considered beneficial and sustainable, waste segregation will be encouraged through the IEC campaign. One possibility being for children to establish resource centres at schools recycling household primary recyclables to aid in school project funding, for the households that presently do not segregate and recycle.

Enforcement

If waste segregation is to be adopted, use of the correct containers needs to be enforced in parallel with an overall anti-littering and illegal dumping campaign. It is common in other countries for the waste collectors not to collect waste unless it is in the prescribed bin. Whilst this seems appropriate, care must be taken to ensure that this does not result in uncontrolled littering as a result of non-collection.

Alternatively the waste which is wrongly binned is still collected and the householder fined.

Adopting either of these options will need to be supported by an anti-littering campaign. Such campaigns in developing countries need to be implemented in parallel with an information and education campaign on the environmental and social impact of uncontrolled littering. There also needs to be a punitive component where a small fine can be issued by City or agency officials for repeated littering offences.

These improvements are best considered as long term issues at this stage of community development.

Collection Fleet Options

The existing fleets are barely adequate to collect waste and dispose of it within the City precinct at the secondary disposal locations.

There will be a general aim in the future, particularly as community wealth increases over time, to increase mechanisation in the collection system by way of garbage compaction trucks and skip or hooklift bins. The options are presented in decreasing order of collection and haulage efficiency and reducing capital cost for system establishment.

Waste Compactor Trucks

Ultimately two sizes of compactor trucks would be required. The larger trucks will be appropriate for the larger roads within the City. The method of operation will involve the driver proceeding slowly down the street with staff walking to each house to collect their rubbish (if door to door collection is eventually adopted) and place it directly in the compaction trough at the rear of the vehicle.

The compactors can also be fitted with arms to lift pushcarts or small skip bins into the rear trough, if those systems are proposed for primary dumping locations in some areas of the City rather than door to door collection.

The compactor truck will continue collection in this manner until the vehicle is full when it will proceed directly to the landfill for emptying.

This means that the compaction vehicles do not need secondary dumping locations as the waste is compacted and it is efficient to haul the waste directly to the landfill. These trucks would be expected to make at least two return trips to the landfill each day.

To navigate the narrower streets and alleyways within the City, a larger number of five cubic metre compacting trucks will be utilised. These vehicles will also continue to navigate the local narrower streets and alleyways until full when they will directly haul the compacted waste to the landfill. These trucks would be expected to make at least two return trips to the landfill each day.

Waste compactor trucks have a number of rams, hoses and hydraulic pumps that require maintenance. In some environments, such maintenance can be lacking and the vehicles can become unserviceable.

However this must be considered in the light of the option of not using compactor vehicles. A compactor truck typically can carry 2 to 3 times the mass of waste compared with an open tipping truck are therefore achieve significant costs and environmental benefits. The basic tipping truck also has the need for an hydraulic pump, ram and hoses but admittedly not as many in a waste compactor vehicle.

Finally there are different options for a waste compactor vehicle that do not utilize a ram system. A rotating trommel design as shown in the adjacent photographs is equipped with a spiral steel plate welded to the external shell. The entire cylinder rotates in a system similar to that of a concrete agitator truck. Therefore the only moving parts are the roller bearings and one motor to drive the cylinder. When the waste has to be emptied from the cylinder, the motor is merely reversed and this spiral plate forces the waste from the vehicle. Such systems are becoming more popular throughout Europe and require far less maintenance than a typical waste compactor vehicles using the traditional ram system.

Skip Bins

Skip bins can also be used for community based collection systems and have the advantage of optional wheels so they can be more easily moved to the truck for emptying rather than Hook-lift bins.

However the main advantage compared with hook lift bins is that the waste is compacted prior to hauling. The main disadvantage is that they must be limited in size to about 4 or 5 cubic metres because of bin weight lifting limits. It is common to have multiple bins in one location if a lot of waste is generated locally.

If there are only a few of the bins in one area, then the large compactor trucks can be fitted with lifting arms to empty the skips into the compactor truck rear, along with general loose waste.

Hooklift Bins

The hooklift bins can vary between a minimum of 5 cubic metres to 30 cubic metres. These can be low side bins equipped with rear entry donors to allow walk-in and drive in access to the bin.

Unless these bins have easy access, experience confirms that people will merely dump the waste by the side rather than either reach over the low side to place waste within the bin or a pushcart or Riksaaf trucks can drive into the bin to empty their load without having to shovel it out.

The large bins up to 30 cubic metres capacity are available and will be effective provided that they are of the “walk in” design where people can access the bin through the opening rear doors. The actual size mix and location of the bins will be determined after a detailed public consultation campaign.

The hook lift trucks are able to cart all these bin sizes.

The hooklift bins will be placed at strategic locations based on the following criteria;

- Bins will be need to be near areas where pushcarts and Riksaafs are used to minimise hauling distances for these small vehicles
- Bins will also be placed near institutions such as schools and commercial precincts, especially markets, where door to door collection is inappropriate
- Preference given to using exiting sites where possible as the local community is familiar with the location

- The final location of the primary dumping areas (hooklift bins) will be determined at the time of detail investigation when the final specification of other haulage equipment is determined and will be based on a series of community consultation meetings and council discussions.
- However the number of bins will be kept to a minimum as the waste in bins is not compacted and therefore represents a less efficient haulage model than garbage compactors or skips bins.
- There will not be any open secondary dumping areas where waste is merely placed on vacant land or into drainage easements.

▪

Tip Trucks

A number of body tipping trucks will always be required for the collection of general litter throughout the City. The trucks can be either 10 wheeler vehicles for larger loads and wider streets or 6 wheeler for narrower streets.

Alternatively additional hooklift trucks and bins could be used for this purpose.

Riksaaf Vehicles or equivalent

There are usually a number of small streets and alleyways that are too narrow and uneven to allow access by even small compactor trucks.

Therefore a number of the Riksaaf three wheel vehicles, or equivalent, capable of carrying 200 kg of waste could be utilised.

These vehicles would collect waste door to door from households and then carry the full load to hooklift bins acting as a limited number of secondary dumping areas.

These will only be used where small compactor trucks cannot reach.

Pushcarts

For the very difficult to access areas, additional pushcarts will be purchased.

The modern pushcarts can have capacities up to 600 litres and are fitted with a tipping mechanism to facilitate easy emptying into the hooklift bins.

Alternatively some larger compactor trucks can be fitted with lifting arms to lift the pushcarts directly into the compactor and so primary dumping location can be avoided for these areas.

There are also versions of pushcarts connected to a bicycle to facilitate quicker turnaround if the collection area is somewhat remote from the primary dumping location.

Determining Vehicle Numbers

In determining the number of new vehicles required in the future, it should be assumed a percentage of the existing haulage fleet in reasonable condition would still be used to haul waste. Obviously over time as the City becomes familiar with utilising the new equipment, the existing system can either be renewed for specific duties or replaced with some other more traditional equipment as listed above.

Three other factors should be used in determining the amount of collection equipment required:

- In some cases the bins (both skip and hook type) and also the compactor trucks will not be full when hauling to the landfill. It has been assumed that on average the loads are only 80 percent of capacity

- With an increased number of mechanised items in the fleet, an allowance must be made for both breakdowns and programmed maintenance. It should be assumed that only 80% to 90% of the mechanical fleet would be available at any one time
- Finally is collection every day or only some days a week. The overall fleet capacity has to be increased if not collecting waste every day of the week.

Need for Transfer Stations

Given that there may eventually be a number of hooklift or skip bins acting as replacements for the old primary dumping locations, another option is to consolidate the number of bins and install a small number of transfer stations instead.

Typically, small to medium transfer stations are direct-discharge stations that provide no intermediate waste storage area. These stations usually have drop-off areas for use by the general public to accompany the principal operating areas dedicated to municipal and private waste collection trucks. Depending on weather, site aesthetics, and environmental concerns, transfer operations of this size may be located either indoors or outdoors.

There are many “rules of thumb” for when a transfer station is more efficient than direct haul. Many suggest that the minimum distance is in the order of 20km each way before a transfer station is required.

More complex small transfer stations are usually attended during hours of operation and may include some simple waste and materials processing facilities. For example, the station might include a recyclable materials separation and processing centre.

Usually, direct-discharge stations have two operating floors. On the lower level, a compactor or open-top container is located. Station users dump wastes into hoppers connected to these containers from the top level, or even directly into large open containers such as 20 cubic metre hook-lift bins or 40 foot long high side tipping trailers.

For longer transfer haul distances, the 40ft tipping articulated trailers are the most efficient and can contain the usual road transport limit of about 20 tonnes net without needing any compaction system. There are two basic types, namely end tipping and side tipping. End tipping can be dangerous at dumpsites where elevated trailers have toppled on their sides because of the unstable ground condition sunder the trailer wheels.

The side tipping option is safer if less common.

The required overall station capacity (i.e., number and size of containers) depends on the size and population density of the area served and the frequency of collection. For ease of loading, a simple retaining wall will allow containers to be at a lower level so that the tops of the containers are at or slightly above ground level in the loading area.

Several different designs for larger transfer operations are common, depending on the transfer distance and vehicle type. Most designs fall into one of the following three categories: (1) direct-discharge no compaction stations, (2) platform/pit non-compaction stations, which are very common and simple, or (3) compaction stations, including the sealed vertical silo systems.

The key factor in determining if a transfer station is required is the haul distance from the collection area to the drop off location. Determining the economic point where a transfer station is less costly than using the collection compactors requires a detailed financial analysis and collection of real travel time data.

Staff Training

OHS training will be essential for collection staff as well as environmental concepts and the need for improved ISWM management approaches and litter avoidance specifically.

Options for primary waste collection process

There are a number of approaches to collection of waste from residences and commercial producers. Together these are described in detail as follows. Presented here are some of the possibilities.

1. Householder separates the organics and fines, composts them at the house, and then places residuals in a small household bin. Door-to-door collection of home bins with manually operated handcart by community worker.

2. Door-to-door collection of home bins with manually operated handcart by community worker.

3. Door-to-door collection of waste piles by community worker.

4. Householder takes waste to community bins as it is produced.

5. Householder places waste in indiscriminate piles, to be collected by community worker.

Separation of wastes for household composting

Single bin for household composting.

Since between 30% and 40% of the waste has been measured as organics and fines, it means that composting at the household level has the potential to have beneficial impacts on ISWM management from primary collection to final disposal. Removing roughly 1/3 of the waste reduces that which needs to be handled at all three levels – storage at the house, secondary storage and landfill space. It also means that it is much easier to separate out other recyclable materials like metal and plastics. Secondly, it means that an extremely valuable soil amendment can be produced and used at virtually no cost to the household.

Depending upon space available, there may not be enough room to compost on-site. However, a mini enterprise for private company could be developed, that could get paid a small amount to take the waste away, than can sell the final product to farmers.

Excellent guidance for backyard composting is available from numerous internet sites. (See the Compost Chapter later for more details) Un-enclosed compost piles are not recommended in an urban setting since these kinds of piles tend to spread out and become unsightly. Home composters are relatively easy to make. However, there are important considerations, such as flies, animals (rats) and odours. A good home compost system will usually have a restriction so that animals cannot get into it. It is usually recommended that meats are not included in the composter.

Alternatively composting can be done even more simply (but less speedily) in ground. Shallow trenches are dug 300mm deep, half filled with organic waste and then covered with soil. The organics remain insitu until sufficiently biodegraded. The compost can then be recovered and used around the compound.

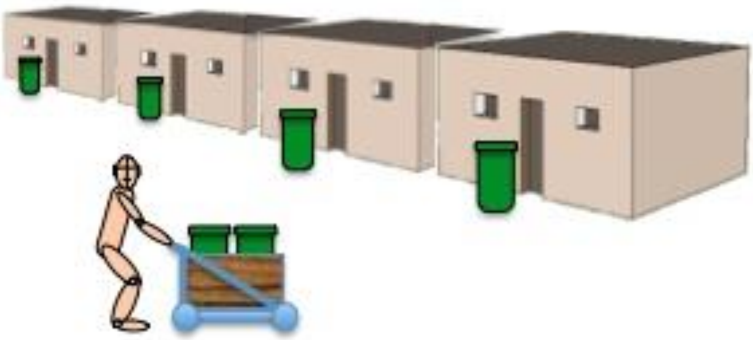
Since this option diverts up to an absolute maximum of 30% of the waste produced, the containers at the residences can be smaller, or transport to secondary waste sites can happen less frequently.

Diversion of the organic waste also reduces the odour and vector attraction of waste stored at the household.

Positives	Negatives
• Cheapest whole-system option as up to 1/3 of the waste stream could be diverted. • Results in a soil amendment but does not replace fertilisers for any crops requiring overall nutrient dosing. • Requires smaller household bins, or less frequent transport to secondary collection. • Encourages communities to take responsibility and ownership of environment and keep community clean. • Citizens are free to choose how they live and operate. • Does not require every household/ commercial enterprise to participate.	• Relies heavily on individual responsibilities; therefore if citizens do not participate, there will be less beneficial impact. • Households would be required to purchase or build their own composters or trenches. Used tyres can be supplied to HHs for use as compost bins. • An aggressive community education campaign would be required, however, this could have far-reaching impacts beyond ISWM. • A demonstration program would likely be required.

Door-to-door collection of home bins

This alternative is very similar to the first alternative, with the exception that there is no composting component. Although it is a far simpler option, it is not as sustainable, and requires potentially much more SW handling.



▪ **Door-to-door collection of home bins.**

In this option, all the household and commercial waste is placed in containers. These containers must be bigger than in the prior option, or emptied more frequently. On a weekly basis, the containers are collected with a manually operated handcart and emptied into a community bin, or taken directly to a truck for transport to the landfill.

Given the highly variable long-term sustainability of compost schemes internationally, bins and haulage systems should be sized on the basis of no household based composting to be conservative.

Positives	Negatives
• Can be conducted by a number of entities, including individual stand-alone operator, community based organization arranged operator, City operated staff, or a combination. • Waste producers (householders) don't have to be physically present to take waste out, bin is left at door for operator to collect. • Community groups can take ownership of local environment to keep it clean. • Requires less community education or reliance upon individual.	• The cost of bins. • Relies on worker being available with equipment to collect waste, requires management and routing designation as well as equipment procurement/ maintenance. • Requires coordination and payment of workers and a system that ensures if a worker is absent, an alternate is available and in place to ensure the system continues without failing. • If collection workers do not conduct primary waste collection for over more than 2 programmed collection cycles, then entire system would likely collapse.

Some typical options for household/commercial bins are presented below.

	Metal Bins (60ltr)	Plastic Bin (60Ltr)	Wheelie Bin (120ltr)
			
Price/unit	US $ 30	US $ 20	US $ 70-100
Positives	• Heavy duty/robust – can withstand heavy handling and heavy/dense waste loads. Repairable if damaged; U.V. resistant • Fabricated locally/cheap	• Cheapest option • Lightweight and therefore easily emptied by collection crews.	• Relatively heavy duty and robust body. • Larger capacity while remaining maneuverable. • Fixed lid
Negatives	• Heavier than plastic therefore can be more difficult for collection worker to empty. • Lid likely to be damaged or lost resulting in open container	• Not U.V. resistant • Not robust (especially given composition and density of waste stream) and easily broken • Un-repairable if damaged • Bought in from abroad • Susceptible to vandalism by burning or theft	• Most effective when collected by vehicle with hydraulic bin lift which are not common in • Heavy when full, awkward to manually empty. • Bought in from abroad • Comparatively expensive. • Susceptible to vandalism by burning or theft

This door to door option has the advantage of allowing the waste collector to charge the household or institution directly for removing their waste, especially if collection is to be privatised.

Door-to-door collection of waste piles by community worker

- **Door-to-door collection of waste piles by community worker.**

Waste can also be removed from small piles outside of houses/ commercial establishments with a manually operated handcart operated by a community crew like Alternative 2.

The obvious primary difference is the lack of a container, and the subsequent potential for indiscriminate dumping.

Secondly open piles are attractive to animals and other vectors, who can spread the waste and break open bags. This greatly reducing the environmental attractiveness of this option, and has associated health issues.

Positives	Negatives
• Can be conducted by a number of entities, including individual stand-alone operator, community based organization arranged operator, City operated staff, or a combination. • Waste producers (householders) don't have to be physically present to take waste out, waste is left in a pile for operator to collect. • Community groups can take ownership of local environment to keep it clean. • Requires less community education or reliance upon individual. • Requires little expense at household level to establish practice (no bins).	• Relies on worker being available with equipment to collect waste, requires management and routing designation as well as equipment procurement/ maintenance. • Requires coordination and payment of workers and a system that ensures if a worker is ill, an alternate is available and in place to ensure the system continues without failing. • If system fails and collection workers don't conduct primary waste collection, then entire system would likely collapse. • Increases the potential for indiscriminate dumping. • Can often be spread by animals • Has environmental and health considerations.

Householder takes waste to community bins

A clean and cost effective option is for the household/ commercial enterprise to carry and place their waste in a secondary collection bin as it is generated on a daily basis. If properly implemented, this would be cost effective and environmentally friendly. Secondly, virtually no coordination is necessary between the household and the collector as the capacity of the community bin provides the temporal buffering required.

The community bin could be a concrete bunker, trailer, hooklift bin or skip bin, or in some cases, a transfer station.

Positives	Negatives
• Cheapest option for the household or commercial enterprise. • Least labor requirements for organized crew, as it relies on individual participation alone to get waste to collection spot. • Encourages communities to take ownership of local environment to keep it clean. • Citizens are free to choose how they live and operate.	• Relies heavily on individual responsibilities and therefore if citizens don't participate and take their own waste to the community bin, it will end up irresponsibly discarded on streets. • Transport to community bins is not easily achieved by households and therefore is not often practiced. • An extensive educational program would be required to institute this to a successful level. • Unorganized and un-managed, it increases the potential for indiscriminate dumping. • May require drop bins to be established at a closer interval.

Waste taken by household to open waste piles

This option is a combination of other options, with potentially the least control. Households and commercial establishments dump their wastes in relatively uncontrolled piles that may or may not be formally designated.

This option is what is happening currently in some locations in the City.

Piles are subject to animal scavenging and scattering of the waste. Although virtually no coordination is necessary between the household and the collector is required, uncontainerised waste requires collection crews to hand-collect loose waste from the street, which is a hazardous and time-consuming practice.

Positives	Negatives
• Existing practice in many places. • Allows haphazard scavenging to occur, and access to animals. • Least labor requirements for organized crew, as it relies on individual participation alone to get waste to collection spot. • Encourages communities to take ownership of local environment to keep it clean. • Citizens are free to choose how they live and operate.	• Alternative that most results in waste being irresponsibly discarded on streets. • Requires collection crews to hand collect loose waste from the street, which is a hazardous and time-consuming practice. • An extensive educational program would be required to institute this to a successful level. • Unorganized and un-managed primary waste collection system; most difficult for the citizens to see a benefit. • Subject to animal attack and waste spreading with greater vermin concerns.

Secondary collection, ditch and street cleaning

Community bins

A number of both formal and informal drop sites exist for community-level solid waste collection at present. This confirms that a certain level of flow from primary to secondary to final deposit already takes place and is accepted by the community.

With most of the options, the waste is collected through the primary collection system and temporarily stored at community collection drop points – “trash dams,” bins, or skips - prior to being transported in bulk to the waste treatment or disposal site, or possibly a transfer station. The function of this component is solely to provide an interim storage site to make operations more efficient. As such, it is very important that they are:

- capable of holding the entire amount of waste brought to them during a set period (for instance, to be able to hold a week’s worth of contributions from primary collection if that is adopted as the collection frequency),
- emptied prior to new cycle of waste being brought to them – that is they are synchronized with primary collection, and
- easily emptied and accessible for transport vehicles.

There are a number of alternatives for drop points (primary dumping locations), including

- not using formal drop points – just allowing uncontrolled open dumping
- uncontainerised, open piles in agreed locations
- trash dams (permanent concrete or steel bunkers)
- hook-lift bins matched to the collection truck.
- skip bins matched to the collection truck

The open pile alternative is by far the least desirable; the hook-lift bins or skips are the most efficient and clean, but are by far the most expensive initial cost requiring specialized matched equipment.

Hook lift bin systems do not provide any compaction and even partially full hook-lift bins will sometimes need to be transported. Bins cannot be added to one another to fill one bin (to maximise haulage efficiencies) unless waste is manually shovelled from one to the other.

Skip bins are loaded into a compactor truck where not only is the partially full bin issue then overcome, but the compactor truck can then double or treble the waste density making haulage far more efficient.

Locating any of these containers is an important decision. It is important to consider:

- Containers are located strategically, taking into account where community workers or households have established past drop practices.
- There is adequate space to place one or more containers, and access by the collection vehicle.
- They do not obstruct the entrance of any building, or hinder traffic.
- Neighbours will not vandalise them if the waste become odorous or if feral animals spread the waste
- The walking distance from the edge of the bin catchment is sufficiently short so that residents will take waste to the primary dumping location and not fly dump or litter instead. Anything less than 250 metres is usually considered sufficiently close, but reducing this to a 100 metre maximum walk if possible has been found to reduce illegal dumping to very low levels.

The value of locating at existing informal waste disposal sites is that the community is used to these drop locations, and the change in appearance (when a bin, skip or trash dam is placed) is a noticeable visual improvement. Thus objections from the community should be minimal in that case.

- **Selected alternatives for community trash collection.**

	Open piles	Trash dams/Bunkers	Hook-lift Bins	Skip bins
				
Price/unit	- 0 -	US$400 to $600	US$600 to $1500	US$400 to $1200
Vehicle required	Non-specific	Non-specific	Hook-lift truck matched to bin	Forklift-type compactor truck matched to bin
Positives	• Low cost • Disposal points presumably established by community needs	• Static so residents have defined disposal point • Relatively inexpensive • Requires no special equipment • Fabricated locally	• Bins easier to relocate as they are not fixed • In an emergency, small bins can be lifted by crane trucks which are relatively abundant, known by mechanics & operators • Fabricated locally • Easily removed, cleaned, repaired and replaced • Bins replaced immediately by empty bin	• Bins easier to locate as they are not fixed • In an emergency, skip bins can be lifted by crane trucks which are relatively abundant, known by mechanics & operators • Fabricated locally • Easily removed, cleaned, repaired and replaced • Skip bins recycled immediately and waste is compacted in truck
Negatives	• Alternative that most results in waste being irresponsibly discarded on streets. • Requires collection crews to hand collect loose waste from the street, which is a hazardous and time-consuming practice.	• Difficult and slow to access & awkward to empty • Manual labor required to empty exposing workers to health hazards • Difficult to locate as residents don't like them beside house	• Requires specific hook-lift truck matched to bin • Lifting and unloading can cause damage to containers. • Very low risk of container being stolen • Does not allow compaction in transit to landfill	• Works best with specific fork truck matched to bin • Lifting and unloading can cause damage to containers. • Low risk of container being stolen • Does allow compaction during transit to landfill

Collection points should be located at a distance not exceeding 250 metres from the primary collection points. That suggests the distance between two bins should not exceed 500 metres. The size of the trash dam or number of bins can be determined on the basis of the volume of waste likely to be received from the area concerned. That requires a count of the households (to get a number of people) and number of commercial establishments, and the estimated waste contribution from each. For households, the data above can be used to make estimates. Waste generated form commercial enterprises will have to be estimated from inspection or interviews of the business.

Secondary Collection

Depending upon the particular system and configuration, the number of trucks required can be determined. This also depends upon how long it takes to load the waste and how far it is to a landfill/disposal site. For instance, shovelling out a concrete trash dam or a scattered pile takes much longer than it takes to pick up a skip or bin. But it is also possible that a dump truck can hold more than the amount of waste in two trash dams, whereas it may be that the flatbed associated with a crane can only transport two skips/bins. A typical calculation might be:

Skip-crane combination

- 2 skips/truck @ 2 trips/truck/day = 4 skips/truck/day
- 6 days/week = 24 skips/week/truck
- 4.5 m^3/ skip * 24 = 108 m^3/truck/week (assuming that the skip is full when collected)

Trash dam (or informal dump site)-dump truck combination

- a standard truck has a capacity of 5 m^3
- one truck load per day at 6 days/week = 30 m^3/week/truck

It is entirely possible that a combination of systems is put in place in any one city. Some possibilities are show and described as follows.

- **Secondary collection of piles by tractor/trailer**

Secondary collection of piles by tractor/trailer	
Cost of vehicle = US $25,000	
Positives	Negatives
• Equipment is relatively cheap with good availability. • Has a good short turning radius, so it is fairly easy to access tight spots, such as within communities. • Still has maintenance issues with hydraulics associated with the trailer lifting ram and the front bucket system	• Fairly labor intensive to fill trailer by hand. • Shoveling waste is a hazardous and time-consuming practice. • A tractor is very slow on the way to the landfill. • Consider using a transfer station to overcome the tractor's slow speed

- **Secondary collection of containers by tractor/trailer..**

Secondary collection of containers by tractor/trailer	
Cost of vehicle = US $25,000	
Positives	Negatives
• This system by-passes the need to have secondary collection stations, as the household/commercial bins are emptied directly into the trailer. • Equipment is relatively cheap with good availability. • Has a good short turning radius, so it is fairly easy to access tight spots, such as within communities. • Still has maintenance issues with hydraulics associated with the trailer lifting ram and the front bucket system	• Fairly labor intensive to collect bins from households and businesses, though it may be less expensive than shoveling out trash dams or open piles. • Some bins may be fairly heavy due to the majority being fines (earth and ask) and food waste. • A tractor is relatively slow on the way to the landfill. • Consider using a transfer station to overcome the tractor's slow speed

- **Secondary collection of waste in trash dams by dump truck.**

Secondary collection of waste in trash dams by dump truck	
Cost of vehicle = US $90,000	
Positives	Negatives
• This system is very similar to the first alternative, but uses a truck with potentially much greater haulage capacity than a trailer pulled by tractor. • Dump trucks are moderately priced with good availability and mechanical support. • Is capable of good road speed when going to the landfill. • Can access replacement trucks easily as these vehicles are used for many other haulage purposes	• Fairly labor intensive to clean out trash dams. • Shoveling waste is a hazardous and time-consuming practice. • A large truck has poor turning radius, so may not be able to negotiate some narrow roads, or turns. But can use a variety of truck sizes to suit road widths in the city • Truck has hydraulic systems for tipping requiring maintenance (same as tractor-trailer systems)

The next step is to the ultimate system of compactor trucks.

- **Secondary collection of waste in bins by SW compactor truck.**

Secondary collection of waste in bins by SW truck	
Cost of vehicle = US $180,000	
Positives	Negatives
• This system is a very quick and clean way to collect containerized waste. • Low labor requirements and costs. • Relatively high weekly waste capacity. • Provides compaction • Good road speed to landfill	• The most expensive in terms of capital investment, and not generally available locally. • Requires significant room to turn, and bin must be aligned with truck. Smaller rear lift vehicles are available for narrow street areas • May require advanced training for mechanics.

One of the key factors that requires a concerted effort and buy-in on the part of the community is proper use of waste drop sites. In many instances, a trash dam is not properly used, so the result is not dissimilar to having an uncontainerized open trash dump site with similar visual, odour and health concerns. This may require an aggressive education effort.

Changing to waste bins (Hook-lift or skip bins) also require some community engagement to ensure that the waste is placed in the bin by the householder or commercial institution, and not just dumped near the bin.

Appendix I - Difficult Waste

Difficult wastes are those wastes that are always allowed to be tipped at the Controlled Landfill but require special treatment to ensure that the best compaction/disposal is achieved. This class does not include hazardous or dangerous wastes, or Special Wastes.

Tyres

Tyres can be a real problem at Controlled Landfills, they are impossible to compact and provide homes for rats. After several weeks or months, tyres "float" to the top of the Controlled Landfill and pierce through the cover. Tyres should be collected in a special area and shredded before they are tipped. Alternatively, the tyres may be useful in remediating the old Dump, or used as scour protection around the external base of the waste mound to prevent erosion from flood flows.

Alternatively tyres can recycled into sandals which is common in Afghanistan.

Mattresses

Mattresses are also hard to compact and are difficult to break up. When found in loads, they should be pushed to the toe of the face and covered.

Whitegoods

When a fridge, freezer or stove is tipped on the working face, it should be carefully crushed to ensure that it is as small as possible. Preferably, these larger items should be stored in the recycling compound and sold to a metal recycler after degassing.

Car Bodies

Car bodies should be collected for sale to metal recyclers. If car parts or bodies are to be tipped, they must be carefully crushed. Operators must take extra care, as there may be petrol left in the tank which could catch fire. If car bodies are collected, they must not be stacked more than 3 high.

Drums

Drums of any material must not be accepted if they are sealed or if they contain any liquid. If a sealed drum is found on the tipping face it must be removed and the Site Foreman notified. He will arrange for the contents to be tested and disposed safely.

Opened drums or large containers of any sort must be crushed before being covered, but should always be recycled if at all possible.

Whitegoods, cars bodies and drums can trap landfill gas and be an explosion danger unless well compacted. In any case, they should always preferentially be recycled.

Appendix J - Special Wastes

These wastes include material that may be accepted into the Controlled Landfill but require special consideration on a case-by-case basis.

Local legislation and ordinances would cover the management of this collective of wastes, when developed, or the national standards and codes as appropriate. These wastes are allowed into the Controlled Landfill on a case-by-case basis only.

Asbestos

Generally the requirement is for all forms (solid sheet and fibrous) of asbestos to be bagged before disposal. Any building (e.g. house) or site where asbestos (even in a sheet form) is being removed, must be:

- removed by a licensed contractor
- site covered with a tent
- all asbestos bagged
- workmen adequately protected in fully enclosed suits and masks, and
- all waste, clothes and tent placed in a shipping container and buried in a defined trench in an approved landfill.

It is proposed that the following procedures be undertaken for the disposal of such waste;

- solid form (fibro-board) - disposal in designated area and covered immediately with night cover
- fibrous/dust form - must be bagged prior to receival at the landfill, disposal in designated area and covered with night cover.

▪

The date and location (grid and depth references) is recorded for each load.

The area where asbestos is deposited is to be identified with date of deposition, quantity, fibrous or bonded, origin, name of contractor and accurate location. It is safe provided that the material bagged and not allowed to escape from the bags in a dry state. It is always safer to keep the asbestos material wet as an added safety precaution.

The asbestos will be managed under any local new legislation, or suitable international standards, such as the Australian Code of Practice for Asbestos Removal and Management NOHSC 2002.

Dead Animals and Obnoxious Waste

Animals and obnoxious wastes will be tipped in front of the Controlled Landfill face and covered immediately. Obnoxious waste would include rotting food produce or other condemned foodstuffs.

The animals and obnoxious wastes should not be placed on the base/liner of the Controlled Landfill.

Non-toxic Liquid Waste

Disposal of large quantities of any liquid wastes and soluble chemical wastes will not be permitted. This may encourage the generation of excessive leachate.

It is common to allow up to five percent (5%) of the total Controlled Landfill waste stream to be liquid. This is because waste usually has a moisture content of 15% to 30%, and is not saturated until the moisture content reaches more than 70%. Leachate will not flow until the waste reaches saturation.

However, because of the moderately high rainfall conditions experienced in the City, liquid waste should not be accepted in large quantities until the Controlled Landfill mound is well established and factual data is derived on leachate generation rates and waste moisture content. Limiting the liquid waste to a maximum of 5% of the waste volume would be appropriate for low toxicity waste, such as grease trap pump-outs.

Preferably, grease trap wastes should be tankered to a sewage treatment plant and discharged to an unmixed, unheated tank. Grease will rise to the surface and form a crust. Solids, such as peelings and scraps, will settle to the tank bottom. The water fraction, which will be the largest volume of the three components, will be drained to the sewage treatment plant inlet works. When the sludge and grease layers build up to excessive levels, the sludge and grease should be pumped out and taken to the Controlled Landfill for co-disposal with the waste. The grease/sludge mixture will be covered as quickly as possible.

Toxic Liquid Waste

These wastes must be recorded for type, source and quantity at the front end of the Controlled Landfill operation. If there is any doubt about the actual content of the load, it should be emptied into a separate trench for subsequent inspection, and if deemed necessary, chemical testing.

The general approach is to pre-treat toxic waste prior to placing in trenches cut into the clay. The waste will then be covered and entombed in the dedicated trench.

An alternative is to store the waste for eventual export to countries, which can provide higher technology solutions. The disadvantages to accessing this higher treatment standard is cost and violation of the general aim that people who produce the waste should manage it themselves and not export their potential problem. Another issue is that the style of treatment proposed for the Controlled Landfill is essentially what happens to most cities' waste in many developed countries in any case.

The possible waste streams and treatment methods are as follows:

Oily Waste Water

The best option is to recycle the oil from the emulsions and suspension. A recovery plant may be available in the future.

These waste waters generally have a high Biochemical Oxygen Demand, high salinity, a waste oil or oil emulsion fraction and potential contaminants such as radiator anti-rust fluids. These wastes usually come from ship bilges and service stations. Because of the potential toxicity, the volume should be limited to 1% of the waste volume. (This is compared with the general non-toxic liquid waste such as grease trap wastes that can be up to 5% of the waste stream)

For quantities exceeding the 1% limit, the waste should be lagooned for separation purposes. The oil film and bottom sludges should be tested for toxins. If below acceptable limits, the solids can be directed into the Controlled Landfill. If the toxin content is considered excessive, solids should be blended with kiln dust, cement, fly ash or clay mixtures to fix the toxins in a cement matrix, and encapsulate any mobile fractions. The resulting solid blocks should be land filled.

Phenolic and Emulsified/Concentrated Oil Waste

This includes wastewaters contaminated with degreasers and decarbonisers, emulsified oils such as machine and cutting oils and other products from light industry and tanker washouts.

Where possible, the phenolics should be oxidised using potassium permanganate. The treatment and disposal method is then the same as for oily wastes.

Acid/Alkali/Metal Wastes

These wastes are derived from metal plating works, metal finishers and the paint manufacturing industry.

Wastes should be neutralised where possible by blending acidic and alkaline wastes. This may require the construction of holding lagoons for the various waste stream components.

The blended product is then treated as for the oily waste by Controlled Landfilling or chemical fixation using cement products. The disposal method is also the same, involving Controlled Landfilling the solidified waste capsules and evaporating where possible the remaining liquid waste fraction.

If evaporation is unsuccessful, the liquid can be added to the Controlled Landfill mound provided that the 1% rule is observed.

Paint/Pesticide/Solvent (PPS) Wastes

This includes all pesticide, fungicide and herbicide wastes, plus solvents such as halogenated cleaners and Methyl Ethyl Ketone derivatives. Sources would include manufacturing processes for the nominated waste types, laboratories and other heavy industry.

This is generally regarded as the most toxic waste stream and requires fixation with cement material, unless the total load can be restricted to less than 1% of the total waste volume. Because the organics do not fix strongly into the cement matrix (unlike metals, which are strongly fixed and become effectively immobile), the resulting cement capsules should be placed in a dedicated disposal trench as monofill. The trench into clay would then be sealed prior to the entry of any stormwater. At least 600 millimetres of low permeability clay should be underneath and around the trench.

The trenches should be located in clay at least 600mm thick below the base of the trench, and at the head of the Controlled Landfill mound to maximise the distance to the creek and any groundwater. Locating the trenches upslope of the Controlled Landfill also allows the surface and groundwater monitoring programs to assess any leakage from the trenches.

The size of the trenches cannot be determined at this time as there is no reliable data on waste generation volumes. They should be sized to accept up to 6 months production of the component waste streams. This will allow the liquid to isolate from surface scums and bottom sludges, and allow evaporation to occur.

The one exception is the Paint/Pesticide/Solvent (PPS) waste, which should be stored for only one month prior to solidifying.

Pathogenic and Medical Waste

Various local medical facilities, such a hospitals and medical clinics, have inadequate facilities to correctly handle all their special waste. This was confirmed by medical wastes appearing in some of the Dumps in the region.

The best solution is to provide a regional medical waste incinerator at the Controlled Landfill. It would be remote from the public, and ash residual could be safely co-disposed with the waste. The incinerator could also treat some of the liquid wastes, such as PPS that has calorific value, provided that the incinerator and anti-pollution equipment is appropriate for these wastes.

The general requirements for an incinerator are that the temperature should be over 1 200º Celsius and a residence time of 2 seconds.

The only residual concern is that the collection and handling of the medical waste must be dedicated and safe, and mediwaste is not co-mingled with other domestic or commercial waste.

Contaminated Soil

This soil can be derived from contaminated sites or dredge spoil. The soil should be tested to ascertain the health and environmental risk profiles, such as using the ASTM Standard Methods for Toxicity Characteristic Leaching Procedure.

There are three options for managing contaminated soil coming to the site, namely;

- Non-acceptance based on laboratory testing, because it is too contaminated for the standard of Controlled Landfill.
- Acceptable into the site but still too contaminated (or unsuitable for some other reason such as too wet) for use as cover material but suitable for incorporation into the waste mound as waste
- Acceptable into the site for use as daily, but not final, cover material

If the soil is determined as being too hazardous for the environmental capabilities of Controlled Landfill, it must not be allowed onto the site and should be directed to a hazardous waste facility. This would apply to highly contaminated soil from an old pesticide factory for example.

However if the soil is not an occupational or health risk, it may be used as daily cover. It must not be used as final cover.

If unsafe to use as cover for whatever reason such as being too wet, it should be incorporated into the Controlled Landfill as normal waste.

Biological Sludge

This material is recyclable, provided that it has been stockpiled or otherwise treated to control pathogens. It should only be Controlled Landfilled if the material is not recyclable, due to excessive heavy metals or biocides or lack of market demand.

The sludge would not require any special treatment prior to Controlled Landfilling with other waste.

Batteries

Lead-acid batteries are recyclable and should not be allowed into the Controlled Landfill.

If the market fails, then batteries should be drained of the acid prior to placing in the mound. However this is a waste of the lead contained in the plates and should only be used as a last resort.

Dry cell batteries, such as torch batteries, should be accepted without any special precautions being required, unless the quantities become significant. This is unlikely however as there is a trend to using rechargeable rather than disposable lead type.

Appendix K - Privatisation

Overview

The options for privatisation are somewhat limited in this case where the operation is just for a single local authority. In cases where a facility is shared between Municipalities in a regional approach, then there is greater scope for private involvement for reasons such as the following;

- The scale of operation is larger, and therefore more attractive for a private company to commit Capex funds and mobilise.
- The regional context means that at least one of the City's cannot be directly involved in the operation of the facility. This can result in some friction between the member City's. Using a third party, possibly the private sector, to operate the facility gets around this issue.
- A further disincentive to involving the private sector is that the work required is relatively low technology, and therefore has low possible margins. The recycling systems for example will most likely be basic Neighbourhood level systems using lower cost civil society or possibly NGO staff. The collection system is unlikely to be mechanised in the foreseeable future to equipment such as side-lift trucks for Mobile Garbage Bins (MGBs) of say 240-litre capacity. Similarly the disposal facility is only a Controlled Landfill which has only basic operational requirements compared with a Sanitary Landfill.

- For these relatively simple operations, the private sector may not be attracted because of the low potential for innovative solutions or management that will make the private sector price cheaper than the cost that the City themselves can operate the facility. Once the Controlled Landfills have to be converted to Sanitary Landfills, or perhaps enlarged to become a regional facility, then there may be more scope to involve the private sector.
-

However if the City is interested in seeking private sector involvement, it can be sought on non-commitment basis. This means that the City can seek tenders for one or more components of their waste management services and compare the offers with their internal records of costs under City operation. If the City appears to be less expensive for the same level of service, then the City would not be obligated to award the tender. In any case, it is likely that the collection, recycling, composting and Controlled Landfill aspects will be undertaken under different arrangements, contractual or otherwise.

It is also critical to consider the length of contracts for privatisation success. Short contracts of a year or two are insufficient to allow the investor to recover his Capex exposure on equipment or site development if a landfilling operation. Any privatisation contracts requiring extensive capital injection by the operator must be at least 5 years in duration, but preferably a minimum of 10 years, to allow amortisation of the capital cost.

The following sub-sections address the most common options for the various levels of private sector participation in the ISWM requirements of the City. The seven (7) generic options are listed below and discussed. The City should just be aware of the privatisation spectrum available to them, and the various pros and cons associated with the options.

Private Sector Involvement Options

The options are described below.

Service Contracts

These delegate particular operations and maintenance (O&M) functions to a private operator for a short period of time (one or two years) in return for a specified fee. These could be appropriate for operating a Controlled Landfill or collection services if the scale of the operation is sufficient.

Management contracts

These allocate responsibility to a private operator for the full range of O&M decisions, typically for three to five years, or longer. The private operator is paid a fee, which may sometimes be linked to performance. It could be appropriate for operating a small Controlled Landfill if the scale of the operation is sufficient.

Lease contracts

These are where a private company is granted the right to the revenue stream from the operation in return for full O&M responsibilities. Ownership of the asset remains in the public sector. These are also known as “contracts d’affermage” or service concessions.

The private operator collects revenues directly from the customer, and pays a percentage as a rental fee (or redevance) to cover the administrative and investment costs of the public entity, which exercises residual ownership of the assets. The responsibility of the public entity typically includes regulating the contract and managing the investment program. The leasee does not therefore invest in fixed assets, but does bear the full commercial risk of running the service. This option would only apply if the City owns the land or collection vehicles.

Concession contracts

These grant a private operator the right to exploit a given service for a fixed period of time (ranging from 15 to 30 years), assuming full commercial risks and responsibility for a specified program of new fixed investments. A formula is set for tariffs to be collected by the operator, to cover the full cost of running the service and capital expenditure.

As with lease contracts, provision is made to renegotiate the tariff formula to reflect changing circumstances throughout the long life of the contract.

These contracts are only appropriate for large Sanitary Landfill operations, a major collection service or perhaps for a very large mechanised MRF.

Build Operate Transfer (BOT) contracts

BOT contracts give the responsibility to a private operator (or consortium) both to finance and construct an infrastructure facility and to operate and maintain it for a specified period of time. At the end of an agreed period, ownership of the facility is transferred to the government at a symbolic cost.

The private operator retains all the revenue from operating the facility for the period of the contract, to pay for the capital and operating expenditure. This revenue stream typically consists of fees paid by the public sector user and commercial operators.

Such a scheme would only be suitable for a very large landfill or major collection service.

Private Sale

This involves selling existing public facilities to a private operator, usually by means of an auction. Private sales may involve majority or minority stakes in the state owned enterprise, and certain restrictions on purchasers. The decision whether or not to participate can only be made on a return on investment basis.

Sale is usually only an option for very large facilities. At present, the City facilities are too small to be an attractive sale option.

Flotation

This involves floating state assets on domestic or foreign stock markets, perhaps with restrictions on share purchase. In particular, governments retain "golden shares" in the Privatised Company, which confer special voting rights and powers of veto.

Flotation is too complex unless a major regional scheme is adopted, and the risks associated with such a private-public sector participation model is accepted by the national government.

At present, the City facilities are too small to be an attractive flotation option.

Criteria for Privatisation Method Decision

The decision on whether to consider privatisation of some sort must be based on suitable criteria, such as those listed below for both the public and private sector perspectives.

Public Sector Perspective

Four groups of criteria can be considered when choosing between privatisation options:

Financial criteria.

State owned utilities can place a variety of financial pressures on the public purse, which governments may wish to reduce:

- Subsidies to loss making utilities to finance existing operations
- Funding of substantial new investment to increase capacity and improve service quality.

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The greater the public sector deficit, the more important financial considerations are likely to be as a motivating factor towards privatisation. Privatisation options may relieve some of the pressure by:

- Reducing or gradually eliminating subsides and cross-subsidies, through greater efficiencies of private sector operation, and the phasing of tariff increases up to cost recovery levels. Such increases may prove politically easier to implement under private rather than public operations.
- Attracting finance to meet new investment needs, thereby avoiding the need to incur additional public expenditure.
- Generating cash revenues through the private sale or flotation of public assets. The funds can be used to create a reduction in public sector debt or to fund alternative projects.

Efficiency of service criteria.

Public owned utilities may have relatively low levels of efficiency, since there are poor incentives for cost reduction. Introducing private expertise and management methods can improve efficiency in a number of different ways:

- Increasing productive efficiency linked to reductions in operating costs even without substantial new investment.
- Stimulating innovation driven by the adoption of new technologies in the context of an investment program.
- Improving the quality of service, as long as targets are clearly set by the public sector.
- Raising accountability to customers, brought about by the market context.
- Increasing tariff/fee collection efficiency, as a result of the profit motive of the private operator.

Ideological criteria.

Where governments are undertaking a wide range of policies involving deregulation and pro-market reforms, privatisation will be enthusiastically embraced. In this context, it is viewed as a means of increasing private participation in the economy and may be used to encourage wider share ownership. Where governments do not espouse to a free market political philosophy, privatisation may be undertaken more reluctantly primarily as a means of funding new investments or improving the efficiency of public services. In these cases privatisation is likely to be accompanied by special measures to ensure continued public control.

A desire to retain maximum public control may lead governments to adopt contractual forms of privatisation as opposed to asset sales. However, asset sales need not entail a loss of public sector control. The government can retain a controlling stake and use the proceeds of privatisation to achieve wider social goals.

Administrative criteria.

Two aspects of the privatisation process will create a significant administrative burden:

- Preparation. Assembling information on the state of the existing infrastructure assets, assessing the quality of the competing bids, providing reliable revenue and cost forecasts for the operation of the contracted services.
- Regulation. Ongoing costs of regulating the activities of the private operator, on both price and non-price performance parameters.

Private Sector Perspective

Private operators will consider the balance between risk and return when selecting between possible investment opportunities.

Potential risks may include:

- Commercial risk from the operation and maintenance of the service, subject to demand, cost and revenue volatility.
- Project risk from uncertainties in forecasting costs and revenues attached to investment responsibilities.

- Country risk from exchange rate volatility, which may affect profitability for foreign operators.
- Regulatory risk from unexpected alterations in the regulatory conditions, such as political interference.
- Force majeure risk from damage to assets owned by the private operator, as a result of natural disasters.

Potential factors affecting the return on investment include;

- Bidding costs. Preparing the bid and participating in the selection procedure, compared to the probability of winning the contract and the resulting revenue stream.
- Cost reduction potential for efficiency gains, and whether the resulting profits can be retained by the operator.
- Revenue expansion through increasing the size of the market and the associated flow of revenues.

▪ In general for private operators:

- Service and management contracts lie at the low level risk, low reward end of the spectrum.
- Lease contracts and concessions offer a somewhat higher level of risk, but offer the opportunity to increase revenues through demand growth.
- BOT and BOO contracts are high risk, with limited scope for demand growth.
- Private sales and flotations also carry significant risk, but may allow high returns depending on the terms of the regulatory regime.

Service Contracts and Management Contracts

Service and management contracts have the lowest degree of private sector involvement. These options give financial relief to governments, and some scope for efficiency improvements by the private operator.

Circumstances in which governments tend to consider service and management contracts are:

- Modest public sector deficit
- Inefficient public services
- High risk environment for private operator
- Desire to experiment with small scale privatisation
- Ideological ambivalence towards privatisation
- Low availability of regulatory capacity

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▪ These conditions generally apply to the current City environment, and as such, Service Contracts and Management Contracts are the most likely options for privatisation locally, from both the public sector and private sector perspective.

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Public Sector Perspective:

The key differences between service and management contracts is that management contracts offer somewhat greater scope and incentive for efficiency improvements, and create a slightly greater administrative burden if there is performance based remuneration.

Advantages.

The advantages of service and management contracts are:

- Minimal ideological implications given the limited responsibilities transferred to the private sector.
- Comparative light administrative and regulatory burden.
- Possible efficiency improvements through skilled private management, which may reduce subsidies or lower customer tariffs, see also disadvantages.
- Possible quality of service improvements through performance related bonuses.
- Opportunity for private operators to acquire experience and knowledge of the local infrastructure, necessary to operate a more comprehensive and demanding contract in the future.

Disadvantages

The disadvantages of service and management contracts are:

- Limited scope for service improvements, with little incentive for cost cutting measures because of the short period over which benefits can be retained by the private sector.
- Efficiency gains are likely to be significantly smaller than they might be under a more complete form of privatisation.
- Improvements may not be transferable to the public sector at the end of the contract -especially if the benefits are largely attributable to the management skills of the private operator. These will be entirely lost unless adequate training measures are incorporated into the contractual structure.
- The separation of responsibility for the operational and investment decisions between private contractors and the public body introduces the danger of coordination problems between these two areas of decisions making.

Private Sector Perceptions

For the private operator, the key difference is that management contracts offer greater autonomy, but also additional risk if the contract is structured to include performance based remuneration.

Advantages.

Such contracts are low risk given that:

- The operator’s compensation generally takes the form of a fixed fee.
- The relatively short duration of the contract reduces exposure to political risk.
- The operator is not required to make any irreversible financial commitment in the form of large investments.

Disadvantages

The rewards are limited, given the:

- Low degree of managerial autonomy
- Relatively small scope and little incentive for cost cutting
- Limited opportunity for expanding revenues.

Lease contracts and concessions

These types of contracts allow governments to obtain substantial relief from expenditure commitments, while preserving ultimate asset ownership. This is an issue with City for large commitments such as sanitary landfill development or for renewing the entire garbage collection fleet.

Both the scope and incentives for efficiency improvements by the private operator are far greater than with service and management contracts.

Circumstances in which governments tend to consider lease contracts and concessions are:

- Public sector deficit
- Inefficient public services
- Public sector desire to retain control over investment
- Unattractive environment for private investment
- Ideological ambivalence towards privatisation
- Medium availability of regulatory capacity

▪

Additional circumstances in which governments tend to prefer concessions over lease contracts are:

- Major infrastructure needs
- Public sector willingness to relinquish investment activities
- Relatively attractive environment for private investment

Public Sector Perspective:

The key differences between lease contracts and concessions are that concessions:

- Provide additional relief from public expenditure commitments associated with infrastructure development, given that the public sector is able to transfer the financing of investment to the private operator.
- May lead to more effective utilisation of resources, since they partially eliminate the coordination problems often present in lease contracts between public authority in charge of investment and the operator responsible for the operation of the system.
- Require additional non-price regulation to monitor and assess the investment decisions of the operator, especially toward the end of the concession period as the date for rebidding the contract approaches. Given the uncertainty of winning a contract renewal, the investment incentives are likely to be weakened towards the end of the contract period.

Advantages.

Lease contracts and concessions offer the following advantages:

- Significant fiscal relief, as they may permit the gradual elimination of public sector subsidies by providing a framework for a phased increase of tariffs/rates/gate fees to actual cost recovery levels. These levels are too low in the City at present for all facets of waste management, from collection and disposal costs, and includes the domestic and commercial/industrial users.
- Significant potential improvements in service efficiency as the private sector enjoys a considerable degree of autonomy and has a much greater incentive to cut costs, given the longer duration of contracts and the ability to retain sufficient efficiency savings as profits.
- Greater degree of private sector participation without transferring asset ownership to the private sector.

Disadvantages.

Lease contracts and concessions require:

- Considerable preparatory work to organise the bidding procedure, provide adequate information to prospective bidders on the state of the assets, and to preselect the bidders on the basis of their technical competence.
- A comprehensive regulatory apparatus to establish and implement a satisfactory tariff formula and to monitor the standards of service provided by the operator. Non-price regulation is particularly important given the operators possible incentive to cut costs at the quality of service.
- A favourable political environment, given the length and scope of private sector involvement, and the magnitude of tariff increases which may follow the granting of the contract.
- Incentives for the operator to carry out proper maintenance of assets, particularly towards the end of the contract period given that asset ownership will revert to the public sector.

Private Sector Perceptions

For the private operator, the key difference is that concessions incur additional investment risk. However, compensating factors are the greater degree of managerial autonomy and the avoidance of coordination problems with agencies responsible for government funded investments.

Advantages.

They provide the operator with the opportunity for relatively high returns given that:

- There will often be significant potential for efficiency improvements over the duration of the contract.
- The operator will benefit from growth in demand for the service, as well as creation of additional network connections.

Disadvantages.

A higher level of risk accompanies the potential for increased return;

- Commercial risk becomes considerable since the operator relies directly on consumer tariffs as a revenue stream. The private operator is directly exposed to the risks of demand volatility, and to the potential difficulties associated with tariff collection, especially where prices may be rising steeply to meet real costs.
- Exchange rate risk can arise since the operator is generally remunerated in local currency. However the contract may periodically allow exchange rate fluctuations to be passed on to the customers through a change in the tariff.
- Regulatory risk is likely to be substantial, given the long-term duration of such contracts.

Evaluation Criteria	Lease	Concession
Commercial risk	Risk due to cost volatility: present Risk due to demand volatility: present, as all of the Operators return comes from tariff revenue. Risk due to bad debtor: present, but may be reduced if the operator has the ability to disconnect customers.	Risk due to cost volatility: as for lease Risk due to demand volatility: as for lease Risk due to bad debtor: as for lease.
Project risk	Minimal	Exists, given the introduction of responsibility for investment financing.
Regulatory risk	Present, given the possibility of unexpected changes in tariff and quality regulation.	As for lease
Country risk	Risk due to exchange rate volatility: present, unless the tariff formula encompasses a pass through term for currency changes. Risk due to political instability: possibility of premature termination of lease contract owing to a change in government.	Risk due to exchange rate volatility: slightly greater than for lease contracts owing to the longer contract duration. Risk to political instability: greater than for lease contracts given the longer contract duration and the profiling of returns (initial outlay, followed by tariff revenue later in the contract.
Force majeure risk	Minimal given that the Operator does not own any infrastructure assets and has no rehabilitation responsibilities.	Limited, connected to the possibility of dangers to fixed assets built by the Operator during the concession.
Bidding costs	Potentially high, relative to the probability of success given the need to technically prequalify and the length of the selection process.	As for lease.
Cost reductions	Significant, given that the operator retains most of the tariff revenue and has a significant time horizon to benefit from cost cutting measures.	As for lease contracts, but with additional scope for efficiency improvements arising from more control over the investment program.
Revenue expansion	Significant, given the possibility of benefiting from demand growth, and service additional customers.	As for lease contracts

BOT and BOO contracts

These contracts are of greatest relevance where governments need to harness private capital to finance rapid expansion in the capacity of infrastructure services. They can be seen as a variant of contracting public works, where the remuneration for the operator is not a lump sum paid up front, but a risk bearing compensation scheme spread over a period of time.

Circumstances in which governments tend to consider BOT and BOO contracts are:

- Public sector deficit
- Major infrastructure needs
- Attractive environment for private investment
- Ideological ambivalence towards privatisation
- Medium availability of regulatory capacity

BOTs and BOOs have been used mainly in power generation, transport infrastructure and water treatment services.

The only real difference between BOT and BOO contracts is the ultimate asset ownership, which may make the BOT option more attractive for governments reluctant to relinquish ownership in the long term. A potential complication with the BOT contract is the loss of incentives for asset maintenance as the transfer date approaches, so additional regulatory effort may be required towards the end of the contract period.

Public Sector Perspective:

Advantages.

The principal advantages of these privatisation options are;

- They enable governments to exploit private sector finance, technology and expertise in the expansion of infrastructure.
- They are relatively uncontroversial from a political standpoint, as private sector involvement is generally limited to a specific infrastructure project.

Disadvantages.

The main problem with BOT and BOO contracts are:

- They can be relatively unattractive to the private sector, given the level of capital expenditure and the degree of risk, resulting in the need to provide revenue guarantees.
- They may require considerable preparatory work prior to the award of the contract to select bidders and provide them with adequate revenue forecasts.

Private Sector Perceptions

Advantages.

The main advantages of these options from a private sector perspective are:

- Where the plants are designed to meet demand peaks, and the revenues are consequently likely to be volatile in nature, it is not unusual for the operator to secure some form of “take or pay” arrangement with the downstream user to provide a minimum guaranteed revenue. This has the advantage of insulating the operator from demand-side risk.

- Such contracts represent a relatively small scale and self-contained involvement, compared with the operation of a complete infrastructure network. They can therefore be used to gain experience of working in a particular country or area with a view to developing further business in that country or area.

Disadvantages:

- Potentially high risk with relatively modest returns. The main risk, given the capital-intensive nature of such contracts, is the potential for construction cost over-runs.
- The financial assessment of such projects depends crucially on the quality of the demand forecasts used to project the revenue stream. Where such forecast are inaccurate, or ill conceived, the commercial viability of the project might be seriously jeopardised.
- The maximum revenue is clearly defined by the capacity limits of the plant, so any upside for the operator must come from capital and operating cost reductions.

Private Sales and Flotations

These are the ultimate forms of privatisation, with the permanent transfer of ownership of infrastructure assets along with full responsibility for management and investment.

Such privatisations have been extremely rare, probably owing to the very limited scope for competition and the social charter of the service, both of which have made governments unwilling to relinquish ownership of assets.

Circumstances in which governments tend to consider private sales are:

- Substantial public sector deficit
- Inefficient public services
- Small scale of enterprise
- Major infrastructure investment needs
- Attractive environment for private investment
- Strong ideological support for privatisation
- High availability of regulatory capacity

Additional circumstances in which governments tend to prefer flotations to private sales are;

- Large scale of enterprise
- Desire to develop capital markets and promote share ownership

Public Sector Perceptions

The principal differences between private sales and flotations are:

- Private sales may not be feasible for enterprises above a certain size. Where a single state owned monopoly is being privatised, flotation may be the only way to go.
- It may be possible in a private sale to obtain greater control over the identity of the purchaser, selected by the government. In flotations, the government’s choice is restricted to whether to undertake a domestic or international public offer.
- Domestic flotations of public utilities can have positive side effects, such as the development of stock markets and broadening share ownership.

Advantages

The advantages associated with private sales and flotations are:

- Considerable fiscal relief, by reducing current expenditure on service subsidies and avoiding additional investment expenditure. In addition significant revenues are generated from the privatisation.
- Full scope for service efficiency improvements through the introduction of the profit motive and reliance on private sector managerial expertise. The extent to which such improvements come about depends critically on the nature of the regulatory regime that is put in place at the time of privatisation.

Disadvantages.

The disadvantages associated with private sales and flotations are:

- A heavy administrative burden in the preparation of the sale. The most difficult issue is the valuation of the existing assets as a basis for an appropriate sale price for the infrastructure.
- The regulatory burden is potentially greater than for any other privatisation mechanism. Success depends to a large degree on the effectiveness of the regulatory system that is put in place.
- A possible negative political reaction, depending on the ideological climate of the country or area. This can potentially be reduced by retaining a controlling government stake, although this will also reduce the proceeds of the sale. Other mechanisms to improve political acceptability are restrictions on foreign ownership, and sales of shares to employees.
- Revenue generation as a motivation for privatisation may conflict with other objectives, such as pro-competitive restructuring of the privatised industry.

Private Sector Perceptions

The key differences between private sales and flotations are:

- Where the flotation entails the complete sale of a private enterprise with no trading restrictions, capital market competition may come in to play, whether by means of mergers or hostile takeovers.
- For the international investor, private sales provide the opportunity to acquire some degree of permanent ownership and managerial control over the utility. Flotations may only offer financial investment opportunities, with only limited scope for exercising control over the privatised enterprise.

Advantages.

The main advantages are;

- Asset ownership by the private operator gives a high degree of decision-making autonomy.
- The prospect of high rewards, given the ability to develop the infrastructure market and the scope for efficiency improvements typically present in formerly state-owned enterprises.

Disadvantages.

The two privatisation options both share the same disadvantage, from a private sector perspective, of being characterised by a relatively high degree of risk associated with:

- Regulation, a primary determinant of the operation's profitability.
- Political interference, which may arise with a change in the prevailing political ideology, and could take a variety of forms ranging from an unanticipated tightening of the regulatory regime to full scale asset appropriation.

Performance Monitoring Measures for Solid Waste Collection Operations

There are numerous criteria for performance monitoring of collection and landfill operations, depending upon the complexity of the privatisation option adopted.

The following tables present typical measures that may be incorporated, wither fully or partially, into any such future contracts.

Performance measures	What is measured ?	How is it measured ?	Where is it measured ?	How often is it measured ?	By whom is it measured ?	Basis for sanction ?
Cleanliness of service areas	Existence of litter Existence of ***clandestine*** waste piles Waste in drains Improperly placed waste bins Regularity and frequency of collection service Cleanliness around ***communal*** containers Weekly washing of communal containers Completeness of collection service – number of collection points unserved False loading of vehicle with water, stone, etc. to increase payments	Zone inspection reports Customer complaints register	Service zones	Daily	Assemblies Districts[1]	Yes
Safe disposal of collected wastes	Waste quantity delivered at official site Clandestine dumping	City-wide inspections Records at disposal site Complaints by witnesses of clandestine dumping	City-wide Disposal sites	Daily	Assemblies Districts	Yes
Customer satisfaction	Perception about cleanliness of zone Willingness to pay Willingness to participate with collection requirements	Surveys of customer satisfaction Surveys of willingness to pay	Service zones	Semi-annually	Assemblies Districts	No
Customer dissatis-faction	Complaints about improperly placed waste bins, damage of waste bins, uncollected wastes, rude behavior by collectors, poor appearance of collection vehicle and collection crew.	Zone inspection reports Records of complaints Records of follow-up of complaints Records on attainment of service frequency targets	Service zones	Weekly	Assemblies Districts	Yes
Worker productivity	Number of workers in service Waste quantity per worker each shift Absenteeism	Zone inspection reports Records at disposal sites Vehicle log books	Service zones Disposal sites	Weekly	Assemblies	No
Vehicle productivity	Number of vehicles in service Waste quantity per vehicle each shift Waste quantity per vehicle each day Vehicle ***downtime***	Records at disposal sites Vehicle log books Zone inspection reports Load inspections at landfill	Service zones Disposal sites	Weekly	Assemblies	No

[1] Each Local Government, whether it be a city, municipality, metropolitan area, or council, has its own terminology for its sub-areas. Assemblies and districts are among the terms most often used for such sub-areas.

Performance measures	*What is measured ?*	*How is it measured ?*	*Where is it measured ?*	*How often is it measured ?*	*By whom is it measured ?*	*Basis for sanction ?*
Recycling achievements	Types of ***secondary*** materials recycled Quantity of secondary materials recycled	Zone inspection reports Records from sales of ***recyclables***	Service zones Records from service provider	Monthly	Assemblies	No
Environmen-tal controls	Exhaust emission control of vehicles ***Sump tank*** control of leakage from wastes in vehicles Control of litter from vehicles Washing of vehicles	Vehicle emission inspection reports Zone inspection reports Complaints about vehicle emissions and litter	Service zones Records from service provider	Weekly	Assemblies Districts	Yes
Occupational health and safety controls	Use of gloves Use of respiratory masks Use of uniforms Tools on vehicle to load loose waste Annual medical checks Provision of vaccinations Control over size and weight of lifted loads Operational status of vehicle lights (night lights, brake lights, and reversing lights) Number of accidents Adequate accident liability coverage (insurance)	Zone inspection reports Survey of workers Medical records Accident records Insurance policies	Service zones Records from service provider	Weekly	Assemblies	Yes
Fair labor practices	Wages paid - minimum or above Payment for overtime Medical expenses coverage Vacation and holiday allowances Adequacy of work breaks Proper hiring and justifiable termination procedures	Zone inspection reports	Service zones Records from service provider	Monthly	Assemblies	Yes
Hazardous waste segregation	Refusal to collect ***hazardous*** waste Provision of special collection for household hazardous waste	Zone inspection reports Inspection of loads at disposal sites	Service zones Disposal sites Records from service Provider	Monthly	Assemblies Districts	Yes
Fuel con-sumption	Fuel records showing consumption – per kilometer and per tonne Maintenance records on engine calibration Route rationalization	Vehicle log books Workshop vehicle records Zone inspection reports Route plans	Service zones Records from service provider	Monthly	Assemblies	No

Performance measures	*What is measured ?*	*How is it measured ?*	*Where is it measured ?*	*How often is it measured ?*	*By whom is it measured ?*	*Basis for sanction ?*
Reliability	Downtime of vehicles Number of accidents Worker strikes Absenteeism, illness and accidents of workers	Vehicle log books Workshop's vehicle records Medical records	Service zones Records from service provider	Monthly	Assemblies	No
Communi-cation	Notification of service problems Continuous radio accessibility Use of designated routes so vehicles can be located	Correspondence files Zone inspection reports Radio functioning between all trucks and central offices Adherence to route plans	Letters from service provider	Monthly	Assemblies	No
Finance	Payment of government property, income, VAT, and corporate taxes, etc., as required Regular payment of fair wages and benefits to workers	Financial records Reports of independent auditor	Records from service provider	Yearly	Assemblies	Yes

Performance Monitoring Measures for Solid Waste Landfill Operations

Performance measures	*What is measured ?*	*How is it measured ?*	*Where is it measured ?*	*How often is it measured ?*	*By whom is it measured ?*	*Basis for sanction ?*
Quantity of waste received for landfill	Waste quantity per shift Waste quantity per day	Landfill inspection reports Landfill records Vehicle log books Zone inspection reports	Landfill	Daily	Assemblies Districts	No
Construction of landfill base according to design	Compaction of base soils at optimum moisture Slope of base soils Placement and sealing of imperme-able ***liners*** Placement and slope of ***leachate*** collection system	Survey instruments observed to be used during construction Construction inspection reports	Landfill	During construction	Assemblies	Yes
Construction of landfill cell according to design	Daily delineation of ***working face*** boundaries Survey of coordinates and elevations of daily ***cell*** construction, including slope of working face Continuous on-site availability of design drawings and O&M manual Closure of cell when final design elevation is reached Respect of maximum angle for side slopes Respect of minimum requirement for base slopes	Survey instruments observed to be used daily Marking up of daily progress in cell construc-tion on design drawings Topographic survey map of completed cell area when final design elevation is reached	Landfill	Daily	Assemblies	Yes

Performance measures	*What is measured ?*	*How is it measured ?*	*Where is it measured ?*	*How often is it measured ?*	*By whom is it measured ?*	*Basis for sanction ?*
Adequacy of internal access roads	Roads free of waste Roads usable in all weathers Adequate drainage to keep roads free of flooding	Vehicle log books (Operational delays of collection vehicles at landfill) Landfill inspection reports	Landfill	Daily	Assemblies Districts	No
Cleanliness of access routes to landfill	Litter Clandestine waste piles Waste in drains Improperly placed waste bins	Zone inspection reports	Service Zones	Daily	Assemblies Districts	Yes
Residents' and private haulers' satisfaction with landfill	Perception about environmental acceptability of landfill operation Willingness to pay Willingness to participate with service requirements	Surveys of customer satisfaction Surveys of willingness to pay	Area around landfill All haulers	Semi-annually	Assemblies Districts	No
Residents' dissatisfaction with landfill	Complaints about landfill noise, dust, odor, traffic, appearance and increase in ***vectors***	Inspection reports Records of complaints	Area around landfill	Monthly	Districts	Yes
Private haulers' dissatisfaction with landfill	Complaints about landfill noise, dust, odor, traffic, appearance Complaints about delays suffered by collection vehicles at landfill, damage to vehicles and tires, inappropriate tipping fee charges, operation of ***weighbridge***, difficulty in driving to working face	Inspection reports Records of complaints Records of follow-up to complaints	All haulers	Monthly	Assemblies	Yes
Worker productivity	Number of workers in service Waste quantity per worker and shift Absenteeism	Landfill inspection reports Records at landfill	Landfill	Weekly	Assemblies	No
Equipment productivity	Number of equipment units in service Waste quantity per equipment unit each shift Waste quantity per equipment unit each day Equipment downtime	Landfill inspection reports Records at landfill	Landfill	Weekly	Assemblies	No
Recycling achievements	Types of ***secondary*** materials recycled Quantity of secondary materials recycled	Landfill inspection reports Records from sales of recyclables	Landfill	Monthly	Assemblies	No

Performance measures	***What is measured ?***	***How is it measured ?***	***Where is it measured ?***	***How often is it measured ?***	***By whom is it measured ?***	***Basis for sanction ?***
Environmental controls	Control of equipment exhaust emissions Windblown litter Dust Noise Control of area of ***working face*** Daily compaction of deposited waste Use of adequate daily cover at the end of each day's work Washing of equipment Flies, rodents, birds Leachate treatment and discharges Control of landfill gas Drainage of surface water – adequacy and maintenance Presence of unauthorized people or animals Presence of ***hazardous*** wastes Recording of all collected waste loads Provision and maintenance of an attractive vegetative ***buffer*** around operational areas	Equipment emission inspection reports Landfill and area inspection reports Complaints about emissions, noise, dust and litter Fly count, rodent count, bird count Pesticide application records Size of daily refuse cell Monitoring of ***leachate*** treatment plant discharges Groundwater and surface water monitoring Monitoring of landfill gases Records of incoming waste loads	Landfill and surrounding area	Weekly	Assemblies Districts	Yes
Hazardous waste segregation	Refusal to accept industrial or commercial hazardous waste Provision of special collection and storage area for household hazardous waste	Landfill inspection reports Inspection of loads at disposal sites	Landfill Disposal sites Records from service provider	Monthly	Assemblies	Yes
Fair labor practices	Wages paid - minimum or above Payment for overtime Medical expenses coverage Vacation and holiday allowances Adequacy of work breaks Proper hiring and justifiable ***termination*** procedures	Landfill inspection reports Survey of workers	Landfill Records from service provider	Monthly	Assemblies	Yes

Performance measures	What is measured ?	How is it measured ?	Where is it measured ?	How often is it measured ?	By whom is it measured ?	Basis for sanction ?
Occupa-tional health and safety controls	Use of gloves and boots Use of respiratory masks Functioning air conditioning on all equipment units Adequacy of roll-bars Replacement of filters on air conditioners Use of uniforms Annual medical checks Provision of vaccinations Control over size and weight of lifted loads Number of accidents Health and safety training of all landfill personnel Practice of emergency and evacuation procedures Continuous presence and function-ality of fire protection and other emergency equipment Continuous on-site presence of health & safety manual Posting of health & safety telephone numbers Adequate accident liability coverage Operational night-time illumination Reversing lights and audio signals on all equipment	Landfill inspection reports Survey of workers Medical records Accident records Inspection of equipment units Insurance policies	Landfill Records from service provider	Weekly	Assemblies	Yes
Fuel consumption	Fuel records on consumption – per hour and per tonne Maintenance records on engine calibration	Equipment log books Equipment maintenance reports	Landfill Records from service provider	Monthly	Assemblies	No
Reliability	***Downtime*** of equipment Number of accidents Number of slides, erosion events Worker strikes Worker illness and accidents	Equipment log books Landfill inspection reports	Landfill Records from service provider	Monthly	Assemblies	No
Communica-tion	Notification of service problems Continuous accessibility by radio	Correspondence files Landfill inspection reports Radio functioning between landfill and central offices	Letters from service provider	Monthly	Assemblies	No
Finance	Payment of government property, income, VAT, and corporate taxes, etc., as required Regular payment of fair wages and benefits to workers	Financial records Independent auditor reports	Records from service provider	Yearly	Assemblies	Yes

Appendix L - Evaluation and Diagnosis

Background

The monitoring and evaluation of the solid waste management program include detailed recording and assessments of the day-to-day operations. It is important to consider all costs incurred, and what category they fall in to. This is important to assess where resources need to be allocated, or conversely, where program changes might be able to reduce costs.

Secondly, both qualitative and quantitative evaluations of the working of the system need to be made. The assessment of the success of the ISWMP depends upon records of the amount of solid waste collected, frequency of collections of both secondary and primary secondary waste points, cleanliness of the various parts of the systems, and general effectiveness of the program.

Monitoring and Evaluation spreadsheets required would include as a minimum:

- Monthly Landfill Operations: Costs and Evaluation
- Monthly Secondary System: Costs and Evaluation
- Monthly Primary Collection: Costs and Evaluation
- Monthly Primary Storage: Costs and Evaluation

The costs and evaluations information needs to be recorded on a daily basis and turned in to the MSW manager on a weekly basis. The manager should summarize the monthly information and prepare a report to the Mayor on a monthly basis.

Steps in Implementation

A ISWM Plan needs to be flexible and capable of modification and adjustment. Over time, plans need to take into account external influences such as availability of funding and resources and interaction with other areas of City activity and policy. The plan must also be strongly managed to ensure successful implementation.

The action plan should focus a short-term action plan and a longer ten year action plan period. The short-term action plan could be based on a 12-month period with two streams of activity.

- Immediate actions which are required to ensure progress could be made during the first year of the strategy;
- Building for the strategy which will involve a period of consensus building with the aim to bring to politicians firm proposals for implementation of the long term strategy;

Implementation of the ISWM plan is likely to require the responsible authority to adapt its structure and resources to suit changing managerial requirements as ISWM projects are developed. Having developed the plan, the process of practical implementation must begin and it is important that the City follows through a logical sequence of steps to ensure successful implementation.

There are a number of examples of good practice that will aid implementation of ISWM plans, particularly for municipal solid waste agencies in low-income countries where comprehensive technical and institutional approaches have not previously been implemented. These include:

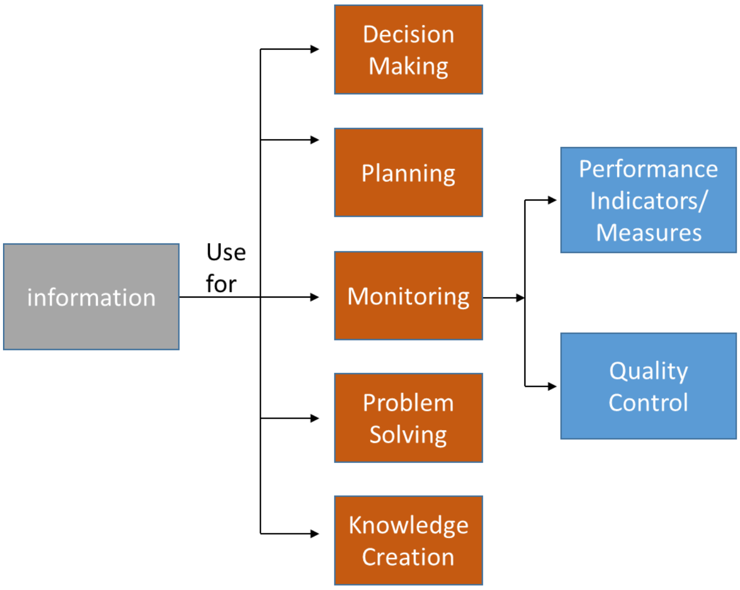
- Communication and evaluation is vital between the City and donor agencies, supervising consultants and among on-the-ground parties in the project are. In many cases inadequate communication and consultation cause project delays.

- Particular attention needs to be paid to the writing of procurement specifications for vehicles and equipment. The need to select appropriate MSW collection vehicles and other equipment has previously been reviewed.
- It is important a solid waste management expert or Working Group (Reporting to the ISWM Committee) is assigned to the implementation stage of the plan. Where the plan involves implementation of a number of technical projects (e.g. development of transfer stations and landfill sites) it may be appropriate for an expert to be on hand at each project location. The expert (or project officer) may well be assigned to the project area for periods of up to several years. In this way continuity is guaranteed between the project planning and project implementation stages.

The process of ISWM action plan implementation must be monitored and regularly reviewed in order to identify weaknesses in the program and to identify actions to update the process. The following sections discusses this aspect of plan evaluation using indicators and measures of ISWM performance and with reference to specific worked examples of implementation monitoring.

Performance Monitoring For Solid Waste Management Services

Throughout this Plan the need for collecting and utilising information has been stressed. Large amounts of data are being collected and processed into useable information. But it has to be kept in mind that information *per se* is only valuable when it is focused and being used to a specific end. The diagram below shows the various possible uses of information.



- **Figure Use of Information**

Why Improve Performance Monitoring?

The monitoring tools frequently used to assess performance of the ISWM system are, among others,

- visual observations;
- general feed-back from the work force; or
- customer complaints.

Such observations can lead to inaccurate and unquantifiable results and present an insufficient basis for making planning decision for system improvement. Additionally, at first

- How effective is the ISWM service that is being provided? Meaning: To what extend does the system presently in place satisfy the need for a ISWM service and where is improvement required?

- How efficient is the ISWM service provided? Meaning: Are we using the available resources in the best possible way and how can we improve their use?

sight seemingly obvious reasons for an unsatisfactory performance of a ISWM function, may, through a more detailed and formal analysis, turn out to not be the reasons at all for the problems.

Lack of funds, for example, is often seen as the reason for low performance of components of the ISWM system in a City. A detailed analysis might reveal that performance could be much improved through improved routing, staffing, more effective management or use of alternative vehicles. An improved planning process, also, will most likely lead to increases in effectiveness and efficiency of the service.

Monitoring the performance of a municipal ISWM system has a number of goals:

- To closely observe the quality of the ISWM service provided in order to maintain or improve service quality;
- To encourage the efficient use of available resources;
- To relate the outputs of a service to inputs (and ultimately their cost);
- To improve service quality overall and relative to cost;
- To enforce accountability of service providers;
- To put downward pressure on cost of service provision;
- To compare and assess services provided against the targets set out in municipal ISWM plan;
- To provide information on which management can make policy and management decision about the service;
- To compare the service provided between two or more sub-municipalities or municipalities in a regional association;
- To compare the quality of service provision in a City with a previous month or year;
- To monitor and evaluate the quality of services provided by private service contractors.

Performance analysis is a key element in the process of providing good quality, value-for-money services. It is a process by which the efficiency of a service can be monitored and compared with similar services offered elsewhere or at an earlier time. Performance review needs to be an integral part of any ISWM process.

The two central questions of ISWM performance monitoring are:

Effectiveness and efficiency are closely related, increases in efficiency lead in most scenarios to increases in effectiveness, provided resources are not cut simultaneously.

In summary,

- we need to know whether we use our money, people and equipment in the best possible way to serve the greatest amount of customers at the highest possible standards, and
- we need to know where the weak points in our present system are to enable us to take steps for implementing improvement.

Definitions of Performance Indicators and Measures

In order to determine the performance of a municipal solid waste management system in general, and its individual components in specific, data and information called “performance indicators” and “performance measures” of ISWM are used.

Performance Indicators – are quantitative data related to ISWM services such as:

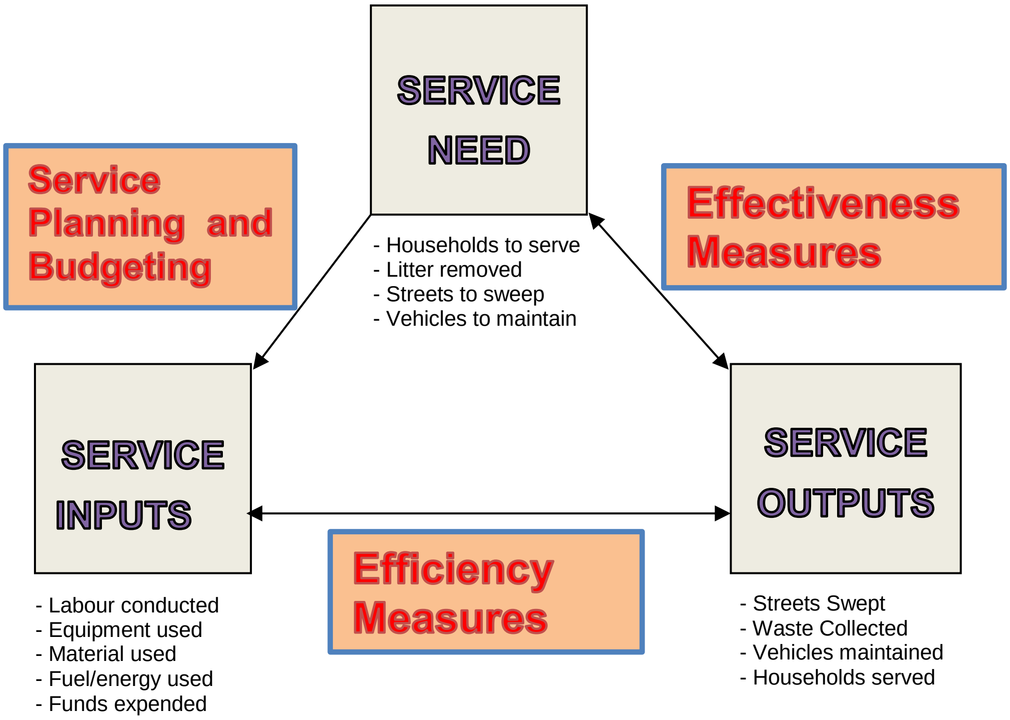
- Number of businesses to be served,
- Kilometres of streets to collect from, or
- Number of employees in service.

Performance Measures – are the result of processing indicators, by relating them to either time or cost, and are the principle tool for assessing the performance of the system under review. For example:

- Cost per ton disposed;
- Number of streets swept per hour etc.

In order to obtain reliable performance measures, the following is needed:

- Accurate, reliable and regular data collection;
- Accurate and reliable cost accounting procedures;
- Weighing of wastes;
- Availability of service operating detail;
- Units to which the performance indicators can be related (e.g. costs per 1000 of population served, costs per household served, time per tonne of waste collected etc.)



- **Indicators and Performance Measures**

Performance Indicators and Measures for ISWM System Analysis

While there are a number of specific performance measures that can be used to assess the individual functional elements or any ISWM system, there are also measures that help gauge the overall performance of the ISWM sector.

As with the performance measures especially focusing on particular functional elements of the system, these general sector performance measures have to be compiled at regular intervals and then be compared over time to enable planners to monitor and detect positive and negative trends in the sector. If for example the billing index (Billing index (%): Number of commercial premises that receive bills divided by number of premises served multiplied by 100) goes down steadily over time, this could be the signal for the ISWM department to revisit the existing billing system for commercial/industrial waste and find ways of improving it.

The following is a summary overview of performance, management and general measures related to ISWM.

- **Overview of performance, management and general measures related to ISWM**

Issues	Indicator
Health	Morbidity and mortality rates due to illnesses related directly or indirectly, with solid wastes, such as, cholera, tetanus, dengue fever, teniasis, hepatitis etc., by urban and peri-urban zones.
Economy	Number of workers employed in the solid wastes sector.
	Number of large, middle, and small companies involved in urban sanitation (fabrication of mechanical equipment, contracting firms of urban sanitation, recycling industries, consulting agencies, maintenance shops, and others)
	Weight percentage of solid wastes recovered over the total of solid wastes generated.
	Increase in the number of tourists relative to the previous year.
Environmental Conditions	Weight percentage of SW collected over SW generated.
	Weight percentage of SW properly disposed over SW collected.
Social Conditions	Percentage of peri-urban population provided with collection services over total peri-urban population.
	Annual increase/decrease in separators in final disposal (last 5 years).
	Number of community health education programs.
Solid Wastes Generation	Per capita production (kg/person/day): Total tonnage of solid wastes collected per day divided per thousand served.
Recovery	Tonnage of solid wastes recovered per day divided by tonnage of solid wastes generated per day multiplied by 100.
Coverage and Access to Urban Sanitation Services	Urban collection: Urban population served divided by total urban population multiplied by 100.
	Peri-urban collection: Peri-urban population served divided by total peri-urban population multiplied by 100.
	Urban composition: Peri-urban population divided by total urban population multiplied by 100.
Management, Operation and finance:	Number of employees of sanitation service per thousand persons served.
	Rate or tariff of urban sanitation monthly average per home, in Local currency.
	Payment capacity: minimum monthly rate or tariff of urban sanitation versus income or monthly minimum salary (%).
	Budget of sanitation service versus total municipal budget (%).
	Capital investments versus total budget of urban sanitation service (%).
	Income generation through tariffs and rates versus total cost of the service (%).
	Efficiency of collection (%): Value collected divided by value billed multiplied by 100.
	Unit cost of sanitation service (Pesos/ton): Sum of all direct annual costs, indirect costs, social benefits, contract payments, financial costs, depreciation and others divided by tonnage received bat site of final disposal per year.
Other Recommended Indicators:	Coverage of street sweeping (%): length of paved streets swept divided by the total length of paved streets multiplied by 100.
	Efficiency of collection equipment maintenance (%): Total equipment divided by number of equipment in operation + reserve equipment + equipment in maintenance multiplied by 100.
	Number of bills paid per month versus total number of bills issued per month multiplied by 100.
	Billing index (%):

Performance Measures for SW Collection

Examples of performance measures for collection services are shown below. A comprehensive listing is also provided of the basic data that any City department wanting to measure the performance of its collection service can use, and the recommended frequency of data collection for each specific item.

All of the indicators highlighted can be used to compare performance on a year-by-year basis within the City and with other similar municipalities. However, the validity of any of these approaches depends on the availability and accuracy of the authority's information management system, and its ability to provide reliable cost and revenue information, and basic data on waste tonnage, or other measures of service provided. Also, comparisons of performance must take into account local geographic or industrial conditions and the standards of service provided.

Service Provision	Measures
	Tonnes/week for each operator
	People served/week/operator
	Vehicles availability and off road time
	Vehicles mileage/day
	Vehicles operating hours
	Reserves as a proportion of vehicle fleet
	Frequency of collection
	% of population receiving collection services
	Number of complaints received from public

Financial Performance	Measures
	Total collection cost/tonne or household
	Vehicle cost/tonne or household
	Labour costs/tonne or household
	Cleansing tax receipts/tonne or household
	Total tax collected as a percentage of revenue
	Revenue collected against cost of collection service
	Revenue collected from commerce and industry

- **Main Performance Measures for the ISWM Collection Service**

- **Data Collection Requirements for Municipalities to Compile and Report Performance of the Solid Waste Collection Services**

		Recommended Frequency of Data Collection
	Overall Service Provision	
1.	Tonnage collected – weighed or estimated vehicle loads	daily
2.	Population or number of households in area of City waste collection responsibility	yearly
3.	Population or number of households actually collected from	yearly
4.	Frequency of collection services by type, domestic, commercial, clinical etc.	yearly
5.	Number of vehicles in City fleet by type, size, age, make, registration number	monthly
6.	Name of person responsible for solid waste collection service	yearly
7.	Management structure and numbers of persons involved in collection service designated: collection: administration: maintenance	yearly
8.	Number of complaints received from public; nature of complaint and action taken	weekly
	Operational Information	
1.	Number of collection vehicles operating and total vehicle hours worked	daily
2.	Number of persons operating collection service designated: collection administration; maintenance	daily
3.	Vehicle operational records by daily driver worksheet: • Identification of vehicle and driver • Vehicle hours working • Vehicle mileage covered • Vehicle fuel used • Number of vehicle trips to disposal sites • Number of operating personnel in vehicle crew.	daily
4.	Vehicle operating costs by maintenance log for each vehicle: • Identification of vehicle • fuel and oil • tires • routine servicing • maintenance and repairs, recording description, cost and time to complete: • engine and transmission and brakes, hydraulic systems chassis and suspension, body work and glass, other	weekly
	Financial Information	
1.	Vehicle operating costs by vehicle and by fleet	monthly
2.	Labour costs: payroll plus overheads, consumables etc.	monthly
3.	All other solid waste collection department costs	monthly
4.	Total costs presented as full cost of the collection operation: • per ton of waste collected • per person/household served • per number of persons employed in solid waste collection	yearly
5.	Revenues collected from Tax	Twice yearly
6.	Revenues collected from commercial and industrial waste producers • As a total sum • As a revenue per ton collected	Twice yearly

Assessment of Solid Waste Disposal Services

Disposal operations should also be monitored to ensure that manpower and other resources are efficiently and effectively managed at all sites.

Efficiency is again measured by computing unit costs for each operation. However, as with all performance measures, care must be taken to ensure that comparisons are made on a consistent basis. As with collection, the reliability of all performance measures depends on the quality of the information on which they are based: for example, weighing of wastes is essential. Comparisons must be made on a consistent basis, taking into account any geographical or other differences between sites.

It must be remembered that in many countries that, current disposal costs are negligible due to the prevalence of open dumping practices. As such, higher operating costs will result, and therefore funding is essential if services are to improve.

The main performance measures for assessing disposal services are highlighted below.

Service Coverage

Tonnes of waste delivered

Density of waste placed

Quantity of leachate treated

Quality of treated effluent

Frequency of daily cover use

Number of complaints received from public

Financial Performance

Total disposal cost/tonne

Total operational cost

Specific operational cost (staff, plant,

environmental management, materials, daily cover)

Income from sales of recovered materials

Transfer costs (where appropriate)

- **Main Performance Measures for the ISWM Disposal Service**

The following Table provides more detail on this issue.

- **Data Collection Requirements for ISWM Disposal Services**

		Recommended Frequency of Data Collection
	Overall Service Provision	
1.	Disposal site locations and type of operations; landfill, incineration, recycling plant etc.	yearly
2.	Tonnage received-weighed or estimated vehicle loads and by waste type and by collection authority: • Domestic • Domestic and commercial • Commercial only • Clinical • Industrial – what type of waste and origin	daily
3.	Vehicles equipment and plant utilised in disposal operations by type, size, age, make, registration number	monthly
4.	Name of person responsible for solid waste collection services	yearly
5.	Management structure and numbers of persons involved in disposal service designated	yearly
6.	Number of complaints received from public: nature of complaint and action taken	weekly
7.	Environmental management at landfill and transfer station sites: pollution incidents, breaches of license conditions, remediation actions, frequency of environmental monitoring	weekly
	Operational Information	
1.	Number of vehicles or equipment operating and total vehicle or equipment hours worked	daily
2.	Number of persons operating disposal or MRF services designated operational administration maintenance	daily
3.	Vehicle or equipment operational records by daily driver worksheet: • Identification of vehicle or equipment and driver • Vehicle or equipment hours working • Vehicle or equipment hours in-operational for maintenance • Vehicle or equipment fuel used	daily
4.	Vehicle or equipment operating costs by maintenance long for each vehicle: • Identification of vehicle or equipment • fuel and oil • tires or tracks • routine servicing • maintenance and repairs, recording description, costs and time to complete: engine, transmission, brakes, hydraulic systems, chassis, suspensions, bodywork, glass, other.	weekly
5.	Leachate management installed on site: • Quantity produced per day – estimated or measures • Type of treatment or disposal • Costs of operation	yearly monthly
6.	Cover material used on site: • how often spread over waste • estimated volume of material used	yearly
7.	Recycling and resource recovery systems and programs in operation by City or private sector materials recovered and method of recovery	yearly
8.	Transfer stations and bulk transportation operations Type, number of vehicles, tonnage transported and mileage covered	yearly

9.	Is there a weighbridge in consistent use at the landfill sites: Records kept of tonnage of waste being disposed.	yearly
	Financial Information	
1.	Plant operation costs for each site	monthly
2.	Labour costs: payroll plus overheads, consumables, etc.	monthly
3.	All other solid waste disposal departmental costs	monthly
4.	Total costs presented as full cost of the disposal operation: • per ton of waste received • per person/household served • per number of persons employed in solid waste disposal	yearly
5.	Revenues from municipalities using disposal service (proportion of Cleansing Tax)	twice yearly
6.	Revenues from receipt of commercial and industrial wastes	monthly
7.	Revenues or grants from any other sources	twice yearly
8.	Revenues from recycling and resource recovery operations	monthly
9.	Transfer and bulk haulage costs if applicable	monthly
10.	Capital repayments on loans for solid waste management projects specify	monthly

Dealing with Information: Management Information System (MIS)

As discussed above, in order to move a waste management system to better performance by increasing its efficiency and effectiveness, the system currently in place has to be assessed and then be continually improved through planning and operational management processes.

A significant part of the resources problem that confronts local government stems from a lack of concern and knowledge about costs, quality and accountability. These problems stem, in part, from the inefficient use of existing resources, and used more efficiently, the same resources could provide better and more comprehensive services. With more, or better-used, information on the ISWM system, its inefficiencies can be removed or diminished. The tool to use to this end is called a Management Information System.

> A Management Information System (MIS) is defined as a system in which information is collected, stored, organised, processed, utilised and disseminated.
>
> A MIS is an on-going process, requiring a regular stream of data to be collected and fed into it. It also requires a medium for storage and processing data.

Benefits of a functioning MIS include:

- Though the provision of accurate, relevant, comparable and up-to-date management information, resources can be costed and matched against outputs delivered;
- Annual budget proposals can be made on the basis of actual needs, taking account of changes in service characteristics, costs and revenues;
- Overall revenue requirements can be better established and politically and socially acceptable charging schemes be devised;
- Revenue collections can be improve through better mobilisation of resources;
- Financial performance can be monitored against objectives;
- Investment planning and decision making procedures can be improved; and

- Information about the total cost and cost effectiveness of service provision give the ISWM department a basis to judge performance on a comparative basis against specified criteria, and gives a guide to future investment requirements.

The collection of management information is not an end in itself. Performance indicators must provide signals for action. Data gathering is a costly and time consuming exercise and if the following basic points are not considered in detail before the data gathering begins, it is possible to end up with large amounts of data, that are either unnecessary or cannot be interpreted.

There are different reports needed that summarise the result of performance measuring. For general planning purposes, and as a basis for updates of the ISWM plan, annual or bi-annual summary reports will be sufficient.

At the other end of the scale, routine management reports will be needed for upper level ISWM managers on a weekly or monthly basis, while operational managers will need daily indication of the progress of general operations.

In summary, as the Municipal support systems improve, the ISWM data should be placed on the MIS.

Revising and Updating the ISWM Plan

The process of ISWM plan review should be regularly undertaken in a planned and scheduled fashion. A regular review of the progress with implementation of the action program is necessary to ensure that targets are being met in terms of service delivery, financial performance et.

The action plan needs to be flexible and there may be a need for the implementation program to adapt to changing circumstances and conditions, such as, for example, changes in the waste stream (e.g. through increased affluence), development of new technologies to treat and dispose of waste, or institutional changes.

A program of regular review can help to increase the City's knowledge and understanding of the ISWM system through a process of interactive review, problem diagnosis and development of remedial action programs.

Appendix M - Typical Facility Drawings

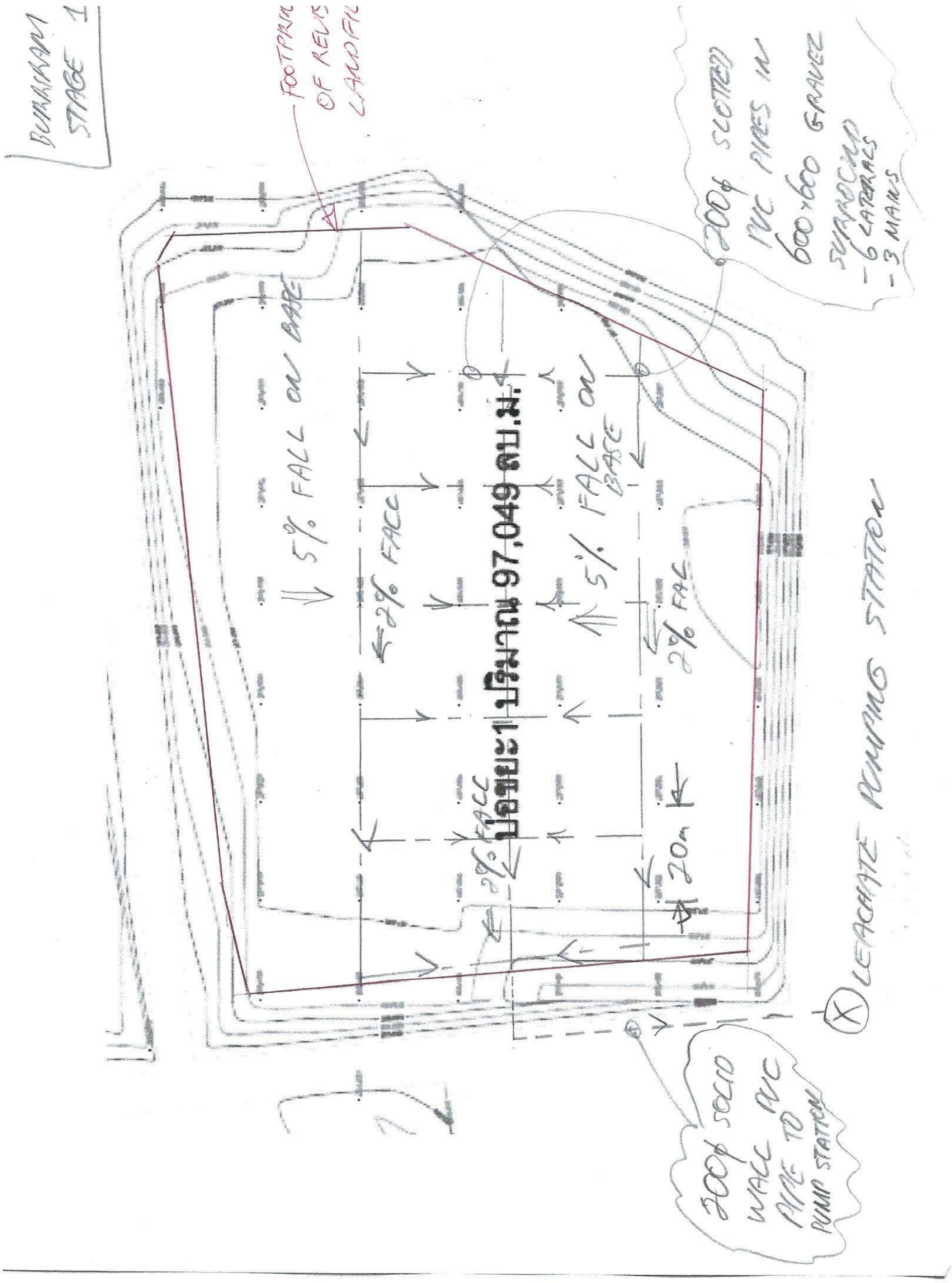

STAGE 1: 3 YEARS (UNTIL 2018)

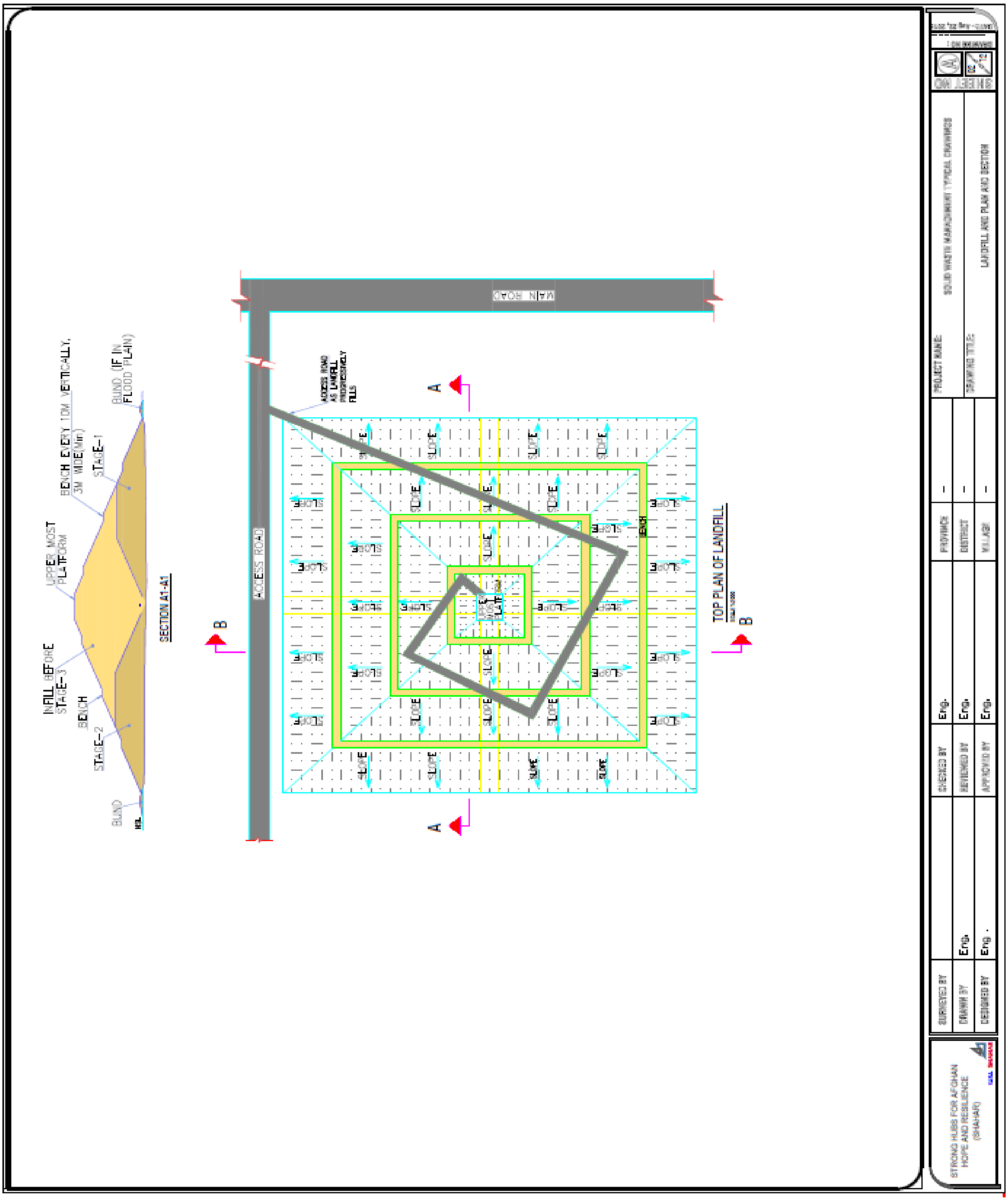

STAGE 2: + 3 YEARS (UNTIL 2021)

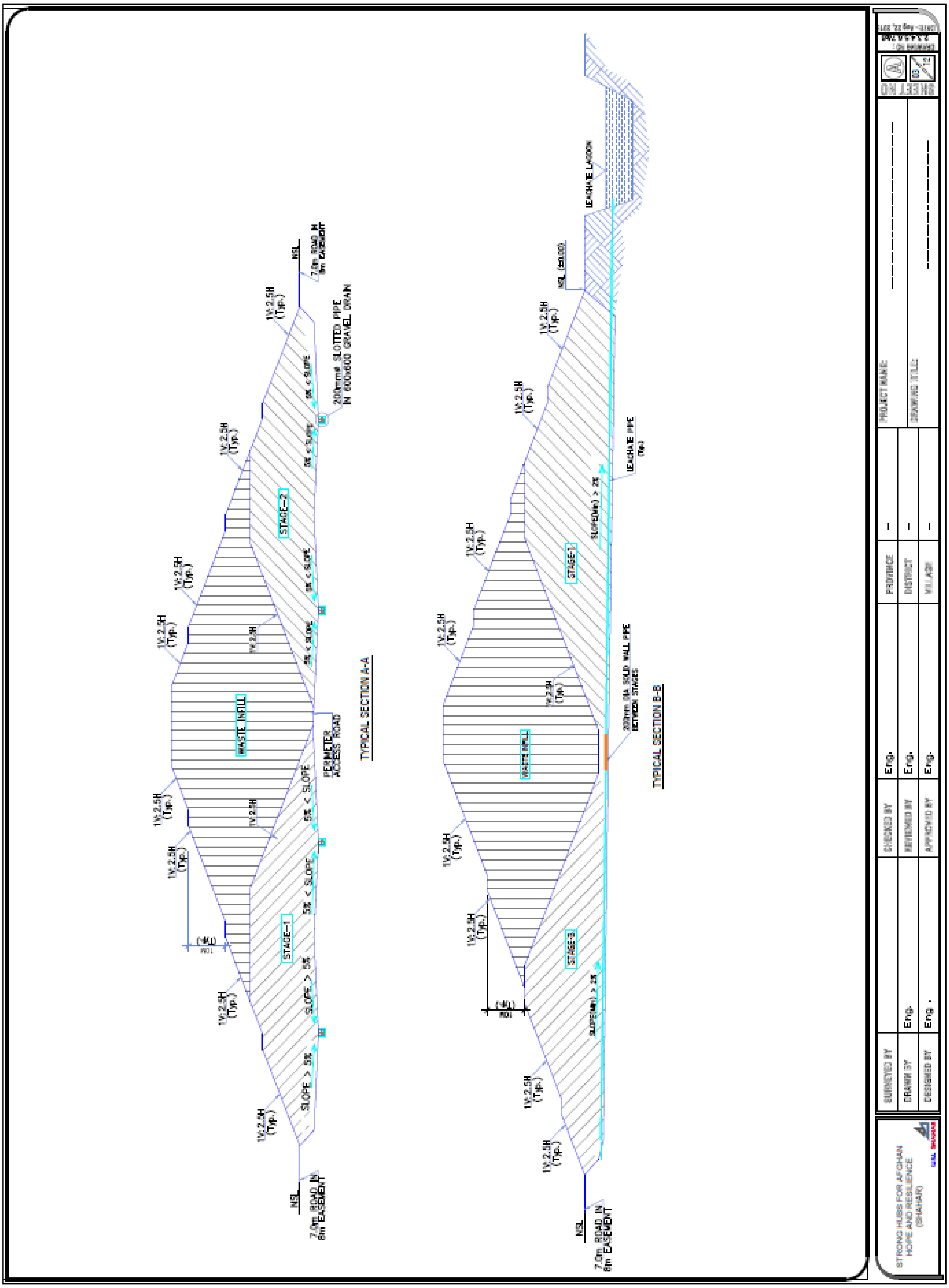

OVERTOPPING STAGE 1 AND 2 –
+3 YEARS (UNTIL 2024)

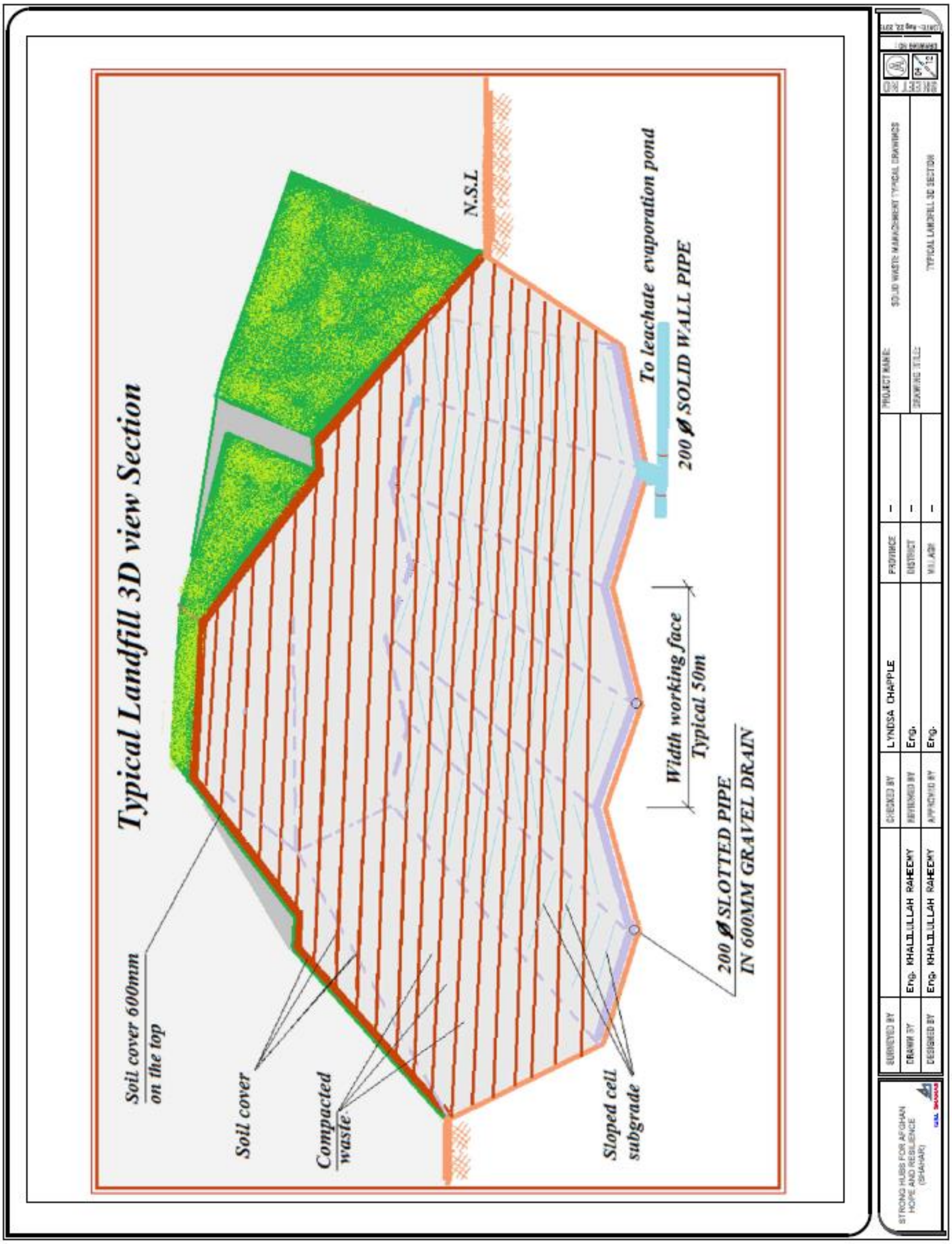

STAGE 3: + 11 YEARS (UNTIL 2035)

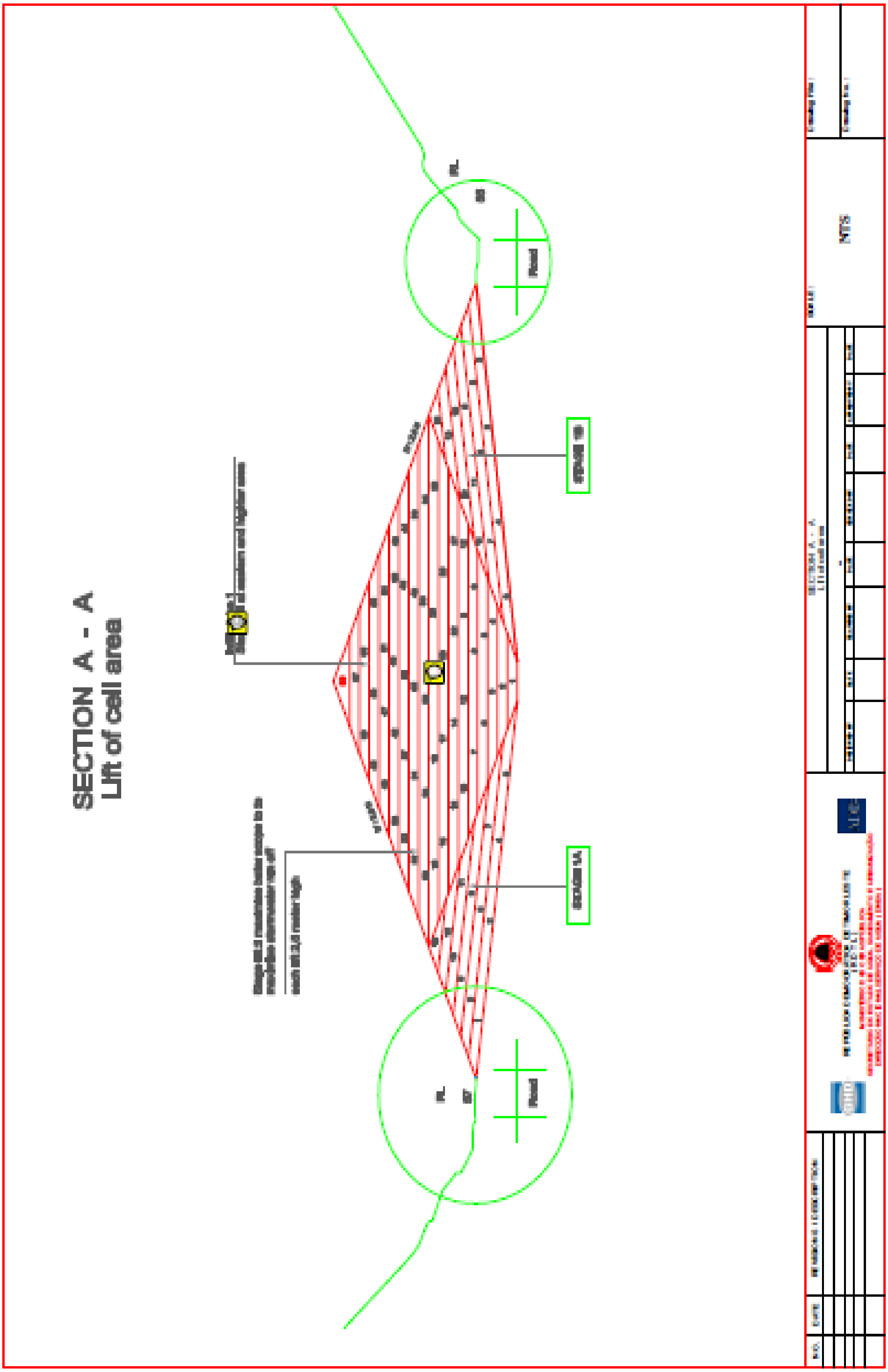

TOTAL SITE: ++10 YEARS
(UNTIL WELL AFTER 2045)


BURIRAM STAGE 1
FOOTPRINT OF REVIS LANDFIL
5% FALL ON BASE
2% FALL
5% FALL ON BASE
2% FAL
2% FALL
20m
บ่อขยะ1 ปริมาณ 97,049 ลบ.ม.
300φ SLOTTED PVC PIPES IN 600x600 GRAVEL SURROUND
- 6 LATERALS
- 3 MAINS
LEACHATE PUMPING STATION
300φ SOLID WALL PVC PIPE TO PUMP STATION


MAIN ROAD
ACCESS ROAD
TOP PLAN OF LANDFILL
SECTION A1-A1
UPPER MOST PLATFORM
BENCH EVERY 10M VERTICALLY, 3M WIDE(Min)
INFILL BEFORE STAGE-3
STAGE-1
STAGE-2
BENCH
BUND
BUND (IF IN FLOOD PLAIN)
SLOPE
STRONG HUBS FOR AFGHAN HOPE AND RESILIENCE (SHAHAR)
PROJECT NAME:
SOLID WASTE MANAGEMENT TYPICAL DRAWINGS
DRAWING TITLE:
LANDFILL AND PLAN AND SECTION
SURVEYED BY
DRAWN BY
DESIGNED BY
CHECKED BY
REVIEWED BY
APPROVED BY
PROVINCE
DISTRICT
VILLAGE
SHEET NO


TYPICAL SECTION A-A
TYPICAL SECTION B-B
WASTE INFILL
STAGE-1
STAGE-2
1V:2.5H (Typ.)
PERIMETER ACCESS ROAD
7.0m ROAD IN 8m EASEMENT
NSL
LEACHATE LAGOON
LEACHATE PIPE
200mm¢ SLOTTED PIPE IN 600x600 GRAVEL DRAIN
STRONG HUBS FOR AFGHAN HOPE AND RESILIENCE (SHAHAR)


Typical Landfill 3D view Section
Soil cover 600mm on the top
Soil cover
Compacted waste
Sloped cell subgrade
N.S.L
To leachate evaporation pond
200 Ø SOLID WALL PIPE
Width working face Typical 50m
200 Ø SLOTTED PIPE IN 600MM GRAVEL DRAIN
STRONG HUBS FOR AFGHAN HOPE AND RESILIENCE (SHAHAR)
SURVEYED BY
DRAWN BY Eng. KHALILULLAH RAHEEMY
DESIGNED BY Eng. KHALILULLAH RAHEEMY
CHECKED BY LYNDSA CHAPPLE
REVIEWED BY Eng.
APPROVED BY Eng.
PROVINCE
DISTRICT
VILLAGE
PROJECT NAME: SOLID WASTE MANAGEMENT TYPICAL DRAWINGS
DRAWING TITLE: TYPICAL LANDFILL 3D SECTION


SECTION A - A
Lift of cell area
NTS