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SECTION 1: PROGNOSIS ON ENVIRONMENTAL EFFECTS IN THE TARGETED REGIONS

1.0. INTRODUCTION

The aim of WP 5 is to evaluate the implications of the proposed waste management measures on the target countries as identified in the previous work packages (WP2, WP 3 and WP 4). The objective of SECTION 1 of task 5.1 is to assess the environmental effects of the measures proposed (e.g. in guides for selection and implementation of ISWMS, and policy guidelines and recommendations) in targeted countries. The proposed measures will be assessed in terms of burden and benefits on the environment. A good waste management plan for the target countries must aim at reducing pollution and conserving natural resources. The activities under this task should demonstrate that the proposed measures will play a major role in reducing impacts of waste management on air, soil and water, considering the following waste categories: municipal waste e.g., residual waste, organic waste, plastic, metal; E-waste; Industrial waste; and Healthcare waste. Life cycle assessment of the waste streams from temporary storage to collection and transport through treatment, disposal & recycling. Some criteria are selected to evaluate the environmental impacts of the proposed measures. These criteria include abiotic depletion, GHG emissions and climate change, acidification, eutrophication, energy consumption, use of water and chemicals in the waste treatment process, and human toxicity effects.

2.0 Comparison of environmental impacts of the current and the proposed collection methods

2.1. Current method

2.1.1 Collection of unsorted waste by informal and formal sector

As described in deliverable 3.1 the collection of waste in the target countries should be optimized balancing out cost factors and convenience elements for the consumer. Separation should be promoted as far as possible at the source of the waste generation and circles for re-integration should be kept as small as possible. The collection system depends on population density, existing infrastructure and on the type of waste to be collected. According to deliverable 2.1, several collection systems co-exist in the target countries: door to door collection or grouped collection with containers. Waste collection is carried out by municipalities, community-based organisations, non-governmental organizations, private companies or unorganised informal private sector operators, using mechanical equipment, or animal- or man-driven carts. There are usually no collection routes with regular collection frequencies. Poor neighbourhoods, suburbs of large cities and rural areas are hardly or not at all covered by waste collection systems. In areas where there are no organized collection systems, the inhabitants may manage their waste by themselves by scattering them, burning them or using them as backfill for buildings. Waste is rarely sorted at source but collected and disposed of as mixed waste. Also waste with special needs like hazardous domestic waste is mingled with the other waste. Sorting at source is only conducted by informal waste buyers who collect waste containing valuable materials like e-waste, metal scrap, plastic, paper and cardboard, or through scavenging from the dumps.

Generally, solid waste collection in the target countries is characterized by inefficient and unreliable methods, as well as insufficient coverage. The collection and sorting itself does not lead to significant environmental impacts, compared to waste treatment methods like open burning and dumping. However, collection and sorting with the possibility to treat waste in an adequate way will massively reduce the overall negative impacts of the wastes. As a result of non-sorting of waste, the economic value of some valuable resources is lost as they cannot be recycled. The insufficient coverage of waste collection results in losses of resources, since waste that is not collected cannot be recycled. The absence of sorting at source also impedes valuable resources to enter recycling processes and replace raw materials from primary production. Non-collected waste may release hazardous substances and cause soil and water pollution through leaching by rainwater, especially for hazardous waste, as well as air pollution when waste is burnt (spontaneous combustion or induced burning). Organic waste that is not properly collected and treated decomposes emitting high quantities of methane. Also the loss of resources through non-collection leads indirectly to the release of greenhouse gases, since the production of secondary raw materials is less energy-intensive than the production of primary raw materials. Emission of methane contributes to global warning. Combustion of non-collected wastes can lead to production of acid gases (i.e., sulphur (IV), nitrogen (IV) and carbon (IV) oxides) which can result in acidification of the environment during wet deposition, as well as emissions of carcinogenic polyaromatic hydrocarbons. Uncontrolled combustion especially of e-waste can result in emissions of dioxins and furans, which are highly toxic. The leaching of nutrients particularly phosphorus and nitrogen from non-collected waste by rainwater may pollute ground and surface water resulting in eutrophication. Human toxicity is caused by the release of hazardous substances due to the non-collection of hazardous waste like e-waste, healthcare waste and household hazardous waste. Inappropriate collection methods may affect the health of people handling the waste through skin contact, injury by sharp objects and inhalation of gases emitted by the waste.

Human toxicity associated with impact of hazardous wastes includes (Njoroge, 2010), skin disorders – fungal infections, allergic dermatitis, pruritis and skin cancer; respiratory abnormalities – bacterial upper respiratory tract infections (pharyngitis, laryngitis and rhinitis), chronic bronchitis and asthma; abdominal and intestinal problems – bacterial enteritis, helminthiasis, amoebiasis, liver cancer, kidney and renal failure; dental disorders – dental carries and dental pain; ear infections – bacterial infections; skeletal muscular systems – back pain; central nervous system – impairment of neurological development, peripheral nerve damage and headaches; eye Infections – allergic conjunctivitis, bacterial eye infections; blood disorders – Iron deficiency anaemia; others – malaria, chicken pox, septic wounds and congenital abnormalities, cardiovascular diseases and lung cancer.

2.2. Proposed measures

2.2.1 House-to-house collection

An organised house-to-house collection would increase the quantity of collected waste and, therefore, increase the quantity of waste that can be fed into recycling and treatment processes. According to Deliverable 3.2, trucks may be used to collect waste from house to house, or tricycles, wheel barrows and carts where accessibility and road networks are poor. If these collection methods are adopted by the target countries, it will lead to increase in wastes that are collected which will consequently decrease the loss of secondary resources, since only collected waste can be recycled. The release of hazardous substances by leaching or burning of non-collected waste is reduced.

Organic wastes that are properly collected and treated emit less methane than non-collected organic waste that decomposes. The potential increase of waste recycling leads to the production of secondary materials, which causes less emission of greenhouse gases than primary production. However, the organisation of house-to-house collection will result in more transportation and in an increase of the emission of greenhouse gases by the engines. Burning of non-collected waste is reduced, and so the acidification potential, as well as the severe environmental and health effects of other hazardous substances. The leaching of hazardous substances from non-collected waste is reduced, and so the eutrophication potential when the hazardous substances gets into both surface and ground water.

In house-to-house collection, wastes can be sorted at source, making recycling easy; it is very compatible with the 3 R's of waste management, reduce, recycling and reuse; overall waste management becomes more efficient; little or no toxic substances are generated; no chance for the pollution of ground and surface water; and aesthetic does not become a problem with collection at source.

2.2.2 Collection in central communal containers at specially designated places

The collection of wastes in central communal containers or specially designated places like shops, schools, markets etc. reduces the transportation distance and is associated with lower logistical efforts (costs) compared to house-to-house collection on the one hand. On the other hand, this type of collection requires large and efficient awareness and educational campaigns on proper waste disposal to inform the population of the existence of the central containers or the specially designated places and the necessity to bring the waste there. At highly frequent collection places, it might pay off to have one or two persons on site surveying and helping people to find the right container. This concept is used on recycling centres in Berlin (Germany) to minimize wrong waste sorting.

The achieved collection rates of central communal containers are usually very low compared to the house-to-house collection. If the collection site and logistics are designed appropriately, the containers can collect all kind of waste, focus on specific waste like hazardous waste, plastic, paper, metals etc. and enable sorting of waste types at source. All types of waste can be collected via this channel.

Environmental and health effects of collection in central communal containers are:

- sorting becomes difficult as wastes are mixed;
- spilling of wastes on the ground along collection bins when full;
- it may lead to pollution of surface water from overflow of leachate from bins;
- difficulty in collection and transportation of waste by managers;
- public health and safety risks regarding people entering bins;
- overflowing containers can attract fly tipping.
- Manual handling is virtually eliminated with communal containers, making it a safer form of refuse collection.

2.2.3. Privatization of pre-collection and collection services

As described in deliverable 2.1, most local waste management authorities in the target countries currently contract private companies for the collection of solid waste. A considerable amount of the generated waste is collected (>70%), but the different waste types are rarely separated. The environmental impacts described below refer to a privatization scheme that leads to an improvement of the current situation, comprising an increase of the current collection rate, a specific separation of the different waste types and the compliance with environment, health and safety (EHS) regulations. This measure is usually applied to normal household waste, but can be extended to more specific household waste types (e.g. cans, batteries, e-waste).

Increasing waste collection rates and improving waste quality (due to separation) reduce the abiotic depletion as more waste material is supplied to the production of secondary raw materials. Primary resources can be substituted to some extent. The release of hazardous substances is reduced due to higher collection rates and the compliances with EHS regulations. The substitution of primary resources by secondary resources generally reduces the emissions of greenhouse gases. The combustion of non-collected waste is reduced, and likewise the acidification potential.
The leaching of non-collected waste by rainwater is reduced, and likewise the eutrophication. The separation of organic waste additionally allows for a specific treatment of this fraction, which reduces its leaching potential in dumpsites/landfills. Exposure of humans to hazardous materials is avoided/reduced by preventing (i) cross-contamination of other waste streams and (ii) the application of inappropriate treatments that release hazardous substances into the environment.

2.2.4. Separation of wastes at the source

Source separation is the segregation of different types of solid waste at the location where they are generated (e.g., household or business). The number and types of categories into which wastes are divided usually depends on the collection system used and the final destination of the wastes. The most common reason for separating wastes at the source is for recycling. Household recyclables that are source separated from trash can either be commingled (all recyclables mixed together in one container) or segregated into individual containers for each material (i.e., glass, newspaper, aluminum). Commingled recyclables are eventually separated manually, mechanically, or by some combination of both at transfer stations or materials recovery facilities. In some cases, commingled recyclables are manually separated at the curbside by the collection crew. Recyclables that residents have separated into individual containers are usually collected in trucks with compartments for each material. The collected materials are then processed further at materials-recovery facilities or other types of recycling plants.

Source separation, also called sorting at source, helps to generate better quality materials for recycling and to limit the contamination generated by hazardous substances (see deliverable 3.2). For example, more organic waste is recoverable if source separation is practiced. The separation of valuable materials like metals and plastics at source facilitates subsequent resource recovery processes. Also source separation requires education and enlightenment to inform the population on how and why waste should be sorted at source. Source-separation programs can reduce the undesirable effects of landfills or incinerators. For instance, batteries and household chemicals can increase the toxicity of landfill leachate, air emissions from incinerators and incinerator ash. In addition, some potentially non-combustible wastes, such as glass, can reduce the efficiency of incinerators. Reducing the volume of residual ash is another incentive for diverting wastes from incineration. Recyclables and special wastes can be retrieved from the waste stream without source separation programs. Many communities find it more convenient or economical to separate wastes after collection. In these programs, recyclables and special wastes are manually or mechanically separated at transfer stations or materials-recovery facilities. Separating recyclables in this way may require more labour and higher energy costs, but it's more convenient for residents since it requires no extra effort beyond regular trash disposal procedures.

The separate collection of hazardous waste prevents contamination of other materials, and therefore reduces pollution of air, soil and water. The potential increase of waste recycling leads to the production of secondary materials, which causes less emission of greenhouse gases than primary production. Sorting of organic waste for adequate treatment reduces the emissions of greenhouse gases (methane) and produces a higher quality compost with the remaining organic matter. Human toxicity is reduced through the decrease of the cross-contamination of the different waste fractions, so that toxic substances are not spread over the rest wastes. In general human toxicity is reduced by adequate treatment of toxic waste, which can be facilitated by source separation. Sorting, recycling and processing at source (e.g. yard composting) contribute to waste minimisation. Economically, it can make sense, as some valuable waste could be separated and recycled thus increasing the profit from the sales of secondary raw materials. Thus, the waste can be collected and treated and does not lead to the pollution of ground or surface water.

2.2.5. Waste Sorting

Waste sorting means the process by which mixed waste streams (recyclable, non-recyclable or hazardous wastes) is separated into different elements. Sorting of waste will be usually necessary when sorting at source (source separation, see chapter 2.2.3) does not take place. Waste sorting can occur in civic amenity sites or automatically separated in material recovery facilities or mechanical biological treatment systems. At these places, waste is segregated into dry waste (including paper, cardboard, glass, tin cans etc.) and wet waste (organic wastes such as vegetable peels, left-over food etc.). Depending on the nature of the source material, there are a plethora of sorting and processing activities utilised that range from labour intensive hand picking operations through to highly mechanised or technically complex processes. The chosen method of sorting will depend on many factors such as the nature of the waste, the ease of segregation and the yield and quality of the resultant recyclates. Sorting of waste itself does not lead to significant environmental impacts, compared to waste treatment methods like open burning and dumping. However, sorting determines the possibility to treat waste in an environmentally sound manner and therefore, indirectly massively influences the overall impacts of waste management systems. Increased sorting of waste streams and their proper recycling in detail have many positive effects which include:

- Reduction in the use of primary resources through waste sorting and recycling
- Reduction in the amount of waste landfilled
- Reduction in the release of hazardous substances, green house gas emissions by leaching or burning of mixed waste-streams
- Prevention of contamination of other waste materials through sorting
- Low tendency for pollution of groundwater and surface water through seepage

However, it is a very cumbersome process requiring a lot of man power. Also, inappropriate sorting methods (especially when there is manual sorting) may damage the health of the workers through skin contact, injury by sharp objects and inhalation of gases emitted by the waste.

2.2.6. Selective collection in waste collection points (transfer station)

A waste transfer station is a facility where solid waste is unloaded from collection vehicles, in some cases compacted, and then reloaded onto larger transport vehicles for shipment to landfills or other disposal treatment operations. Waste transfer stations play an important intermediate role between the collection and the treatment or final disposal of waste. Their purpose is usually to collect together relatively small amounts of waste until sufficient quantities are accumulated to merit transportation to the relevant waste management option. Waste transfer stations help achieve a more environmentally sustainable system of waste management as they can reduce transport requirements, particularly long distance haulage, and allow a greater proportion of the waste stream to be recycled, treated and/or recovered.

Waste collections points which function as transfer stations are designed to control, separate and hand over the different waste streams to recycling sites, waste treatment plants or landfills. In Rio de Janeiro (Brazil) for instance (Buchert et al. 2012), six large waste collection points (transfer stations) are planned within the city (one of them is already working) for the whole amount of household waste (9.000 t/d). From these collection points, the household waste is transported to the new large landfill outside Rio (80km away from the city centre) by a private company. At the collection points the separation of fractions like metals, PET bottles, plastic bags, cardboard etc. from household waste will be improved. The city gives former informal waste pickers (now organized in SMEs) the opportunity to separate and collect valuable materials at the collection points out of the waste streams for a living. In this way the total amount of waste for land filling is reduced. Of course such collection points/transfer stations are also appropriate for the separation of valuable materials out of e-waste streams etc. The advantage of large collection points is the possibility to build up a sophisticated infrastructure for waste storage, separation and logistics. Some of the impacts are:

- Decrease in the losses of secondary resources through increase of controlled waste collection
- Collection points/transfer stations have the potential to improve environmental sanitation The release of hazardous substances GHGs and acid gases by leaching or burning of non-collected waste is reduced
- At the collection points are wastes with a high toxicity potential like e-waste and healthcare waste are separated

2.2.7 Selective collection systems using sidewalk containers

The selective collection of waste by containers located at sidewalks is suitable for residential areas which are not accessible by trucks. For instance, in Rio the Janeiro (Brazil) containers were located at the edge of favelas (low income communities within the city) to give the local communities the opportunity to collect waste (for disposal) or for recycling (PET bottles etc.). Sidewalk containers are an important option for waste collection in areas not suitable for house-to-house collection (Buchert et al. 2012).

The impacts of selective collection system by sidewalk containers are:

- Increase of waste collection decreases the losses of secondary resources (littering)
- With sidewalk containers, the amount of waste for final disposal (landfill) could be reduced remarkably and significant resources could be saved
- The release of hazardous substances by leaching or combustion of non-collected waste is reduced
- The potential increase of waste recycling leads to the production of secondary materials, which causes less emission of greenhouse gases, acidification and eutrophication of the environment.

2.2.8. Municipal collection point

The waste collection based on municipal collection points has similar effects like the collection with communal containers at designated places. It especially reduces the transportation distance compared to house-to-house collection and thus emission of greenhouse gases.

2.2.9. Producer/retailer take-back

Producer/retailer take-back systems enhance the separation of specific waste types at the source. They potentially increase their collection rates, as it is comfortable for consumers to hand in their used product at the retailer. Producer/retailer take-back systems are applied for many waste types (OECD, 2001) e.g.:

- packaging
- cans
- (plastic) bottles
- batteries
- e-waste
- medication/healthcare waste
- tyres
- vehicles

To be effective, their implementation requires great efforts by the producers/retailers in order to encourage consumers to return their obsolete products, e.g. awareness creation campaigns and the establishment of an easily accessible and intelligible system.
Producer/retailer take-back schemes allow for transferring waste types containing hazardous or valuable materials to appropriate recycling and refining channels (e.g. e-waste, batteries or medication/healthcare waste). The release to the environment or loss of those materials can thus be reduced or even avoided. Increased waste collection rates and improved waste quality (due to separation) reduce the abiotic depletion, as more waste material is supplied to the production of secondary raw materials. Primary resources can be substituted to some extent.

The separation of waste that contains hazardous substances (e.g. e-waste, medication/healthcare waste) prevents the contamination of other waste types and allows for the appropriate treatment/recovery of the hazardous as well as the non-hazardous wastes. The release of hazardous substances is reduced. The substitution of primary resources by secondary resources generally reduces the emissions of greenhouse gases. Open burning of non-collected waste is prevented, and thus the acidification potential of the concerned waste is reduced. For organic waste, as it is usually not covered by such take-back schemes, no significant impact is expected.

3.0 Environmental impacts of the current and proposed transportation and equipment maintenance methods

3.1. Current methods

3.1.1. Non-motorized transport

Currently in the target countries, methods of transportation are non-motorized transport (NMT) in the case of areas of low income and even parts of cities. NMT mainly consists of carts, non-motorized tricycles, and wheelbarrows, which are convenient to the local conditions.Motorized transport is also used but in limited areas with adequate roads and in the last phase of collection in certain densely populated areas. E-waste, industrial waste and healthcare waste are most often found mixed with the municipal waste and transported as such.

An advantage of the NMT methods is that it is zero-carbon and more labour intensive thus providing jobs. Health and environmental impacts and hazards are however evident, as enlisted in Section 2.1 of this report regarding collection.

Furthermore, there are specific impacts of the informal sector's malpractice (and sometimes private sector as well in absence of strict monitoring) from illegal dumping of waste in non-authorized locations, in addition to littering during transportation. With the lack of convenient disposal sites, disposal of waste often occurs either in informal dumpsites, or on the way in less inhabited locations such as a roadside open space. Another impact specific to animal driven carts is that it leaves trails of excrements in the street.

3.1.2. Motorized transport

Vehicles (and containers) are currently often not adaptable to the local conditions and topography, and are often poorly maintained and not operational for a long time. Also, lack of a vehicle replacement policy, which further motivates the use of carts for collection where convenient also affect waste transportation.

Motorized methods of waste transportation is conducted using compactor trucks, skip trucks, tipper trucks, roll-on roll-off trucks, and to a greater extent in rural areas, tractors. The key environmental impacts of poor maintenance (and inadequate vehicle specifications) are noise, poor quality vehicle exhaust, and odour, in addition to littering (waste dropping off of the vehicles during transportation and leaching). This is in addition to the workers exposure to hazardous wastes.

One one hand, more mechanized handling and motorized transportation indeed limits the level of exposure of workers to hazardous waste and ensures contained transportation. On the other hand, the current poor maintenance implies poorer safety conditions during transportation, loading and unloading, frequent breakdowns and traffic accidents.

Furthermore, with the lack of convenient disposal sites and monitoring of vehicle trips, loading and unloading, disposal of waste often occurs either in informal dumpsites, or even on the way in less inhabited locations where decomposition of organic wastes can generate methane, a greenhouse gas. Having unpaved roads encourages vehicle drivers to dispose of waste at the earliest chance after collection to reduce transportation costs and costs of the wear and tear of tyres and the vehicle in the absence of supervision and adequate record keeping. Leaching of nutrients, acid gases and hazardous wastes can be encouraged with disposal of wastes in illegal areas.

3.2. Proposed measures

The proposed methods generally involve using the same affordable technologies but with a greater collection frequency, better maintenance, improved logistical planning, trained staff, and cooperation/integration with the informal sector, while strictly enforcing regulations. Furthermore, stricter monitoring of industrial waste handling and hazardous wastes will imply a need for separate transportation or containers for these waste streams, and therefore more vehicle-kilometres but less risk of adverse environmental impacts.

3.2.1. Use of well-maintained tricycles, carts, wheelbarrows and higher frequency

In the upgrade and expansion of the use of NMT for transportation of waste and the integration of the informal sector, it is essential to set standard specifications for equipment used for collection and transportation adaptable to the local conditions in the respective area covered, and establish a strict monitoring system. A higher frequency of vehicle trips, dictated by factors including climatic conditions, such as those in tropical areas (high heat and humidity). It must be ensured that waste is not left too long so that it produces leachate, odour, or burns (either self-ignited or otherwise) and litters the area surrounding the container during trips, loading, and unloading. Separate handling of hazardous waste will reduce the workers exposure to hazardous substances that they were previously exposed to without any precautionary measures. Hazardous wastes must be collected separately and has to be handled with utmost care to prevent adverse health and environmental impacts.

3.2.2. Use of well-maintained motorized vehicles and higher frequency

The fleet of vehicles used for transportation of waste encompasses skip trucks, tipper trucks, roll-on roll-off trucks, motorized tricycles, and tractors. Expansion of the fleet to meet the needs of the under-served areas (and also to meet the new needs of a separate transportation system for hazardous and industrial wastes) will imply greater fuel consumption, but however the local emissions due to incomplete fuel combustion of poorly tuned vehicles will be lower with newer and better-maintained vehicles complying with modern fuel efficiency requirements. Furthermore, with adequate specifications of specialized vehicles and better waste containment, less odour, leakages, and littering will occur during transportation as compared with the current scenario.

3.2.3. Strict Monitoring and Maintenance Programme

Monitoring of the performance of the entire transportation system and maintenance will ensure the mitigation of the main environmental impacts and health hazards of the poor transportation system mentioned above. Preventive maintenance rather than reactive maintenance will ensure mitigation of risks such as frequent break downs and delays in collection, leakages, littering, or health hazards and safety risks to workers during loading, unloading, and transportation.

The environmental impacts of proper maintenance programs for transportation vehicles include higher rates of waste collection, recycling and proper treatment. This leads to conservation of resources, by decreasing the loss of secondary resources due to higher rates of recycling and a better quality of wastes maintained. The use of liquid-tight closed containers prevents leaching and leakages during transportation, odours, and littering, thereby preventing pollution of air, soil, surface and groundwater contamination

4.0. Environmental impacts of the current and proposed treatment methods

4.1. Current methods

4.1.1. Open burning

Open burning of waste is simply defined as "the burning of wastes in such a manner that products of combustion resulting from the burning are emitted directly into the ambient (surrounding outside) air without passing through an adequate stack, duct or chimney". In the target countries, sorting or segregation of wastes at the source of waste generation is not widely practised; The waste burnt therefore can contain all the waste streams.

Municipal solid waste has poor combustion efficiency. As a result, many pollutants are generated and emitted directly into the air. These pollutants includes high levels of particulates, acid gases, heavy metal vapours', carbon monoxide, dioxins, furans, polyaromatic hydrocarbos and other toxins, some of which are carcinogenic. They also produce large amounts of ash and debris and increases acidification potentials. Open burning leads to loss of valuable and some finite resources or depreciation in value of these resources that could otherwise have been harvested for reuse or recycling. It also produces offensive greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) etc., which contribute to global warming and climate change. Runoff from these sites could contain hazardous chemicals that may contaminate soil, ground and surface water. Uncontrolled hazardous wastes from industries mixing up with municipal wastes create potential risks to human health.

4.1.2. Crude recovery/recycling methods

In the target countries, waste pickers often adopt crude methods to recycle solid wastes usually dumped at the waste disposal sites. This crude recovery/recycling techniques is often employed by the waste pickers to recycle or recover copper wires and other valuable products from e – waste and dismantling of other gadgets for scrap metals. This leads to recovery of low quality materials and increased health risk. For instance electrical wires and e-wastes are burnt openly to recover valuable metals.

4.2. Proposed treatment measures

4.2.1. Organic waste treatment

Organic waste can be recycled in a number of ways; through composting or anaerobic digestion, as animal feed or refuse-derived fuel (see deliverables 3.1, 3.2 and 3.3 for information on treatment of organic waste) . In all cases, a major environmental benefit is from the avoided negative environmental effects of other waste treatment methods, such as open dumping or burning, or sanitary landfilling (see Chapter 4.1 and Chapter 4.2.7). There are numerous life cycle analyses from Europe showing the reduction in environmental impact, when organic waste is composted or digested compared to landfilling (see Valerio, 2010, for a review).

In chapter 4.2.2 – 4.2.5, the environmental effects are specified for each of the recycling methods composting, anaerobic digestion, animal feed production and refuse-derived fuel production.

Environmental effects of organic waste treatment and recycling by any method is summarised below;

1. A benefit of treating and recycling organic waste instead of landfilling is that less landfill space is used, and the life span of current landfills is prolonged.

2. Resources are conserved as nutrients, organic matter or energy are recovered when organic waste is treated and recycled.

3. Pollution of air, soil, surface and groundwater contaminations is prevented by recycling instead of landfilling, there is no leakage of leachate to ground- and surface water.

4. In landfills, organic matter is microbially decomposed to methane, which is a strong greenhouse gas, twenty (20) times stronger than carbon dioxide. Avoidance of greenhouse gas emissions is thus a major benefit of any treatment process that diverts biodegradable waste from landfills.

5. The emissions of acidifying substances from burning, dumping or landfilling are avoided. The emissions of eutrophying substances from burning, dumping or landfilling are also avoided.

6. Organic waste management has occupational health risks, and precautions should be taken to prevent negative effects on health. There is a risk of odour from any process treating biodegradable waste.

4.2.2. Composting

In composting, organic matter is decomposed aerobically, i.e. with exposure to oxygen (air), and methane production is therefore avoided, while producing the compost product which recycles nutrients back to soil. Reuse of nutrients and organic matter from biodegradable waste is very beneficial to soils. Organic matter in compost improves the soil water holding capacity. Compost from solid waste contains both micro and macro nutrients, but the nitrogen content is normally low compared to other organic fertilizers such as manure (Hofny-Collins 2006). It is important that the composting process is managed correctly to avoid problems with methane slip, insects, rodents and odour. A summary of the environmental impacts of composting;

1. Composting conserves resources by making it possible to recycle macronutrients, such as nitrogen and phosphorous, micronutrients, and organic matter to soil, reducing the need for mineral fertilizers. Conditions for agriculture are improved by increased soil productivity and water retention capacity.

2. There is a risk of accumulation of metals in soil, if the waste is contaminated, thereby leading to possible contamination of air, soil, surface and groundwater. Another risk is that humans take up these toxic metals with food grown on soils amended with such compost substrates.

3. Using compost instead of mineral fertilizers causes less emission of greenhouse gases from primary production of mineral fertilizers. Also, carbon sequestration in soil organic matter is increased. Emissions of ozone depleting substances and of greenhouse gases from fertilizers applied on fields, e.g. nitrous oxide (N_2O), are avoided as well.

4. If composting is not performed correctly, methane gas can be formed and emitted from the compost.

5. Ammonia emitted from compost has acidification potential. The decreased need for mineral fertilizers reduces eutrophication.

6. Accumulation of organic waste increases the risk of pathogens, and insects and rodents that spread them. High concentrations of carbon monoxide, carbon dioxide, hydrogen sulphide and ammonia in gases from compost, which are potentially toxic.

4.2.3. Anaerobic digestion for biogas production and methanisation

In controlled anaerobic digestion, the methane generated is captured and combusted, avoiding methane emissions and producing beneficial energy instead. This also produces a product, the digestate, which is also used to recycle nutrients back to soil. It is important to take proper care when handling methane as it is an explosive gas.

Anaerobic digestion conserves resources. Use of digestate as fertilizer recycles micronutrients, nitrogen, phosphorous and organic matter to soil, reducing the need for mineral fertilizers. Conditions for agriculture are improved by increased soil productivity and water retention capacity. However, using digestate as fertilizer may lead to increased concentrations of metals in soil if contaminated. If the digestate is not used as fertilizer, but instead dumped or released to waterways, there is a risk of water pollution. When methane is used as a source of energy, it potentially replaces use of fossil fuels that emit carbon dioxide. Using digestate instead of mineral fertilizers causes less emissions of greenhouse gases from primary production of mineral fertilizers. Also, carbon sequestration in soil organic matter is increased. There is a risk of methane slip from biogas production; and the decreased need for mineral fertilizers reduces eutrophication. High concentrations of carbon monoxide, carbon dioxide, hydrogen sulphide and ammonia in gases from compost are potentially toxic. However, humans are not exposed if anaerobic digestion is managed properly.

4.2.4. Reuse of organic waste as animal feeds

Reusing organic waste as animal feeds is highly beneficial since this is reducing the environmental impacts from feed production. The need for arable land and space for landfills is reduced. The environmental effects of using waste as animal feed depends largely on the alternative feed source. Reuse of organic waste as animal feed saves resources needed for alternative feed production, such as land, water, fertilizers etc. It also reduces pollutants derived from alternative feed production; causes less emissions of methane, nitrous oxide and carbon dioxide from alternative feed production and causes less emissions of acidification potential from feed production. Reusing organic waste as animal feeds causes less emissions that leads to eutrophication from feed production, however, it increases the risk of spreading of pathogens. If the organic waste is not pure, but mixed with other substances, there is a risk that animals can accumulate toxic substances such as heavy metals, which are passed on to the humans that eat them. There is also a risk that animals get injured by impurities in the waste.

4.2.5. Refuse-derived fuel

Using organic waste as fuel means that the need for fossil fuel is reduced. Thus, even though combustion of refuse-derived fuels gives rise to emissions of pollutants, the total amount of emissions does not increase. It is important when studying refuse-derived fuels to compare the effects with those of the alternative fuels. Refuse-derived fuel reduces the need for energy from other sources, thus conserving resources. It can however cause air pollution, by releasing dioxins, nitrogen oxides and particulate matter to the atmosphere. Ash from burning of refuse-derived fuel can pollute soils with water, but also provide beneficial minerals to soils.

Combustion of refuse-derived fuels causes emissions of nitrogen oxides, which contribute to acidification and eutrophication. However, fuels from organic waste often substitute other fuels and do not necessarily increase the total amount of nitrogen oxide emissions. Combustion of refuse-derived fuels causes emissions of dioxins and particulate matter. However, fuels from organic waste often substitute other fuels and does not necessarily increase the total amount of toxic emissions.

4.2.6. Repair or disassembly of e-waste using environmentally sound practices

Repair or disassembly of e-waste should be done with the correct tools/equipment using environmentally sound practices (ESP) rather than the current crude method where valuable resources are lost. The informal sector, which is mostly involved in dismantling of e-waste should be taught how to dismantle without risk to their health and the environment. Repair prolongs the life span of the equipment. ESP conserves valuable resources such as valuable metals some of these metals include iron, aluminium, nickel, copper, and some precious metals. The precious metals include gold, silver and the platinum-group metals.

ESP of e-waste would prevent contamination of air, soil, surface and ground water from heavy metals such as mercury (in fluorescent lamps, batteries or switches) or lead (applied in solder), polybrominated biphenyls (PBBs) or polybrominated diphenyl ethers (PBDE) used as flame retardants in plastics. ESP of e-waste would prevent the current metal recovery practice of burning the plastic cables which releases toxic substances, in particular polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) produced during low-temperature combustion that contaminate air, soil as well as surface and groundwater. This would also reduce the global warming, acidification and eutrophication potentials.

The elimination of this practice and its replacement by efficient, professional repairing and refurbishing workshops and modern recycling facilities will improve the health of the workers and of the neighbouring communities that can be affected.

4.2.7. Stabilisation/solidification

Solidification/stabilization (S/S) techniques, though not mentioned in earlier chapters, is however important as an effective way of disposing of some types of waste. Solidification refers to techniques that encapsulate the waste in a monolithic solid of high structural integrity. The encapsulation may be of fine waste particles (microencapsulation) or of a large block or container of wastes (macroencapsulation). Solidification does not necessarily involve a chemical interaction between the wastes and the solidifying reagents but may mechanically bind the waste into the monolith. Contaminant migration is restricted by vastly decreasing the surface area exposed to leaching and/or by isolating the wastes within an impervious capsule.

Stabilization refers to those techniques that reduce the hazard potential of a waste by converting the contaminants into their least soluble, mobile, or toxic form. The physical nature and handling characteristics of the waste are not necessarily changed by stabilization. The target contaminant group for physical S/S is generally inorganics, such as heavy metals in the soil. While it may be effective for some organics, this technology may have limited effectiveness with semi volatile organic compounds (SVOCs) and pesticides. Solidification/stabilization can be used for disposal of drilling wastes, which had been mentioned in Deliverable 2.1 especially in Nigeria in the oil industry. The resulting materials have been used for road foundations, backfill for earthworks, and as building materials, etc. (Morillon et al. 2002, BMT Cordah Limited 2002). This method is also used as safe environmental remediation of contaminated land with cement. The cement solidifies the contaminated soil and prevents pollutants from moving, thereby preventing leaching of pollutants into surface and groundwater. It also reduces pressure on landfills.

4.2.8. Waste incineration for energy recovery

Waste incineration, just above landfill, is the least desirable waste management option in the EC priority as defined in the Waste Framework Directive of 2008. In addition, a modern incinerator is much more expensive to build and operate than an engineered landfill.

Waste incineration means that valuable recyclable materials such as paper, cardboard, plastics and some metals are burned, i.e. turned into ashes and toxic particles disseminate into air, on the land and in surface water, instead of being recycled and reinvested in the manufacturing industry.

Waste incinerators are huge air polluters: CO_2, heavy metal particles, nanoparticles, ammonia, chlorinated dioxins, brominated dioxins, small particles, furans etc., and many other chemical cocktails that have not been studied yet. The level of pollution depends, however, on the quality of the filters integrated on the chimneys of the incinerator and on the process used in the incineration plant.

In the EU, filters are now supposed to be very efficient in terms of dioxin filtering which has been identified as a cause of cancer. Like disposal in sanitary landfills, incineration of waste causes greenhouse gases (GHG) emissions depending on the nature of waste incinerated. The carbon content of waste varies, 0.38 grams per grams of dry weight waste for food waste; 0.49 for garden waste (leaves, grass); 0.46 for paper waste; 0.5 for wood waste; 0.5 for textile waste; 0.75 for plastics waste, 0 for inert waste (IPCC guidelines, 2006).

Incineration with energy recovery to produce heating or electricity has less impacts on climate change, because this energy can be used as a substitute to fossil fuels, thus avoiding GHG emissions. Incineration with energy recovery hardly compensates the direct GHG emissions caused by waste incineration. In addition, even the best available processes to limit the negative environmental impacts of incineration are not completely neutral: for instance, ammonia is used in incinerator filtering techniques to clean the fumes of the chimneys but it is then released into the air, thus contributing to acidification of ecosystems.

.All types of dust and particles emitted into air by incinerators, even those well equipped with expensive dust removal devises, have negative impacts on respiratory systems and aggravate asthma, have abrasive effects, etc.

4.2.9. Chemical treatment

On the landfill, waste can be chemically treated in order to lower the toxicity, mobility and reactivity of the waste by changing it's chemical nature. Some chemical treatment methods used are:

- Dechlorination
- Hydrolysis
- Neutralization
- Oxidation
- Reduction
- precipitation

5.0. Environmental impacts of the current and proposed final disposal methods

5.2. Current method

5.1.1. Disposal in uncontrolled dumpsites

Final disposal practices are almost the same for all the waste streams in the target countries. According to section 3 of D2.1 of IWWA report, the final disposal methods identified to be currently practised by the target countries include disposal of all the categories of waste in official (sometimes a quarry used as an open landfill) or illegal open dumpsites and water ways

5.1.2. Open dumping and burning on land

The term "open dump" is used to characterize a land disposal site where the indiscriminate deposit of solid waste takes place with either no, or at best very limited measures to control the operation and to protect the surrounding environment from the negative environmental and health impacts arising from the dumped wastes over time.

Various activities occur on the dumpsites to reduce the volume of the wastes. On the official dumpsites, the waste may be compacted with trucks or set on fire. If the wastes are only compacted, the wind may blow off plastic bags to fields, where they prevent water from penetrating into soils and, if swallowed by wild animals, can lead to their death. Wash off from contaminated pesticides plastic containers can also contaminate the environment and from the environment to food web. Birds, rats, flies and other animals can be attracted to the dumpsites by kitchen wastes. Animals feeding at the dumpsites may transmit diseases to humans living in the vicinity. Emission of methane from anaerobic decomposition of compacted organic waste from MSW can cause odour and also contribute to green house effects. Generally, on the official dumpsites there are no provisions for gas treatment or leachate control. In addition, weak organic acids such as methanoic and acetic acids originating from anaerobic decomposition of organic wastes on the dumpsites can make a significant contribution to rainwater acidity. Acid rain can acidify water bodies leading to death of aquatic organisms. During wet season, leachates which contain hazardous substances from e-waste and healthcare waste co-disposed on the dumpsites can run to a nearby river or penetrates groundwater.

Apart from compaction on open dumpsites, open air burning of the waste is a common occurrence. Mass burning of co-disposed waste streams on open dumpsites as a way to reduce the volume of wastes is currently practised in the target countries. This practice appears to be cheaper and easier when compared with engineer landfilling and incineration which are scarce due to the cost, modalities, fear of encroachment associated with siting landfills and unsuitable waste composition (high organic fraction, high moisture percentages and low calorific value) for incineration. However, the environmental impacts associated with this practice undermine the advantage of waste volume reduction. This practice exposes communities to multiple environmental problems ranging from littering, surface and groundwater pollution as well as air pollution due to frequent burning of waste. Thermal combustion of organic waste causes generation of CO_2, a greenhouse gas. Incomplete combustion of plastic containers and electric cables can cause emission of dioxins and furans which are carcinogenic to man and animals. Organophosphate insecticides and NPK fertilizer containers can leach phosphorus and nitrogen into nearby streams leading to eutrophication. Eutrophication is the increase in the concentration of nutrients in a water body. Leachates from open dumpsites containing high levels of nitrogen (N) and phosphorus (P) discharging into water bodies can lead to an increase in the phytoplankton population (algal boom). The algae when becomes so thick prevent penetration of light into the water bodies and algae beneath the surface die due to the absence of light. As the algae decomposes, the dissolved oxygen is used up and due to oxygen starvation aquatic organisms begin to die. Heavy metals release from ash residues of electronic waste, healthcare and hazardous wastes during burning operations can equally leach into soil, surface water and groundwater. This pollution of soil, water and air can impact human health negatively. Non-valuable or toxic fractions resulting from e-waste recycling such as plastic cases and leaded glass from CRT screens, batteries, capacitors together with hazardous household wastes (drugs, batteries, waste paints, electric bulbs e.t.c.) can release hazardous chemicals. Healthcare wastes, which include infectious and anatomical wastes are usually co-disposed with municipal domestic wastes in open dumpsites. Besides their potential to release hazardous elements such as mercury, breeding of pathogens and harmful bacteria in the open dumpsites are also possible effects of healthcare wastes. Medical waste can transmit disease, poisoning people, livestock, wild animals, plants, and entire ecosystems.

5.1.3. Uncontrolled incineration

Incineration in locally built and void of engineered equipment to reduce the volume of the waste or burial in the hospital premises is another practice employed in the target countries particularly to dispose of healthcare waste. Some private and government owned hospitals/healthcare centres manage their waste by themselves through locally constructed incineration or burying them underground. These crude methods are potential sources of emission of hazardous gases into the atmosphere and groundwater contamination with chemicals and pathogens. Incomplete combustion in the incinerator is capable of releasing fine particulates (fly and bottom ashes), acid gases (NOx and SOx) and substances such as furan, dioxins, and polyaromatic hydrocarbons (PAHs) to the environment. The ash residues which contain hazardous metals from incineration operation are dumped along together with municipal domestic waste and finally dispose in the official dumpsites. These by products could have adverse effects on public health and natural resources. Industrial waste is mainly disposed of together with municipal waste in the official dumpsites or dumped indiscriminately on illegal dumpsites. Burning of solid waste can lead to emissions of SOx which is responsible for acid rain. Anaerobic decomposition of industrial sludge in dumpsite can lead to emission of methane, and other greenhouse gases.

5.1.4. Open dumping in waterways

In the target countries like most other developing countries, solid wastes are usually dumped into open drains, stream, rivers and other water bodies causing contamination. In addition, these wastes block the normal flow of water bodies and also serve as breeding grounds for disease causing organisms such as cholera, malaria, etc. Another effect of this method of solid waste disposal in the target countries is that it causes flooding and produces bad or foul stench from the decomposition of the wastes.

5.2 Proposed disposal measures

5.2.1. Engineered landfilling with leachate control

In Western Africa, landfills are usually simple open air landfills, without any kind of control of the contamination caused by the anaerobic fermentation of waste and the liquids contaminated by the great variety of materials (e.g., organic waste, chemicals, medical waste, e-waste, heavy metals) contained on such landfills. Engineered landfills with leachate control, and even sometimes with biogas extraction system are seen as an adapted solution and most municipalities invest in such technologies.

Yet, the past of industrialised countries cannot be the future of developing countries. Landfill used to be the main option for waste management in the EU but it is less and less the case now. In 1995, the average landfill rate in the EU was 68 %, in 2008 it had fallen to 40 % (Bakas et al, 2011). The Landfill Directive in the EU (Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste) sets objectives for the Member States in terms of *"reduction of biodegradable waste going into landfills"* (article 5) and requires them to *"take measures in order that the following wastes are not accepted in a landfill:*

(a) liquid waste;

(b) wastes, which in the conditions of landfill, is explosive, corrosive, oxidising, highly flammable or flammable (…);

(c) hospital and other clinical wastes arising from medical or veterinary establishments (…), (d) whole used tyres" (article 5).

Last but not the least, landfills are usually classified in industrialized countries into 3 categories: - landfill for hazardous waste, landfill for non-hazardous waste, and landfill for inert waste. However, very low waste separation at the source does not guarantee that there is no hazardous waste that ends up in a landfill for non-hazardous waste. This is the reason why the new EC waste framework directive (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives) aims at *"[moving] the EU closer to a "recycling society"*, seeking to avoid waste generation and to use waste as a resource" and sets in its article

4 a *"waste hierarchy [that] shall apply as a priority order in waste prevention and management legislation and policy:*

(a) prevention;

(b) preparing for re-use;

(c) recycling;

(d) other recovery, e.g. energy recovery; and

(e) disposal. "

According to this hierarchy, waste disposal, i.e. landfills, even engineered landfills, are the last option for waste management. Western African municipalities should therefore not invest the majority of their resources into such facilities, but rather in the 4 other options, and in particular, in the re-use and recycling sectors which already exist and only need to be better organised.

Landfills are not a solution to preserve natural resources especially metals (gold, copper, iron...) because those valuable metals are buried under the ground again (after having been extracted from mines) and new mines have to be opened to extract new metals to feed the industry. However, landfills are considered as "urban mines" by some recycling companies that consider that one day, landfills might be exploited as mines to extract valuable materials. This is not optimal in terms of cost/benefits compared to waste separation at the source, as valuable metals might be damaged by other waste (oxidation).

The main source of soil, surface and groundwater contamination by landfills comes from leachates, which is taken care of in a sanitary landfill. Landfills contribute to warming the climate because of the landfill gases (carbon dioxide and methane) that are emitted by the degradation of waste, especially organic waste. Contrary to greenhouse gas emissions from waste incinerators and composting plants, landfill greenhouse gas emissions are characterised by the large time lag of emissions. Biodegradable waste landfilled today may start gas production next year, reach a peak in 4-10 year's time, and prolong its production for up to 50-60 years (Bakas et al, 2011).

Pipes allow the capture of landfill gases, that can be flared (methane is then transformed into CO_2, which minimizes the impact on climate change) or used as energy to produce electricity, heating or fuel for vehicles. However, these technologies do not solve the problem entirely, because in the EU, where the best and the more expensive technologies are available, the maximum feasible recovery rate for methane on landfill is assumed to be 50% (Bakas et al, 2011). The IPCC assumes a recovery rate of 20% as an international average. This means that despite gas capture installations, large quantities of landfill gases continue to be released in the atmosphere.

The main pollutants involved in acidification are sulphur and nitrogen compounds (sulphur oxides, sulphuric acid, hydrochloric acid, ammonia). All of these pollutants are to be found in landfills, where all kinds of waste are mingled. In addition, the fact that such chemicals are mingled on a landfill produces ever new and un-anticipated "chemical cocktails" whose effects on the environment are not known.

Landfill leachates contain phosphates that can go into the water bodies nearby the landfill and cause eutrophication, lack of oxygen and the death of many species in surface waters, and contamination of ground water. Communities leaving next to landfill are disturbed by strong smells coming from the degradation of mingled waste and contaminated drinking water, if they depend on the local ground water resources.

5.2.2. Landfilling in engineered sanitary landfills with leachate treatment

Sanitary landfilling, which is the controlled disposal of waste on the land, is well suited to target Western African countries as a means of managing the disposal of wastes because of the flexibility and relative simplicity of the technology. The practice of sanitary landfilling, however, should be adopted in accordance with other modern waste management strategies that emphasise waste reduction, recycling, and sustainable development.

In order to be designated a sanitary landfill a disposal site must meet the following three general but basic conditions:

1. Compaction of the wastes
2. Daily covering of the wastes (with soil or other material) to remove them from the influence of the outside environment, and
3. Control and prevention of negative impacts on the public health and the environment (e.g., odours, contaminated water supplies, etc.) by installation of an impermeable base or by least selecting an appropriate location where naturally water-impermeable layers prevent the contamination of ground water

Landfilling should be the least preferred method of waste disposal; only the waste that cannot be reused, recovered/recycled or disposed of in any other way should be landfilled. Landfills of preference must take care of leachates/landfill runoff, emissions of landfill gases, the level of the water table and groundwater quality under and near the landfill. A proper engineered landfill is designed to collect and treat leachate and also collect landfill gases. The landfills that are properly protected in this way will ensure minimization of the harmful environmental impact of landfilling waste. Through sanitary landfilling, disposal is accomplished in such a way that contact between wastes and the environment is significantly reduced, and wastes are concentrated in a well defined area. The result is good control of landfill gas and leachate, and limited access of vectors (e.g., rodents, flies, etc.) to the wastes. Controlled anaerobic decomposition of the organic waste dispose of in the landfills after recycling generates methane. The methane gas can be captured in closed landfills for use as a source of energy thereby contributing to prevention of abiotic depletion. With the right operations as in engineered landfill site, like dumping in cells and daily covering of the waste as well as lining of the site to collect and treat leachate, the problem of vermin breeding and leachate run offs can be prevented and by extension possibility of eutrophication is minimised. Open burning of waste is not allowed in engineered sanitary landfills so greenhouse and acid gases are rarely generated. Consequently, effects of global warming and acid rain are reduced. Risks to human arising from the effects of acid rain, global warming and eutrophication are curtailed.

5.2.3. Engineered incineration with waste air purification

With reference to IWWA D3.2 report, engineered incineration with waste air purification has been proposed as the final disposal method for unwanted parts of e-waste, healthcare wastes and conversion of organic waste and plastic to energy as opposed to open dumping of wastes. When the recycling of wastes is not feasible or there is no market for the recycled product, incineration can be used to generate energy from the waste combustion with heat. Some wastes as plastics are materials of high calorific value, hence plastic wastes can greatly contribute to the energy produced in incineration plants. As a viable alternative to fossil fuels or nuclear power, clean energy from waste can contribute to reducing the use of non-renewable resources (Conservation of natural resources).

Incineration is the most commonly used thermal process in the treatment of hazardous wastes. This means the final waste disposal is usually accompanied with both particulate and gaseous emissions. Thermal incineration uses high temperature thermal oxidation to destroy hazardous wastes. Hazardous emissions from hazardous waste incinerator can include particulate matters, compounds of heavy metals (e.g., Pb, Cd, Zn, Cr) in case of e-waste, mercury vapour in case of healthcare waste, gaseous emissions (sulphur dioxide (SO_2), hydrogen chloride (HCl), hydrogen fluoride (HF), oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons (HCs)), dioxins, furans and dioxin-like polychlorinated biphenyls from the categories of waste streams.

A properly designed incineration system must take care of these pollutants from incineration of wastes. Particulate matters in incinerator emissions can be removed with cyclones, bag filters, electrostatic cleaning systems and wet scrubbers. Wet scrubbers are also used to remove harmful gases such as HCl, HF and SO_2 from the emissions. NO_x can be removed by wet scrubbing, although difficulties are encountered in making NO_X into solution. CO and HCs are results of incomplete combustion, insufficient excess air in the combustion system and insufficient temperature for complete combustion. CO and HCs emissions can be controlled by careful attention to the quantity and distribution of excess air. High temperatures (> 1000℃) and sufficient retention times destroy dioxins and furans.

Liquid and solid wastes from incineration must be treated. Effluent produced by wet scrubbing of gaseous emissions has to be treated before disposal. Engineered incinerators take care of all the emissions and releases thereby reducing the associated environmental effects. Reduction or elimination of acid gases controls acid rain. Air, soil and water pollution with persistent organic pollutants is removed. Effect of global warming due to emission of greenhouse gases from open dumpsites is reduced. The leaching of open dumpsite waste by rainwater is reduced, and so the eutrophication. The overall effect of reduction in environmental impacts is protection of human health and other living organisms.

6. Summary and conclusion

In the target countries, Nigeria, Ghana, Senegal and Cote D'Ivoire, the current practices of waste management and proposed measures were assessed in terms of their potential burden and benefit for the environment and human health. The assessment was based on management of municipal waste (e.g., residual waste, organic waste, plastic, metal), e-waste, industrial waste and healthcare waste. Environmental criteria such as conservation of resources, GHG emissions and climate change, acidification, eutrophication and human toxicity were selected for the assessment.

Insufficient waste collection, inadequate transportation and treatment and disposal practices damaging human health and the environment are common in the target countries. Recycling receives too little attention. The current waste management practices favour abiotic depletion, global warming, and contamination of soil, air, and water with releases of waste-oriented hazardous chemical substances, loss of forests and endangered species through acid rain and loss of aquatic lives via algal booming. Through implementation of waste management systems proposed in the IWWA reports all the environmental impacts can be reduced to barest minimum or eliminated completely. Collection of waste, including house-to-house collection and sorting does not lead to significant environmental effects compared to waste treatment methods in an unsustainable and environmentally friendly manner. Source separation can reduce the undesirable effects of landfilling and incineration while engineered incineration takes care of all the emissions and releases thereby reducing the associated environmental effects. The table below summarises the reduction in pollution and environmental benefits achievable through the proposed measures.

Table 1: Summary of the possible environmental impacts of the current and proposed waste management systems

Elements of waste management	Environmental/human impact of the waste management systems	
	Current methods	Proposed methods
Collection	Co-collection of waste streams, irregular collection, inadequate or	Source separation, segregation, house-to-house collection, sorting

methods	incomplete collection: loss of useful materials, depletion of abiotic resources, contamination of inert wastes, contamination of soil, air and water due to leakage, breeding grounds for disease vectors such as rats and flies which leads to rise in disease transmission threatening public health. Waste-handlers and waste-pickers stand the risks of contracting and transmitting diseases, especially with co-collection of MSW with medical waste/hazardous wastes. Flooding, emission of methane, eutrophication can result from accumulation of wastes in open land.	at transfer stations and material recovery facility, more frequent collection, will lead to conservation of resources, reduction in global warming, eutrophication, pollution of soil, air, water and less hazards to human.
Transportation	Motorized transport and non-motorised transport: noise, poor quality vehicle exhaust, and odour, in addition to littering (waste dropping off of the vehicles during transportation and leachate leaking). This is in addition to the workers exposure to hazardous wastes.	Collect and transport all waste effectively and efficiently through the use of well-maintained tricycles, carts, wheelbarrows and higher frequency. Use of well-maintained motorized vehicles: higher strict monitoring and Maintenance Programme: emissions due to incomplete fuel combustion of poorly tuned vehicles will be lower with newer and better-maintained vehicles, better waste containment, less odour, leakages, and littering will occur during transportation as compared with the current scenario. Preventive maintenance rather than reactive maintenance will ensure mitigation of risks such as frequent break downs and delays in collection, leakages, littering, or health hazards and safety risks to workers during loading, unloading, and transportation. The environmental impacts of proper maintenance program for transportation vehicle include higher rates of waste collection, recycling and proper treatment. This leads to conservation of resources, by decreasing the loss of secondary resources, use of liquid-tight closed containers prevents leaching and leakages during transportation, odours, and

		littering, GHG reduction etc.
Treatment	Open burning; open dumping on land, open dumping in waterways, uncontrolled incineration, crude recovery/recycling: decomposition of organic materials produces methane, an ozone layer depletion gas. Biological and chemical reactions occurring in open dumps produces hazardous leachates, which contaminate soil and water bodies, sometimes resulting in eutrophication. Open burning generates smoke and contributing to air pollution with persistent organic pollutants, acid gases (acid rain), GHG (climate change)	Organic treatment, repair/disassembly, stabilisation: composting of organic wastes recycles nutrients back to the soil. Recycling and recovery of high-value waste streams, such as paper, supply of inexpensive raw materials to industries from recycling/recovery of e-waste. Reduction in global warming, acidification, eutrophication and pollution of soil, air and water. Recycling reduces the need for landfilling and incineration.
Disposal	Open dumpsites, unsanitary landfilling, local incineration: contamination of ground and surface water via leachate. Emissions of carbon monoxide, smoke particles, greenhouse gases (CH_4 and CO_2), acid gases (NOx and SOx), PAHs, dioxins, furans. Ecosystems damage (e.g eutrophication of aquatic habitat)	Engineered incineration and landfilling: Incineration may lead to energy recovery. Effect of global warming due to emission of greenhouse gases from open dumpsites is reduced. The leaching of open dumpsite waste by rainwater is reduced, and so the eutrophication. Open burning of waste is not allowed in engineered sanitary landfills so greenhouse and acid gases are rarely generated. The overall effect of reduction in environmental impacts is protection of human health and other living organisms.

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SECTION 2: PROGNOSIS OF SOCIO-ECONOMIC EFFECTS OF THE PROPOSED METHODS IN THE TARGETED REGIONS

1.0. INTRODUCTION

The effectiveness of dealing with solid waste in the target countries depends on the degree to which the served population identifies with and takes .ownership of the systems and facilities. To this end, it is important that the people be involved from the outset in the planning of the local segments of waste management systems. It is within this context that under work package 2 (WP2): 'Analysis and Evaluation of current situation in the target countries'. As a result of this mapping major barriers and waste problems in Western Africa arose. During work package 3, IWWA partners identified best integrated solid waste management systems and approaches in Europe. Based on the recommendation of these best practices, a guideline was developed on how to select the most suitable ISWMS as well as how to implement the chosen suitable ISWMS by the target countries. In work package 4, policy options were evaluated in relation to results of previous work packages, and an elaborated policy recommendations as well as development of roadmap for the management and planning strategies in a multidisciplinary approach for the promotion of region-adapted waste management solutions.

The identified best ISWM system, development of the most appropriate guideline for the implementation as well as how to implement the most suitable chosen ISWM system for the target countries, also the various policy recommendations as well as the development of roadmap for the implementation the most ISWM systems will have some implications on the socio – economic well – being of residents of the target countries who will make use of these methods. It is against this background that under the current task, IWWA partners are evaluating the effects that the proposed changes will have on the socio – economic well – being of residents of the targeted countries.

2.0. Integrated solid waste management options for the target countries

Municipal solid waste management is considered as a critical problem in the target countries (i.e., Ghana, Nigeria, Cote d'Ivoire and Senegal). The current methods of disposal of municipal solid waste in the target countries include but not limited to collection, transportation, partial treatment of the waste (which include open burning, open dumping on land, uncontrolled incineration, crude method of recovering materials resulting in the release of toxic chemicals such as heavy metals, PAHs, dioxins, etc which contaminate land and water bodies) and disposal (dumping of the waste at unsanitary landfill sites and local incineration. Open dumping of waste at unsanitary landfill sites as well as open burning of waste is still the predominant management option because of less initial capital and operating cost than the other options. However, landfilling is regarded as unsustainable due to its harmful impacts on the environment. In the past, waste generation rates were far less than at present and the distance to disposal sites were within reasonable distances. However, according to the large amount of waste generated per year in each community, the rapidly high increasing land use for landfilling and the higher concerns in health and environmental impacts, landfilling is the waste management option that should be eliminated.

It is within this context that under the IWWA project, the target countries in West Africa were exposed to the integrated solid waste management options as spelt out in part A of this deliverable. Successful implementation of the methods proposed in part A above will lead to sustainable management of solid waste in the target countries. Sustainable management of solid waste in the target countries demands an integrated approach based on the waste management strategy shown in figure 1.0.

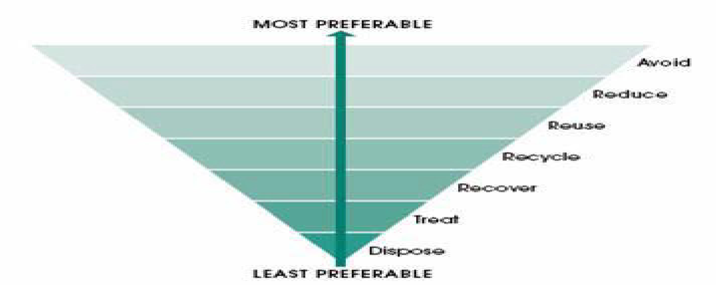

Figure1: Integrated solid waste management strategy

It is unlikely that the only single option of waste management is sufficient to deal with the current problem of MSW. Therefore, the integrated solid waste management (ISWM) system is must be considered. The example of ISWM is shown in figure 2.0. It is obviously that the first and the most preferable option is prevention and reduced generation of solid waste in the target countries. According to Azapagic et al., (2005), waste prevention is closely linked with influencing consumers to demand greener products and less packaging.

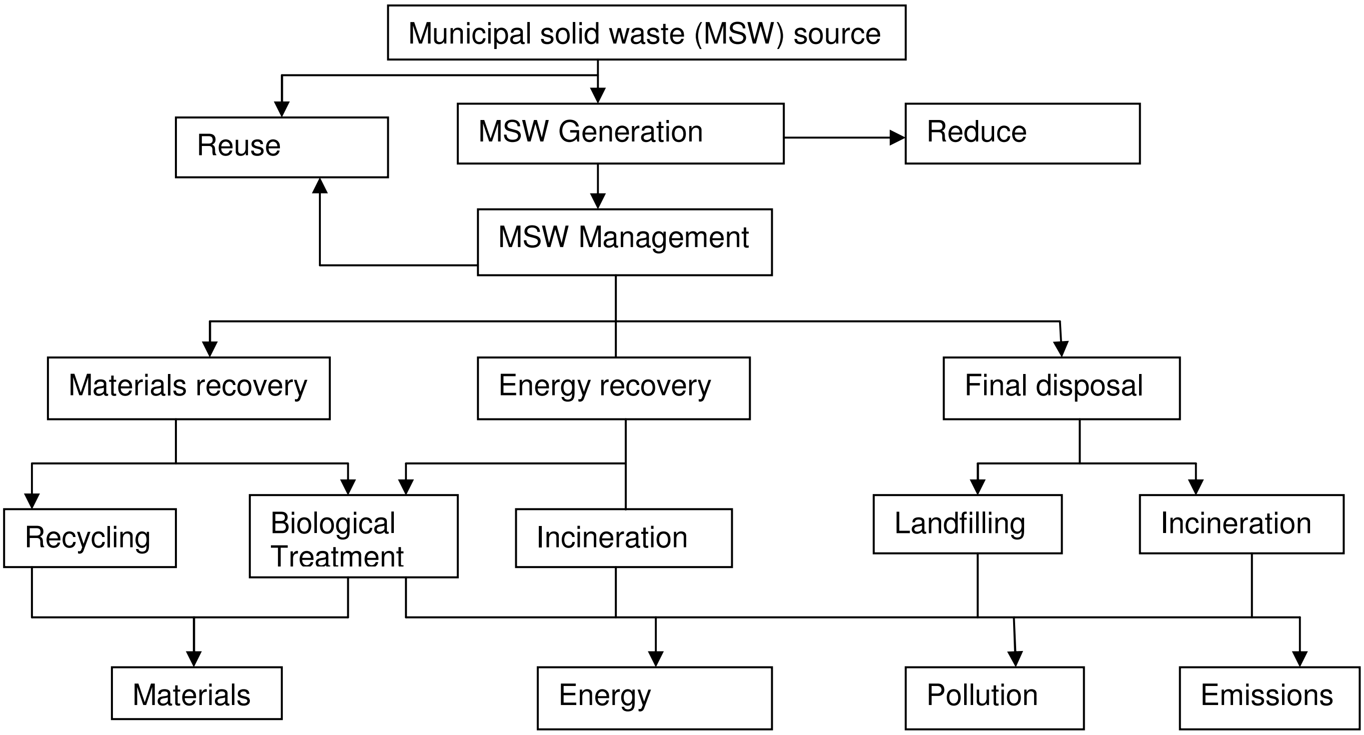

Figure 2: Integrated solid waste management options.

3.0. Waste prognoses methods

Health and environmental impacts of municipal solid waste is based on the analysis of how the waste is generated. Analysis of municipal solid waste generation is also based on the analysis of historical data for both waste and waste-related information on social, economic or other border conditions. The goal of these analyses is to accurately assess the influence of one waste factor as well as a set of waste factors on either the total or partial streams (e.g. recyclables) of municipal solid waste generated.

The concept of prognosis is not new. Prognosis methods have been developed in disciplines such as business administration, economics or engineering. Experiences in these mentioned fields have

lead to a wide range of approved prognosis tools which can be applied in the area of integrated solid waste management in the target countries.
There are two methods of waste prognosis analysis. These are the quantitative and qualitative methods.

3.1. Quantitative solid waste management Prognosis

Quantitative waste prognosis methods are based on either statistical or econometric methods and are normally used for short-term (till one year) or mid-term (1 to 5 years) forecasting the effects of a particular solid waste management options.

If no other input parameters are required beside historic time series, then **time series analysis method** of analysis of the waste management option comes into mind. Depending on the level of sophistication, these methods range from linear extrapolation over smoothing methods to ARIMA (autoregressive integrated moving average) modeling (CHANG & LIN, 2001) or Fuzzy Logic. The objective for the time series analysis of the solid waste management option is to evaluate the short term effect of seasonal fluctuations of waste generation using a seasonal ARIMA model.

Alternatively, if more input parameters are required beside the historic time series, then the **Coefficient models** are used. The model describes functional relationships between waste quantities and one or more parameters, regarding economic activity, the number of residents, or the number of overnight stays of tourists. The estimation of the coefficients respectively multipliers result from assumptions about specific performance figures, regression analysis (using the ordinary least square method) or sophisticated time series methods which consider input parameters.

3.2. Qualitative solid waste management prognosis

Qualitative forecasting methods come from the assumption of functionally defined relationships between waste generation and certain variables. The implication of possible changes of border conditions of these methods leads to the application for long-term developments.

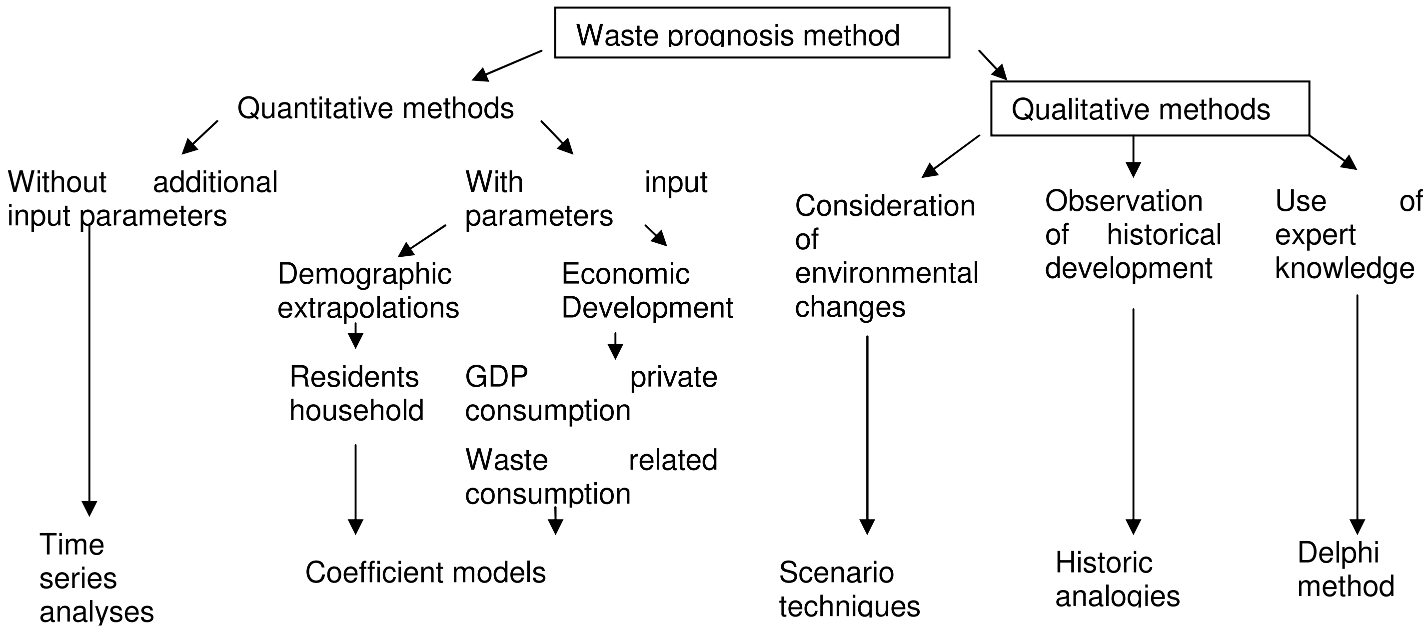

Figure 3: waste prognosis methods

By means of the **scenario techniques**, possible deviations of a forecasted trend are estimated through a small number of bundles of possible, more or less realistic assumptions (e.g. especially optimistic or pessimistic economic development). The use of scenarios is not an independent methodical forecasting approach, because the output of each scenario has to be estimated with another method as shown in figure 3.0 above.

It involves two main approaches. These are the **Delphi Method** and the **Historic analogies.** The Delphi method is a multi-stage inquiry of experts. The required number of experts to consulted usually ranges from 50 up to 100 with regard to a certain topic on ISWM. The field of application covers long term forecasts on the basis of little or lacking objective information which requires the consideration of subjective, qualitative estimations of experts. Disadvantages of this method are the high expenses due to the extensive time exposure.
Historic analogies are based on qualitative judgments about similar developments. It is assumed that knowledge about an observed historic development (e.g. related to a defined region or a product life cycle) improves the assessment of the future development under similar border conditions.

4.0. Life cycle analysis of integrated solid waste management

According to Azapagic et al., (2005), life cycle analysis of the ISWM system is a tool used to identify the impacts associated with each of waste management alternatives from 'cradle to grave' in order to help to make an assessment.

The LCA assessment is divided into environmental, social and economic aspects. The assessment of environmental impact is linked with the pollutant emissions and the consumption of resources within the system. The impacts arising at the construction phase are excluded from assessment. For the economic assessment, the cost of the system is concerned which includes investment in waste containers, collection and transport vehicles and treatment plants.

4.1. LCA of ISWM - social assessment

4.1.1. Social acceptability of the proposed methods for ISWM for the target countries

According to Beigl et al., (2004), the effectiveness of any SWM system in any country depends to a large extent on developmental and socio - economic indicators such as GDP, population density, life expectancy, infant mortality, GDP, household income levels, cost of waste collection, income distribution (prosperity levels). These indicators can also be used as a measure of social sustainability of an effective solid waste management system in any given community or country. Based on this assertion, in deliverable 2.1 of work package 2, IWWA partners used the above indicators to evaluate the existing solid waste management practices in the target countries. The various socio – economic and developmental indicators used in deliverable 2.1 of work package 2 for each target country have been presented in tables 1.0 and 2.0 below.

Table 1: Demographic characteristic for the target countries

Criterion	Côte d'Ivoire	Ghana	Nigeria	Senegal
Expected yearly population growth from 2005-2015	1,8%	1,9%	2,2%	2,5%
Population density	64.7	79.3	46.5	62.3
Life expectancy at birth	47.4	59.1	46.5	62.3
Infant mortality (number of deaths/1000 births)	112	8.93	16.31	10.72

Source: IWWA report: deliverable 2.1 – Regional evaluation of the situation in the target countries

Table 2: Economic characteristics for the target countries

Criterion	Côte d'Ivoire	Ghana	Nigeria
Annual Gross Domestic Product	-0.5%	2.0%	0.8%
Household income (USD per person)	900	485	752
Income distribution - Gini Coefficient (GC) 1. Complete equality (GC = 0) 2. Variable levels of Equality (0<GC<100) 3. Complete Inequality (GC = 100)	44,6 Variable levels of Equality	40,8 Variable levels of Equality	43,7 Variable levels of Equality
Quality of life (The Economist Intelligence Unit's quality-of-life index, 2005 report. Ranked from 1 to 10 (10= best)	No data	5.174	4.505
Financial capacity of households: percentage of the population living below the poverty line i.e. with less than 1.25 US$ per day (poverty rate)	No data	29,99 % (in 2006)	No data
Cost of waste collection and disposal (national average for annual cost in dollars per household)	1500 FCFA per month i.e. 18 000 FCFA per year	$ 60	Mainland : $3.50c -$16 Island: $17- $35
Expenditure on waste collection and disposal (at household level)	5% of household income is spent on waste disposal	7% of household income is estimated to be spent on waste disposal	No data

Source: IWWA report: deliverable 2.1 – Regional evaluation of the situation in the target countries

From Tables 1.0 and 2.0 above, it can be seen clearly that most of the residents in each of these countries live in rural communities, where solid waste management services are not well structured and even in urban communities where solid waste management is well structured, most resident are not able to afford the cost of waste collection as well as embracing the concept of ISWM.

The concept of ISWM which mainly focuses on the 3Rs is not widely practised in the target countries. Also the proposed methods by IWWA partners for implementation in the target countries have not been tested, it is therefore important that in other to ensure social acceptability of these methods, members of the target countries educate the citizens before its implementation.
Since solid waste management issues are best handled with the participation of all concerned citizens, on a relevant level. The traditional top down strategy (also known as "*DAD*": Decide,

Announce, Defend) should be gradually be replaced by a range of responsive and trust-building community involvement processes.

It is important to note that public involvement in decision-making is not necessarily being driven solely by considerations of transparency, democracy or social justice. Change is also driven by the demands for higher levels of technical competency and improved risk management. Involving general public in waste management decision making leads to more technically competent and defensible decisions that reduce the risks for government and also ensures social acceptability of the decisions made. Likewise, public participation in the decision-making process introduces a broader range of ideas, experiences, and expertise that motivate the development of alternative solutions which also ensures social acceptability of the proposed methods.

The strategy to achieve social acceptability of the solid waste management will differ from one location to the other, however it must highlight the strengthening of the capacities of civil society and of government institutions at all levels, and outline mechanisms for soliciting, receiving, and integrating public input, and expanding opportunities for government and civil society to interact. Some principles can be proposed on a general scope:

1) ***Proactivity.*** Public participation requires that governments and civil society take initiatives, in accordance with their respective roles, to develop their maximum potential and enrich the process of decision-making for sustainable development.

2) ***Inclusiveness.*** Full participation by all those interested in and/or affected by sustainable development issues is essential to achievement of durable solutions. Special efforts should be made to include the participation of the private sector, and to create equal opportunities for women and vulnerable groups such as indigenous populations, youth, disadvantaged racial and ethnic minorities (including disadvantaged populations of African descent), and other traditionally marginalized groups.

3) ***Shared Responsibility.*** Governments and civil society must share equitably the commitments, burdens, and benefits of development.

4) ***Openness throughout the Process.*** Inclusive and continuous participation throughout the process of design, implementation, and evaluation of projects, policies, or programs inspires new ideas and expertise, legitimizes decisions, and enriches outcomes. A decision-making process that is open to input at all phases can benefit from adjustments wherever they are needed to respond to new information or circumstances.

5) ***Access***. The involvement of civil society in development decisions is essential for lasting solutions. In order to participate effectively, citizens must have timely access, at the various levels of government, to information, to the political process, and to the justice system.

6) **Working with the Media and NGOs.** Newspapers, television, radio, magazines, and other media can be used to quickly reach a large number of people. The print, broadcast, and Internet media can be a powerful ally in educating the public on waste management matters. The media will need to be educated in building capacity to report on waste management matters. This can be done informally, through regular briefings and information centres that are accessible to the media and to the public. These centres may be run by a governmental agency or Ministry or by an NGO. An information centre may disseminate recent information such as press releases, have a public library with a range of environmental resources, and actively disseminate information.

7) **Educating Community and Traditional Leaders.** Traditional and religious institutions still play a key role in Africa. Traditional, religious, and local community leaders can play an influential or even decisive role in how people act. This is particularly true in rural areas. Involvement and education of these leaders can assist in influencing People's attitudes and contributions to waste minimization, waste separation and recovery. In working with such leaders, the following needs to be taken into consideration:

- **Language:** educational materials may be more accessible if they are in the local language. **Literacy:** posters, radio presentations, and other approaches may be advisable if the local population (or leaders) have limited literacy;

- **Clarity and Plain Language:** The materials should be easily understood, particularly if they are written in what may be a person's second or third language. This means short sentences, simple words, and active verbs.

8). **Celebrities in Media Campaigns.** The involvement of local celebrities that is well-known and respected. Public figures in media campaigns can be a potent way of increasing understanding of the importance of waste minimization, waste separation and recovery and other environmental issues and enforcement.

9). **Focusing Environmental Awareness Campaigns for Specific Sectors.** Awareness raising campaigns are often most successful when they are targeted at specific groups, rather than general, because information can be tailored to the activities, needs and challenges of the group. Additionally, involving organisations and communities in environmental protection and enforcement can create a sense of stewardship towards the environment, ease hardship through the collaboration and provide a forum for new ideas and greater participation.

10) **Environmental Awareness in Teaching Programmes.** "Mainstreaming" environmental education programmes on benefits of 3R into schools as a regular part of the curriculum increases public environmental awareness and demonstrates a commitment to environmental protection. This can be introduced as early as primary school as well as in adult education programmes.

11) **Environmental Education Programmes for Women and Youth.** Mobilizing and unearthing the full potential of women as major contributors in national environmental management through workshops and training programmes.

12) **Availability of information on location of recycling facilities.** Availability of recycling facilities and nearness of location of the facilities from homes and information on availability of recyclable items market will encourage the public to be committed to the 3Rs.

4.1.2. Social equity assessment of the proposed ISWM methods for the target countries

Poor communities have no access to better waste management services as compared to their well to do counterparts. This is because they:

1. are unable to pay for services provided.
2. have bad road network which make accessibility very difficult.
3. have very poor spatial arrangements making it difficult to design a formal waste service plan.
4. have high population density which affects the rate of waste generation.
5. Have poor attitude towards waste management.

Payment for service provision alone is not enough to address the problem of lack of equity in service provision. The above mentioned factors had to be given detailed consideration with special interventions by authorities to address the issue on how to give better services in waste management. Some of these interventions could be:

A. **Payment of subsidies**:

The authorities could pay subsidies to service providers to bridge up the difference between fees paid by the high class and the low class communities.

B. The use of the informal waste collectors in the poor communities.

The informal waste collectors could be integrated into the waste collection plan to allow for collection of waste in areas difficult to access by the waste collection trucks. The use of those informal waste collectors will help create employment for the section of the youth involved whilst at the same time extending services to areas which are deprived of better services due to poor spatial arrangement and poor road network.

C. The use of the Central Communal Containers.

Central communal containers should be placed at vantage points for dumping and lifting to disposal sites.

D. Introduction of Community Recycling of Organics.

Community composting could be encouraged in these poor communities to allow for total reduction in the volume of waste to handle whilst at the same time creating job opportunity, boosting agricultural activities and ensuring food security.

In developing countries, particularly in Western Africa, solid waste management still suffers from a low level of integration of the community in existing management systems. This is due both to internal and external factors.

Internal factors are mainly a lack of awareness about environmental protection, inadequate behaviours of some inhabitants and the general lack of concern about public areas that are considered "*both as everybody's property and as nobody's property".*

The main external factors are on the one hand a lack of dialogue between communities and the authorities responsible for waste management, and on the second hand a lack of community empowerment on an issue that affects them directly. If communities were well integrated into waste management systems, they could contribute to improving them in a sustainable way.

As producers of household waste, communities should be the main actors to manage this waste. To achieve this, they should understand what waste management is, and the related issues, including economic, social, health, environmental and even political aspects.

Communities can play a leading role in waste management, at the household level, at the neighbourhood level and at neighbourhood clusters level.

At home, it is important to involve all family members on the practical aspects of waste disposal in the backyard. This approach should from the beginning, focus on waste separation at the source, by encouraging households to identify, separate recyclable materials or re-use some goods according to their category.

In the neighbourhoods or neighbourhood clusters, citizen control over waste management should be encouraged through the establishment of local organisations dedicated to salubrity, such as "neighbourhood committees" or "salubrity groups".

These organisations should be trained on waste management and all related issues. They could also benefit from material support (small sanitation and cleaning equipment) and be trained on how to use and maintain the equipment. Members should be volunteers, ready to serve the general interest in their neighbourhoods.

These adequately trained and equipped organisations might then be involved in household waste pre-collection. This should be done under formal agreements with the authority responsible for solid waste management. This is already the case in some municipalities such as Bamako, Mali where the city has sub-contracted household waste collection and transportation to transfer stations to micro-entrepreneurs (in French : "*GIE*" meaning *Groupementsd'IntérêtEconomique*).

These neighbourhood organisations may also link up municipalities, waste management companies and residents by encouraging and even implementing actions :

- to raise public awareness on good waste management practices, on the definition of collection timetables and roads with municipal officers and waste collection companies,
- to hold dialogue sessions around community-based waste management in the neighbourhoods. These dialogue sessions would be used to debate on the challenges identified and take decisions by mutual agreement on the solutions to be adopted.

Bearing in mind the objectives of empowerment and wealth creation for the poorest, community-based waste management organisations should not limit themselves to the job that big companies decline to do because it is too expensive or because their collection vehicles are inadequate (i.e. waste pre-collection in poor, densely inhabited neighbourhoods). On the contrary, public authorities should even encourage community-based waste management organisations to acquire new skills and position themselves in sectors with more added value such as the recycling sector, the management of composting units/gardens, the management of semi-industrial biogas production plants, or in any other sector relevant in terms of income-generation, environmental protection and social usefulness.

4.2. Economic assessment of the proposed methods for ISWM in the target countries The economic assessment in this LCA-IWM assessment tool provides the economic evaluation of waste management scenario using the principles of economic sustainability. The economic assessment in this LCA assessment involves the following areas:

- *Economic efficiency:*

It is measured by;

- ISWM cost per ton, per household or per person

- Revenue from recovered material and energy

- ISWM cost as % of Gross National Product (GNP) of the city

- Diversion between revenue and expenditures for ISWM system.

- *Equity:*

The goal of using equity as a criterion is to examine the economic burden of ISWM system which is distributed among the citizens. It is measured by;

- ISWM cost per person as % of minimum wage per person; and

- ISWM cost per person/income per person.

- *Dependence on subsidies:*

The purpose of this criterion is to examine whether the ISWM is self sustainable or based on the external financial sources. It is measured by using the Subsidies or grants per person as an indicator.

5.0. Assessment of the appropriateness of the measures for stakeholders involved in SWM in the target countries

All the measures recommended to improve solid waste management in West Africa can be assessed in the light of the socio-economic indicators that were discussed under WP 2, Deliverable 2.1. Based on the indicators in D2.1 that are relevant here, as well as some broad economic criteria such as economic efficiency, equity and dependence on subsidies and broad social indicators such as social acceptability, social equity and social benefits (Pukrittayakamee, Prin, 2010. Community-scale Integrated Solid Waste Management System. MSc thesis, University of Strathclyde, Dept of Mechanical Engineering pp26-28), it can be seen that the methods proposed in WP 3&4 do indeed have the potential to improve the socio-economic status within the target countries.

Because of the lack of data and the qualitative nature of this study, however, it is not possible to calculate in quantitative terms the difference that the proposed measures will produce, for example, between costs of SWM and income that will be generated by recovered energy and materials. Until their actual data available from pilot projects implementing some of these recommendations, the assessment can only be qualitative.

Table 4.0 is a summary of the qualitative assessment how appropriate the recommended measures are for the different stakeholder groupings that are dealt with throughout this study. The relevant indicators that are linked to the measures for each stakeholder grouping are also included in the last column of the table.

Table 3.0: Assessment of the appropriateness of the measures for stakeholders involved SWM in the target countries

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
Household Waste producers/Users of SWM service (formal households, urbanized, high density dwellings, and commercial areas)	Householders identify, separate recyclable materials or re-use some goods according to their category at household level Have strong public participation in setting up systems, whether community-based or local authority initiatives. Waste producers have access to information 'User pays', but pay service fees according to affordability, with poor households being subsidised Door to door or neighborhood/district wide collection service (with satellite collection points) for household waste Extend collection service to semi-urban areas Provide public or privately run drop off facilities for recyclables and compostables Provide litter bins in CBD Educate on integrated waste management and wise consumption especially at school level	Clean and healthy CBDs in large metropolis Recovery of high value recyclables at source Satellite stations collect organics for further more centralized processing Job creation and earnings from waste within the community Ownership of SWM systems and increased accountability of the users Increased recycling and waste awareness More positive attitudes towards SWM	Door to door collection can be achieved affordably using community contractors and by recovering service fees Municipal drop off sites (outsourced to private contractor mandated to recover, recyclables from household waste) can be very effective for suburbs, secondary type cities where municipal collection services are not in place Mobile chippers at a drop off are suitable to pre-process organics for composting elsewhere Litter bins are only useful if they can be serviced regularly by the municipality or an appointed PPP High income is generally linked to better educational levels and always to high waste volumes – educational campaigns need to target that sector rather than trying a "one size fits all" approach for all types of residents Job creation is very appropriate here	Household income level Employment status Financial capacity of households Social acceptability Social benefits Social equity Dependence on subsidies reduced Economic equity Economic efficiency

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
Informal Waste Producers/ Non-users of SWM service (informal households) Low waste production with much higher organic fraction	Consult with communities in setting up systems Develop local, decentralized waste solutions such as home composting or community recycling of organics Provide infrastructure and training for simple value adding steps to make useful saleable products (e.g. alternative building materials with tyres, cans and glass bottles; shoe soles; fuel replacement bricks from wastepaper; waste2art craft from plastics; swings from tyres; (http://www.earthships.co.za/) Introduce community contractors/manual collection systems for inaccessible areas that link with a formal motorized	Basic service to urban informal communities People more able to help themselves – community-based SWM systems Job creation and alternative local product and art development. Poverty alleviation and house building material alternatives Changed mindsets Gender sensitive solutions	Suitable for the urban context where waste transport costs are often prohibitive. The more costly it is to collect and transport waste to a centralized separation and processing point or a landfill the more attractive are strategies that are geared at decentralized, source based local self-reliance waste solutions. Socio-economic spin-offs such as stimulation of entrepreneurship and job creation from waste beneficiation programmes can assist with slowing down the current rapid rate of urbanization as people find survival in rural communities increasingly more difficult Resistance to change may be encountered	Household income level Employment status Financial capacity of households Social acceptability Social benefits Dependence on subsidies reduced Economic equity Economic efficiency

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
	system Access to information			
Waste producers: industrial manufacturers, importers, distributers	Make industrial producers responsible for production AND post-consumer waste Introduce clear legal requirement for "Industrial Waste Management Plans" for certain problematic waste streams. Such plans must state type and amounts of waste and how it will be managed. Required to supply data to Waste Information System that will enable waste exchange schemes and Cleaner production interventions. Legislate for producers and importers to internalize and fully realize costs of safe treatment and take-back of waste items as part of their total life-cycle. Introduce "Extended Producer Responsibility" for hazardous waste streams such as industrial wastes and effluents, e-waste, and certain health care risk waste such as expired pharmaceuticals Have access to information Strong participation in SWM	Industrial Waste Management plans will enable Government to plan ahead better for large scale waste re-use, industrial symbioses, eco-industrial park programmes. Waste that is properly measured and accounted for can be managed better both by the producer as well as by Government. More accurate budgeting for large capital expenditures such as a future landfill development. Waste exchanges set up EPR can provide financial and structural support for community waste collection schemes. Local companies would be able to follow Brazil's model where leading global co-operations all jointly support the formation of "waste picker collectives" country-wide. These receive both pre-consumer waste for value added processing (such as sorting, baling, granulating) and get access to municipal waste through special agreements with participating municipalities that are much less costly than the same services rendered by private waste service	Industrial WM Plans are highly effective to capture industrial bulk waste generators and for government to fully grasp the implications of their operations (in terms of industrial waste produced) as well as their contribution to the post-consumer municipal waste stream. Underfunded, fragmented, unskilled and understaffed municipalities in West Africa are hard-pressed to fulfill their mandate of managing wastes and landfills responsibly. Municipal waste mandates should not go beyond the handling of municipal waste. Hazardous waste management should be outsourced to specialists. Any other waste type such as e-waste, household hazardous waste, industrial wastes needs to be linked FIRMLY back to the generator who must take ultimate responsibility for all associated WM costs. Co-operatives are highly recommended as a model to	Employment status Social acceptability Social benefits Social equity Dependence on subsidies reduced Economic equity Economic efficiency

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
	initiatives	providers*. [*CEMPRE case studyhttp://www.worldbank.org/urban/solid_wm/erm/Annexes/US%20Sizes/New%20Annex%204B.6.pdf] True market price-related cost sharing can be achieved. Deposits or levies raised on a product at the point of purchase ensure that products will maintain value at all times and become a potential new resource when turning into waste. Deposits encourage the public to bring waste back to the sales point from where further take-back should be ideally arranged to a local recycler or local producer. Deposited packaging items are also rarely found and disposed of as "litter" as they have value. Research and development opportunities in piloting new schemes.	ensure that producers fulfill their "cradle to cradle" product life-cycle obligations while the public and particular the poorest of the poor can benefit at large from a set-up that favours low-tech, high labour intensive collection and processing structures suitable for the typical challenging socio-economic profile of West African countries. Deposits are highly effective to ensure that packaging waste finds its way back to the nearest buy-back centre and they work particularly well in rural environments as an incentive to collect and sell for subsequent financial rewards. Other incentives that have worked to motivate people to bring back waste to collection points include tickets for free public transport, basic meals etc. Again such incentives should be financed largely by the industrial stakeholders with the role of the municipality being to participate, advise and engage as a key stakeholder but not as the party ultimate responsible for a successful take-back system.	

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
Formal Private Waste Service providers/ Private Operators: At each step in the SWM system: • Pre-collection • Collection & transport • Reuse & recycling • Treatment & disposal	Have greater participation of private sector in planning and setting up systems Have timeous access to information Private sector must handle responsibly hazardous type wastes such as industrial waste, Health Care Risk Waste which a municipality typically does not manage. Provide services outsourced to Private Sector where appropriate; enter into Public Private Partnerships with Government bodies Tender processes must be accountable and transparent; required by law to register with their respective municipality, District, or Province, as an "accredited" and auditable service provider. Must comply with basic international handling, transportation and disposal standards to qualify Must disclose basic information	Participation leads to greater buy-in, innovation and more professional services Qualified and suitably equipped service providers to handle and dispose problematic waste types and therefore ensure that the public safety is not endangered Partners with municipalities must offer truly "integrated" waste management solutions in key areas such as metropolis Partners with local industries and businesses must fulfill their obligations (as part of the latter's industrial waste management plan) of responsible, waste prevention oriented waste management Moving away from the current role of disposal only service provider to a more inclusive ongoing consultative arrangement where private waste service providers look out for opportunities for industries to reduce waste to landfill (e.g. by setting up private waste exchange arrangements) and get a share of the resulting savings achieved. More economic opportunities e.g.	The role of sufficiently skilled and equipped formal private service providers important to handle industrial waste management activities. The costs of utilizing a private formal waste service provider to aid a municipality with "add on" delivery items such as a household recycling collection and sorting service must be determined. Alternatively cooperatives from members in the informal waste sector might be used. Obtaining even basic information from the private waste sector is likely to be very challenging (due to the fiercely competitive nature of the industry). Clear legal mandates for "accreditation" are likely to be required to get any private sector information that might assist governments to see the full picture and hence have a chance of better municipal planning and budgeting New technology often has high investment costs	Economic equity Economic efficiency Distribution of income Household income level Employment status Production sectors Cost of waste collection and disposal Expenditure on waste collection and disposal Distribution of income Social equity

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
	to government on the type and quantities of waste they handle for the National Waste Information System to be developed. Municipalities can work with them on high-end PPPs such as assistance with collection of recyclables from high income, high density households Integrate informal WM sector where possible – build links Have equal opportunities for women and vulnerable groups	energy from waste benefits	Government must pay private service providers timeously Need to prevent the emergence of waste or recycling cartels	
Informal Waste Operators, Handlers and Dealers [Note: Informal waste operators, individuals tend to be highly self-organised, flexible and strongly day-to-day market-driven in their activities. Typically they are uneducated in the conventional	Introduce instruments and strategies to stabilize and strengthen informal sector's valuable contribution to waste management strategies: • guarantee buy-back prices of materials (if necessary directly subsidized by the relevant industry), • incentives to join co-ops that build skills • counseling and educational programmes after hours and beyond waste picking with a view to improve their overall living conditions. • Give them an official voice and clear and protected	Stabilised informal workforce able to organize themselves Very attractive to work with for municipalities in the form of "co-ops" as much cheaper and more flexible than the formal waste management sector. Partnerships can keep down cost for transportation in particular in more remote lying areas outside key metropolis. Better working conditions for informal operators with improved health and safety,earnings and access to social services	As described above in much detail organizing informal waste operator into coops (which are funded and directly supported by the corporations who typically cause the waste problem and pollution problem in the first place through a similar model such as CEMPRE) as well as municipalities (who employ them where required to enhance and complement traditional municipal services) seems to be a working strategy in the context of developing countries such as Brazil. It is highly recommended to test-drive such a strategy in West Africa too. South Africa is	Economic equity Economic efficiency Distribution of income Household income level Employment status Production sectors Cost of waste collection and disposal Expenditure on waste collection and disposal Distribution of income Social equity

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
sense, very poor and rely on low tech (e.g. transport by an ox cart instead of a conventional petrol driven waste collection vehicle), high labour intensive operational set-up. Increasingly alcohol and drug abuse are making this already (by nature) unstable work-force even more unreliable.]	mandate in the country's overall waste management strategy Provide buy–back points where fair payment is offered of all types of e-waste and prior to any dismantling to reduce exposure of informal waste operators to very toxic materials in recovering valuable components of e-waste. Formal dismantlers of e-waste can pay bulk prices per kg of e-scrap to prevent this. Have equal opportunities for women and vulnerable groups		likely to embark on a very similar path and the South African Packaging Industry is relying heavily on boosting and fully developing this sector as part of fulfilling their mandate as requested in the National Waste Act and expressed in the industry's industrial waste management plan.	
Public Sector: National/State Level Authorities/ Regulators/ Government Agencies (Not for profit)/ Traditional Authorities	Develop and/or review integrated SWM policies and legal framework to make them more cohesive and aligned to the hierarchical management of waste. Require the development of integrated SWM plans at each level of government. Develop policy and legislation that is built on the principle of trading according "Best International Practice" i.e. global corporations and importers of goods must apply the same	Effective, harmonised SWM policies, laws, and economic instruments Better cooperative governance once roles and responsibilities clarified. Waste Information System developed Enforcement and compliance monitoring strengthened Increased accountability of producers, waste operators and government officials Increased stakeholder participation, awareness and cooperation Reduced levels of conflict around WM issues Increase capacity to manage waste	Integrated SWM plans will address the critical need for more cohesive and focused approach to SWM for all role players Changed attitudes in the users around improved SWM could lead to greater willingness to pay for services In West Africa it is appropriate to set an entry level trading requirement to avoid being exposed to outdated technologies, dangerous goods	Economic sustainability Economic equity Economic efficiency Distribution of income Employment status Production sectors Cost of waste collection and disposal Expenditure on waste collection and disposal Distribution of

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
	standards they offer as international best practice elsewhere. Strengthen public participation Make SWM information freely available Make available strategically zoned land for competent private waste management operators to be contracted to operate in these allotted areas. Make it possible for private contractors to obtain attractive loans or funding (guaranteed, concessionary, grants, etc) to grow especially in technology transfer, acquisition of assets, and capacity building.	properly More positive attitudes towards SWM Authorities willing to make land available Planned approach allows for review and continuous improvement	and blatant lack of product stewardship Much depends on political will and buy in of the political leaders for improved SWM to be successful.	income Social equity Dependence on subsidies reduced
Public Sector: Local/District Level	Develop Integrated SWM Plans Develop specific local bylaws and regulations aligned to national policy and legislation Ensure compliance of SWM operations from cradle to grave Fair, open and transparent tendering for outsourcing and PPP contracts Carry out compliance monitoring and enforcement Create a climate conducive for recycling and other waste minimisation initiatives. Greater stakeholder participation and cooperation	Local laws and regulations harmonized and compliance monitoring and enforcement made easier Financial planning and dedicated budgets for SWM Reduced costs for clean-up of illegal dumping Alternative sources of income from waste management activities Strengthened monitoring and enforcement incentivizes improved SWM Improved SWM standards and compliance Improved revenue collection and	Realistic service fees for users will ensure affordability Shared accountability – waste producers must take on responsibility for their own waste Recommended measures meet the need for • Greater compliance • Improved co-operation amongst stakeholders • Integrated SWM systems to reduce waste disposed to landfill Need political will and buy-in and no political interference in awarding of tenders	Economic equity Economic efficiency Distribution of income Household income level Employment status Production sectors Cost of waste collection and disposal Expenditure on waste collection and disposal Distribution of income

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
	Create equal opportunities for women and vulnerable groups Make available strategically zoned land for competent private waste management operators to be contracted to operate in these allotted areas.	payment for services Reduced risk of failure of SWM systems if strong public buy-in		Social equity Social acceptability
NGOs/CBOs, Community Leaders	Assist government and its agencies with Integrated SWM measures, training, awareness raising activities Hold governments and institutions accountable to delivering on promises Whistleblowers if any irregularities occur	Increased involvement and support Raised awareness on SWM More opportunities for identification and implementation of initiatives that derive economic and social benefits from waste Increased knowledge and skills around waste management Improved attitudes towards integrated SWM	NGOs and CBOs involvement includes playing a 'watchdog' role. This is appropriate in a developing country.	Economic equity Economic efficiency Household income level Employment status Production sectors Cost of waste collection and disposal Expenditure on waste collection and disposal Social equity Social acceptability
Education and Research Bodies	Mainstream environmental education in school curricula, including WM Provide education programmes for women and youth Ensure that there are (preferably) accredited courses that are accessible and funded to professionalise SWM Run awareness campaigns that focus on specific sectors to be effective Research and development to	Educated informed staff professionalise the waste industry Increased involvement and support improves SWM technologies and management systems Piloting of new systems Trained staff are able to earn higher income Research and development initiative contribute valuable data to the Waste Information System Attitudes towards waste positively influenced by awareness-building	Although there are costs involved in research and development these are very necessary for progress to be made Improved data enhances the ability to plan effectively	Economic efficiency Production sectors Cost of waste collection and disposal Expenditure on waste collection and disposal Social equity Social acceptability Indicators would be project specific

Stakeholder Group	Recommendations made	Desired effects/benefits	How Appropriate for W Africa?	Indicators that will improve
	investigate innovations in SWM	campaigns and educational measures		
Development Partners/ Funders	Should not set unrealistic conditions for funding that are not appropriate for beneficiaries. Support should be closely aligned to the integrated SWM plan in beneficiary institutions	Improved governance and accountability in SWM will attract more support from development partners Beneficiary institutions will be empowered to negotiate donor interventions that are appropriately aligned to their integrated SWM plans	Appropriate interventions by development partners are needed so that they are not skewed to fulfill a donor's agenda rather than to provide what is needed for the beneficiary institution	Economic efficiency Economic equity Cost of waste collection and disposal Expenditure on waste collection and disposal Social equity Social acceptability Indicators would be project specific
Media	Must be educated in SWM matters Feed through regular news items to radio, TV, newspapers etc. Involve local celebrities who emphasised the importance of good SWM	Media promote positive messages around SWM Increased public awareness Large numbers of people rapidly become aware of SWM	Can be very effective if delivered in a local language and can reach into rural areas where literacy levels may be low Large numbers of people can be reached quickly	Social acceptability

6. Summary and conclusion

Municipal Solid Waste Management (MSWM) is a major responsibility of local governments. It is a complex task which requires appropriate organizational capacity and cooperation between numerous stakeholders in the private and public sectors. Although it is essential to public health and environmental protection, solid waste management in most cities of developing countries is highly unsatisfactory.

The functioning of MSWM systems and the impact of related development activities depends on their adaptation to particular characteristics of the political, social, economic and environmental context of the respective city and country. An assessment of the proposed methods in work packages 2, 3 and 4 IWWA partners in this task have revealed the following:

- Waste generation patterns are determined by people's attitudes as well as their socio-economic characteristics. Attitudes towards waste may be positively influenced by awareness-building campaigns and educational measures.
- In many low-income residential areas, community-based solid waste management is the only feasible solution. Functional links between community-based activities and the municipal system are very important.
- Even where municipal waste collection services are provided, user cooperation is essential to efficient MSWM operations. Cooperation may be promoted through general awareness-building programmes as well as focused MSWM information campaigns.
- Waste workers especially those in the informal private sector live and work under socially precarious conditions and are subject to serious health risks. Support should aim to improve their working conditions, earnings, and access to social services.
- Solid waste generation and the demand for waste collection services generally increase with economic development.
- A trade-off is normally required between the objectives of low-cost collection service and environmental protection.
- The economic effectiveness of MSWM systems depends upon the life-cycle costs of facilities and equipment and the long-term economic impact of services provided.
- Economic strategies should seek, firstly, to increase effectiveness and labour productivity of MSWM and, secondly, to generate employment by expanding service coverage.

In conclusion, it is important to note that social sustainability of waste management in the target countries should be regarded as an ethical behaviour of a waste management system towards society (den Boer et al., 2005). This means that the management of municipal waste responsibility of society is not just making legislation but rather securing social acceptability of the waste management system. The acceptance of the society is very significant and every effort must be made to achieve the principles of the 3Rs in ISWM.

Reference

1. Beigl, P., Wasserman, G., Schneider, F. and Salhofer, S. (2004): Forcasting municipal solid waste generation in major European cities. Vienna: Institute of Waste Management, Boku – University of Natural Resources and Applied Life Sciences.
2. Chang N. B. and Lin Y. T. (2001): An analysis of recycling impacts of solid waste generation by time series intervention modelling. Resources, Conservation and Recycling, Vol. 19, pp 165 - 186

SECTION 3: EXEMPLARY CASE STUDY OF FUTURE SCENARIOS IN THE REGION OF MATAM

1.0. Introduction

As stated in Work Package 5 of IWWA program, Enda carried out an exemplary case study on the Solid Waste Management (SWM) in the City of Matam, Senegal.

The objective was to evaluate the impact of the project measures by presenting an exemplary case study of future environmental and socio-economic scenarios in the region of Matam for which strengths, weaknesses, opportunities and threats were defined in a SWOT analysis.

The methodology used to carry out this case study consisted of documentary review and recent studies. The available and most recent studies were the following, asproduced by a Senegalese research institute (IAGU), a Senegalese consultancy firm (CIME), and the bilateral Luxemburg cooperation:

- Institut Africain de Gestion Urbaine (IAGU), 2005. Environmental profile of the City of Matam.
- Cabinet d'Ingénierie et de Management de l'Environnement (CIME), 2011. Study on waste characterization and valorization potential in the Region of Matam.
- Luxemburg Cooperation (Lux-Dev), 2006. Project document SEN/025 on basic health and sanitation.
- Lux-Dev, 2010. Mid-term evaluation of the program SEN/025.

In addition to that, the Regional Council of Matam and Enda co-organized a workshop in Matam, on May 3rd, 2012 with 25 participants which provided the opportunity to debate on the past, the on-going initiatives and the perspectives.

Figures are presented in FCFA, the local currency in Senegal, and converted into euros by using the fix exchange rate of 1 euro = 655.957 FCFA.

The City of Matam was considered to be a more relevant scale for the case study than the Region of Matam, mainly because of the scarcity of available, updated statistics on this rural area, and also because waste management is part of the mandate of cities but not regions in Senegal.

2.0. Presentation of the context

Senegal has approximately 12 million inhabitants in 2011, an urbanization rate of 42% and an household income of 707 USD per inhabitant per year, although the Gross Domestic Product growth rate is moderate: 1.2% (1990-2005).

The average waste production is 0.5 kg per day per inhabitant at the national level. The average coverage rate of formal waste collection reaches only 40% of the total waste generated, meaning that 60% of waste is either not collected at all and stays where it is dumped, i.e. in the streets, in the river, etc. or gets collected by the informal sector without any management by the City Administration.

The proportion of the budget dedicated to solid waste management (SWM) by Senegalese municipalities is in average 10% which represents less than 1000 FCFA (1.5 euros) per inhabitant per year.

2.1. The Region of Matam

The Region of Matam is situated in the North-Eastern part of Senegal. It was created by a presidential decree in 2002. It is therefore a very recent institution, only 10-years old. It has no specific mandate to work on SWM issues.

The Region of Matam is characterized by a Sahelian climate, with less than 500 mm of rainwater per year, high temperatures (up to 48℃ in the dry season). It is close to the Mauritanian desert which brings a lot of dry winds carrying sand and dust. The rainy season lasts for only 3 months.

The Region of Matam has a total of 461 000 inhabitants. The main economic activity for 70% of the population is the primary sector, in particular agriculture, cattle breeding and fishing in the Senegal River.

There are very few industries except some phosphate mines and tomato-processing plants.

As a consequence of the lack of economic perspectives in terms of employment and wealth creation, there is a high emigration rate to Dakar, Mauritania, other African countries, Europe and the USA. Many Senegalese migrants present in Europe come from these disadvantaged Northern regions of Senegal known as « the valley of the Senegal river ».

2.2. The City of Matam

The city of Matam was created in 1952 during the French colonization. It has been since 2002 the capital of the Region of Matam. The total municipal budget amounted to 399 million FCFA (608 271 €) in 2005.

The city of Matam is located 691 km away from Dakar. The last population census dates back from 2002 and had recorded a total of 14,620 inhabitants with an annual growth rate of 1.99% in the past ten years (DPS, 2002). It was estimated in 1998 that 60% of the population is below 20 years old (DPS, 1998).

The urbanization rate in the city of Matam is 14% (IAGU, 2002) which is much lower than the national average urbanization rate. 80% of the houses in Matam are made of local traditional material; backyards are usually sandy as few households have the financial means to cement their backyards. This has an impact on household waste characterization (sand).

The economical context in not different from the context in the region of Matam: two thirds of adults are farmers or fishermen, one fourth are in small businesses or work as civil servants, and the rest are jobless. There is no local industry, but many craftsmen. As a regional capital, the city of Matam hosts several administration buildings mainly regional and departmental offices.

The average monthly income per person is quite low, around 50 000 FCFA i.e. 76 € (1998 figures). However, some families get complementary incomes through remittances from the migrants.

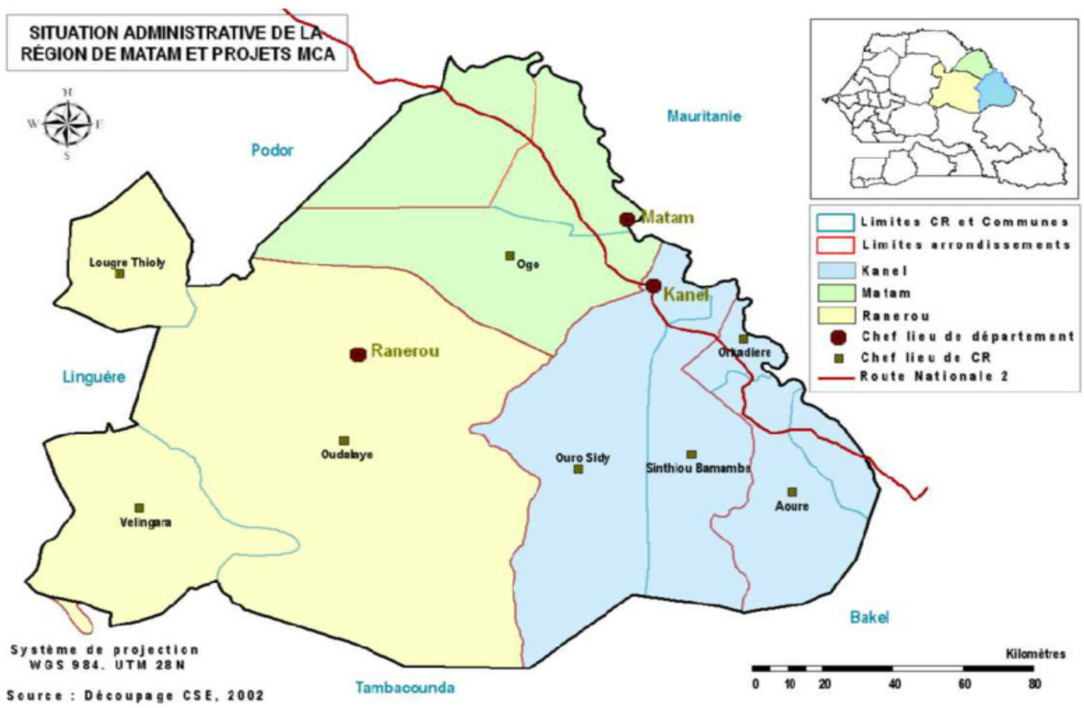

Figure 5 : Administrative map of the Region of Matam

3.0. Assessment of the current situation on waste management in the City of Matam

Concerning waste quantities, there are no reliable statistics, only estimations, as the city of Matam does neither have a properly organized collection system nor a unique disposal site equipped with a weighing bridge. Most studies reviewed indicated that Matam's waste production rate is 0.5 kg of waste/person/day in average as in comparable Senegalese cities.

The main sources of waste are households, restaurants (*dibiteries: small restaurants specialized in mutton meat*), markets and offices. A waste characterization was carried out in November 2011 by a consultancy firm (CIME) in the City of Matam. Three types of neighborhoods were selected and studied for the characterization.

Table 12 : Description of neighborhoods selected for the waste characterization in the City of Matam

Neighborhoods	Characteristics
I – Soubalo, Diamel, Navel	Traditional neighborhoods, a majority of fishermen and farmers. Low incomes.
II – Gourel Serigne	Predominance of administrative activities. Relatively high incomes.
III – Tantadji	Mainly small businesses. Relatively high incomes.

The neighborhood where the main market is located was not included in the study, as the municipality considers that the collection and treatment of market waste is not within its mandate.

The results of waste characterization in Matam revealed a very large proportion of organic waste, especially in the neighborhood with many small businesses (more than 55%), and a large proportion of fines, mainly of sand (more than 50%), especially in the low-income neighborhoods, which is due to the local habitat and climate.

The proportion of recyclable materials such as rubber, glass, plastics, paper, cardboard, ferrous metals is between 2 and 10%; the largest proportion was found in the neighborhood where administrative buildings are concentrated.

Waste collection practices in the City of Matam are not very developed. At the formal level, the association / micro-entreprise (in French: "*groupement d'intérêt économique*" - GIE) called « *Jardin Espaces* » is in charge of waste collection under agreement with the City of Matam. The association currently has 9 employees and very basic equipment.

The household waste collection fee is 1000 FCFA/month (1.5 €).

The City Administration has a tractor that sometimes transports bigger quantities of waste to a dumpsite outside the city. The City administration does not organize a street sweeping service.

There are many small illegal dumpsites in and outside the city, and as market waste is not collected, it is often burnt on the market.

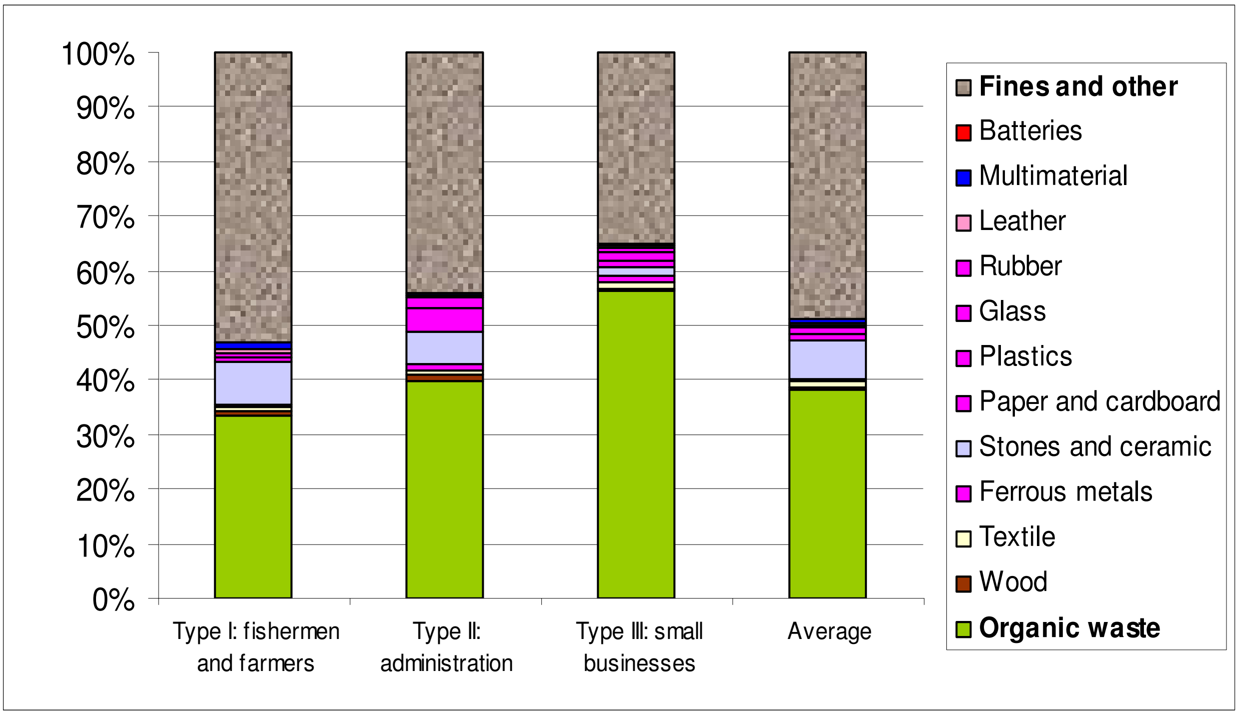

Figure 6 : Waste characterization in the City of Matam (Source: CIME, 2011)

Picture 2: A typical view of a market in the Region of Matam littered with waste (Source: Enda, 2012)

At the informal level, there are some recycling and re-use practices that have not been studied into much detail yet but that can be summarized as follows:

- Recovery and local re-sale of ferrous metals (100 FCFA i.e. 0.15 € per kg)

- Recovery and re-sale of plastic shoe soles (10 FCFA i.e. 0.01 € per pair of soles) to Malian businessmen on the road from the city of Dagana (Region of Saint Louis, Senegal) to the city Matam.
- The organic waste produced by cattle is sometimes used as organic fertilizer in the fields, but domestic organic waste is not valorized.

The graph below presents estimations on the various destinations of waste in Matam. Half of the waste ends up being dumped; the other half is burnt in an open-air manner.

A very small proportion (less than 1%) is recycled or composted.

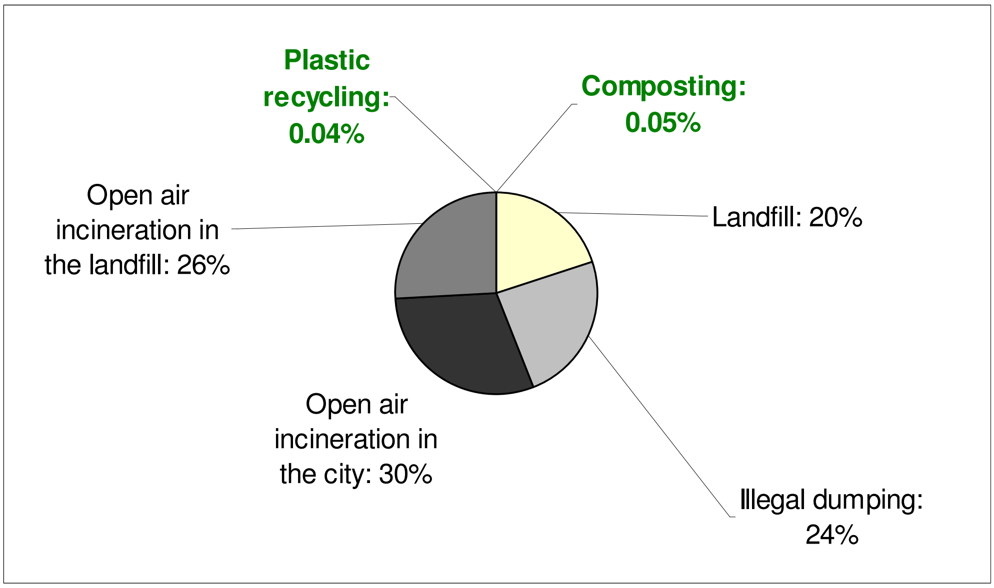

Figure 7: Waste treatment and disposal in the city of Matam (Source : City Administration of Matam, 2012)

Local and foreign actors have taken some initiatives to improve waste management practices in Matam. So far, all of them faced difficulties that hindered the sustainability of the actions taken.

In 1991, the UNICEF helped to set up « salubrity committes » that were supposed to collect a small fee from households and improve the cleanliness of the neighborhoods. But, due to money embezzlement by some of the committees' members, and also due to the fact that the City did not keep its commitments, the system did not work.

Five years after, in 1996, the French association ADOS helped to set up pre-collection groups and equipped them with carts and donkeys. But, the donkeys died because of the lack of adequate veterinary care.

In the 90s, the UNICEF supported women groups and trained them on the techniques to recycle plastic bags by doing handmade objects such as hand bags, dolls, ropes etc. However, there was no local market for these products as Matam is not really a touristic area.

From the 2000s onwards, initiatives started to be taken also by institutions. In 2003, the City of Matam wrote its Agenda 21 (an action plan on sustainable development goals encompassing social, environmental and economical aspects of urban management) which mentioned waste collection as an issue to be tackled. But due to the lack of efforts on behalf of the municipality to promote the active participation of the population, there is a persistent lack of ownership of this action plan.

In 2008, the Luxemburg cooperation together with the Senegalese government launched a program on basic health and sanitation in the Northern regions of Senegal, for a total of 24 millions euros cofunded by Luxemburg and Senegal, which includes a component on SWM and which was supposed to be finalized by end of March 2012. It is still being implemented and has been quite delayed, mainly for financial reasons because the City Administration and the inhabitants were asked to contribute financially to the implementation and many households still refuse to pay the waste collection fee which shows that awareness-raising has not been carried out in a way to motivate them.

3.0. Presentation of the 3 scenarios on Solid Waste Management in the City of Matam

The sub-task team composed of Enda and the Regional Council of Matam, chose 3 scenarios to analyze future SWM policy in the city of Matam and its potential effects:

- a short-term (1 year) scenario,
- a medium-term (5 years) scenario,
- and a long-term (20 years) scenario.

According to the available information and figures, the first two scenarios are more elaborated than the third one.

3.1. Scenario 1: The short-term scenario

The timeframe of this scenario is short term (1 year).

This scenario is based on the action plan regarding the SWM component of the on-going program (2008 – 2012) co-funded by the Luxemburg cooperation (12 million €) and the Senegalese government (10 million €) in the regions of Louga, St Louis and Matam on basic health and sanitation.

The measures included in this scenario are listed as follows:

- Improvement of the collection system: providing waste bins for households, waste bins for markets, collection equipment (wheelbarrows, rakes, sweepers, shovels…), horses, horse carts for the pre-collection association sub-contracted by the City Administration, and tractors for the City Administration
- Building of 3 stables/transfer stations (in Soubalo, Diamel and Gourel Serigne neighborhoods) with 4 m3 waste skips for the City Administration– *in progress*
- Building of 1 sanitary landfill in Soubalo and 1 mini landfill in Diamel for the City Administration – *in progress*
- Trainings and basic equipment for the separation of plastics, ferrous metals and organic waste (compost production and demonstration sites) by 23 employees of the association sub-contracted by the City Administratin – *not operational*

The hypothesis on which Scenario 1 is based was taken from the study the study carried out in 2011 by the local consultancy firm « CIME » on the potential for recyclable materials in Matam.

Table 13: Hypothesis for scenario 1

Type of hypothesis	Hypothesis
Population	17,470 inhabitants in 2011 (available census for 2002, with an annual growth rate of 1.99%)
Waste generation rate	0.85 kg/inhabitant/day (here, it should be noted that the consultancy firm applied an over-estimated rate, as the waste generation rate is currently 0.5 kg in Dakar, with incomes and consumption levels that are significantly higher than in Matam).
Waste collection rate	The initial target of the Luxemburg/Senegal program was to collect 80% of the waste generated in Matam. The target considered as achievable by CIME is 20%, as it is believed that in this region, the collection rate is rarely above 30% because of parallel circuits, households lack of willingness to pay and the lack of law enforcement.
Hypothesis in terms of prices of recyclable materials	Current prices of recyclable high density plastics (PET, PE containers…): • Price paid to the informal collectors: 40 FCFA/kg (0.06 €) • Price for cleaned / shredded plastic: 250 FCFA/kg (0.4 €) Estimated prices of recyclable low density plastics (plastic bags): • Price to be paid by the APROSEN in the « recup plast shops »: 25 FCFA/kg (0.04 €) • Price to be paid paid by the SOCOCIM to use the plastics as fuel in the cement production plants: n/a.
Concerning compost production	Water content of compost: 40% 1.2 tons of compost produced / employee / month (part-time employees) Due to the very dry and hot climate, an input of 2.5 m3 of water is necessary to produce 1 ton of compost. 1 m3 of water currently costs 200 FCFA (0.3 €).

Source : CIME, 2011.

Based on these hypotheses, the consultancy firm carried out an economic analysis of the system based on estimations of incomes and costs.

They started by estimating the potential for metal and plastic recovery by the formal system in the City of Matam, which is presented in the following table.

Table 14 : Estimation of the potential yearly incomes from metals and plastics recycling in Matam

Type of recyclable materials	Proportion in domestic waste in Matam	Kg of recoverable materials per year	Potential incomes per year
Ferrous metals	0.5 %	2,850	285,000 FCFA (434 €)
High-density plastics	1.1 %	6,270	156 750 FCFA (239 €)
low density plastics	n.a.	n.a.	150 000 FCFA (229 €)

Source: CIME, 2011.

Concerning compost production, they estimated that 220 tons of compost could be produced every year, representing a volume of 55 m^3 that requires a surface of minimum 110 m².

Then, they considered that compost bags would be sold to the local farmers. The usual price for a 50-kg compost bag in the area is 2500 FCFA but they decided to offer the compost at a cheaper price to increase the chances to sell quantities as large as possible, ideally, 100% of the compost produced. They calculated the estimated incomes using 3 different prices for a 50-kg bag of compost: 0.76 euros, 1.14 euros, and 1.52 euros.

Table 15: Estimation of incomes generated by compost production in the City of Matam

Number of 50-kg bags sold / year	**4 400**	**3 480**	**4 290**
Tons of compost sold /year	220	174	215
Tons of compost produced /year	**220**		
m^3 of water necessary / year	550		
	Very low price	**Low price**	**Highest price**
Price in FCFA for a 50-kg compost bag	**500**	**750**	**1000**
Price in EUR for a 50-kg compost bag	**0,76**	**1,14**	**1,52**
Gross income in FCFA / year	2 200 000	2 610 000	4 290 000
Gross income in EUR / year	3 354	3 979	6 540

Water costs in FCFA /year	110 000		
Water costs in EUR / year	168		
Net income in FCFA / year (after deduction of water costs)	**2 090 000**	**2 500 000**	**4 180 000**
Net income in EUR / year	**3 186**	**3 811**	**6 372**

Source : CIME, 2011.

The net income of compost production does not include the value of the land nor the human resource costs.

All in all, potential incomes from recycling activities per year would represent a maximum amount of 7,274 euros, which is a relatively high amount for a small town in a rural area.

Table 16: Summary of potential yearly incomes from recycling activities in the City of Matam

	In FCFA	In EUR
From high density plastics	156 750	239
From low density plastics	150 000	229
From non ferrous metals	285 000	434
From compost	2 090 000 to 4 180 000	3 186 to 6 540
Total	**2 396 750 to 4 771 750**	**4 088 to 7 274**

Source : CIME, 2011.

Table 17: Estimation of investment costs for the City of Matam to develop separation of metals, plastics and compost production

	Equipment of transfer stations and landfill	Equipment	Communication and marketing of the compost	Compost in demonstration sites	Consultant for the compost	Total
in FCFA	3 600 000	2 392 500	5 000 000	2 090 000	5 000 000	**18 082 500**
in EUR	5 488	3 647	7 622	3 186	7 622	**27 567**

Source: CIME, 2011.

The necessary equipment for waste separation would be for the whole city : 20 forks, 20 shovels, 20 rakes, 8 sieves, 20 watering cans, 8 wheelbarrows, 8 eight-liter containers, 20 protective equipment, 20 machetes, 610 fifty-kg compost bags.

Compost has to face a strong competition of chemical fertilizers that are very wide-spread in the area. If the City Administration wishes to sell larger quantities of compost, it needs to convince local farmer that it is preferable to chemical fertilizers. The strategy would consist in an awareness-raising campaign in the community and in the local media, as well as in the setting up of demonstration sites. The project would buy the compost at 10 FCFA/kg to give it to farmers that would accept to use it and show the results to the other farmers and visitors in demonstration sites.

The approach concerning recurrent costs was based on the following assumptions:

- Recycling would take place 8 months a year (not in the rainy season)
- The same staff would do both waste collection and recycling, so they would be 50% dedicated to collection and 50% to separation of recyclable materials / compost production
- The total necessary staff would be 23 employees of the GIE (not the City Administration) and they would be paid approximately 50 000 FCFA i.e. 76 €/month/employee
- The transportation costs for domestic waste would represent 40 liters of gasoil per week (City Administration tractor)

- An optimistic approach is based on a total of 100% of households paying the waste collection fee (1000 FCFA or 1.5 euros/month), and high prices of recyclable materials and compost;
- A moderately optimistic approach counts with a total of 50% of households paying the waste collection fee, and relatively high prices for recyclable materials and compost;
- A pessimistic approach counts with only 20% of households paying the waste collection fee (the current proportion is even lower), and low prices for recyclable materials and compost.

With these elements, IWWA project team then tried to establish the annual budget for ISWM in Matam.

Table 18: Elements of the SWM yearly budget in the city of Matam

	FCFA			EUR		
	Optimistic	**Moderately optimistic**	**Pessimistic**	**Optimistic**	**Moderately optimistic**	**Pessimistic**
Yearly incomes						
Collection fee	30 000 000	15 000 000	6 000 000	45 735	22 867	9 147
Recycling	4 771 750	3 091 750	2 396 750	7 274	4 713	3 654
Yearly expenses						
Human Ressources (HR) managed by the association (23 staff from the association)	13 800 000	13 800 000	13 800 000	21 038	21 038	21 038
HR of the city administration (1 driver + 4 guards)	4 440 000	4 440 000	4 440 000	6 769	6 769	6 769
Transportation (gasoil of the City Administration)	2 080 000	2 080 000	2 080 000	3 171	3 171	3 171
Balance	**14 451 750**	**-2 228 250**	**-11 923 250**	**22 032**	**-3 397**	**-18 177**

The following costs were not included in the calculation:

- Maintenance costs of the tractor, as it is done together with the maintenance of the other vehicles owned by the City Administration;
- Maintenance costs of the carts, donkeys and other collection equipment under the responsibility of the association;
- Amortization of investments (land, buildings, vehicles…)

This table shows that, even with some expenditures missing, the municipal budget for SWM is not sustainable with the level of collection fee currently charged to households, and the limited ambitions in terms of waste collection and recovery of recyclable materials.

IWWA project team together with the participants to the workshop held in Matam on May 3rd 2012 carried out a SWOT analysis of the Scenario 1, whose results are presented below.

Table 19: SWOT analysis of Scenario 1

Strengths	Weaknesses
- Strong institutionalization: City Administration and decentralized national services (through the Consultative Technical Committee responsible of the follow up) - Financial support from Luxemburg	-No public strategy on SWM -Lack of skilled staff, equipment and financial means (low % of household collection fee actually recovered) -Landfill area is liable to flooding -No integration of the existing informal sector: the public formal sector would act as a competitor and only recover a small proportion of recyclable material - Matam is far way from the recycling plants (high transportation costs to Dakar)
Opportunities	**Threats**
- High potential of recycling activities in terms of jobs and income-generation - Sincere desire to get rid of the many illegal dumpsites	-Political instability - Low incomes of households - No maintenance and renewal plan for the equipment -Spontaneous urbanization close to the landfill - Growing environmental contamination due to the lack of ambition of the program in terms of collection and recycling targets

The social, economical and environmental impacts of the Scenario 1 were then assessed.

Table 20: Assessment of the appropriateness of measures proposed in scenario 1

Measure	Indicators that will improve
Door to door collection using community contractors (donkey-driven carts) and recovering service fees	Social : • 23 jobs created • Social acceptability • Improvement of the working conditions of waste collectors Economical • Dependence on subsidies reduced • Economic equity • Economic efficiency Environmental : • No CO_2 emitted with this kind of non-motorized transportation
Decentralized transfer stations where recyclable materials (metals, plastics) as well as organic matters are sorted.	Social : • 23 full time jobs created (half time on collection, half time on recycling) • Complementary income for the waste collectors : will increase their motivation Economical : • More income for ISWM municipal budget in Matam • On the long-term : cleaner neighborhoods where solid waste is collected regularly will contribue to improve the image of the city and its attractiveness for businesses and tourists. Environmental : • Reduction of methane gas emitted by the decay of organic waste on dumpsites • Reduction of smell and other nuisances • Reduction of leachate • On the long term : reduction of th e pressure on the natural (primary) resources by the promotion of the use of secondary resources (recycled materials).

3.2. Scenario 2: The medium-term scenario

The timeframe of this scenario is medium term (5 years). This scenario was developed by the participants to the workshop organized by Enda and the Regional Council of Matam under IWWA on May 3rd, 2012.

This scenario includes the following measures:

- Elaborating a regional strategy on integrated solid waste management. This is the wish of the Regional Council of Matam. It would be an innovation, as these kinds of strategies are not mandatory in Senegal, contrary to France for instance, where all departments (provinces) have the obligation to write and follow up waste management plans localizing the national targets in terms of reduction of the quantities of waste going to landfill and incinerators, increase of collection of recyclable materials, etc ;
- Negotiating inter-municipalities agreements (in French : *intercommunalité*) with neighboring towns to put resources in common such as SWM budget to build and operate common disposal facilities ;
- Carrying out an awareness-raising campaign in households, schools, businesses, health centers… on topics such as the separation of sand at the source so that it does not get collected along with municipal waste, or inappropriate practices such as open-air burning and dumping;
- Formalizing the municipal supervision of SWM with service agreements with the private sector;
- Conducting experimentation with a separation plant & composting plant at the landfill (to avoid nuisances in the city center which will probably be the case with the transfer stations).

As with Scenario 1, IWWA project team conducted a SWOT analysis of the measures proposed in Scenario 2, whose main conclusions are presented in the table below.

Table 21: SWOT analysis of Scenario 2

Strengths	Weaknesses
- Stronger institutionalization - More public awareness activities	- Lack of involvement of the population and the informal sector
Opportunities	Threats
- Political will to set up inter-municipalities partnership (intercommunalité) - High potential of recycling activities - Sincere desire to get rid of illegal dumpsites	- Political instability - Conflicts between the formal and the informal sector on the recyclable materials - Difficulties to mobilize funds

Then as with Scenario 1, the social, environmental and economical impacts of measures were assessed.

Table 22: Assessment of the appropriateness of the measures proposed in Scenario 2

Measure	Indicators that will improve
Regional strategy on ISWM.	Social : • Social acceptability (if the elaboration process of this strategy is participatory)
Inter-municipalities agreements.	Economical : • Potential economies of scale if agreements are clear and well managed (eg. sharing of investment costs in a common treatment facility) Environmental : • Potential reduction of CO_2 emissions if waste transportation is re-organized in a more rational way (optimization of collection circuits)
Awareness-raising campaign	Social : • Social acceptability with households (yet, the social acceptability with the existing informal sector in the separation of recyclable material depends on the competition or integration schemes that are going to be set up with the formal schemes for separation of recyclable materials) Economical : • Households with an environmental conscience will be more willing to pay the waste collection fee as they will understand and approve its purpose. Environmental • Sustainable and significant reduction of open air burning and dumping practices will prevent future contamination of air, water and soil.
Service agreements with the private sector.	Economical • For the time being, the City Administration works with only one micro-enterprise/association. The idea is to have several companies that can then compete to deliver the most appropriate service at the fair price.

Measure	Indicators that will improve
Separation plant and composting plant at the landfill	Social : • Reduction of smell and other nuisances in the city center : improved social acceptability Economical : • The quality of recoverable materials is likely to be worse than in decentralized separation plants because waste will arrive more mingled and in greater quantities, which does not facilitate the separation of recyclable materials Environmental • If less recyclable materials are actually recovered, a large proportion of these materials will still go to the landfill and produce methane, leachate…

3.3. Scenario 3: The long-term scenario

The timeframe of this scenario is long-term (20 years). It was developed by Enda considering the figures obtained for the waste characterization in the city of Matam in 2011.

The hypotheses used to create this scenario are as follows:

- An annual demographic growth rate of 1.99%. By 2030, the city of Matam would have 25,403 inhabitants which means 1.4 times the estimated number of inhabitants in 2011 (17,470 persons).
- Changing consumption patterns leading to the production of 100 additional grams of waste each day per inhabitant every 5 year : 0.5 kg/day/inhabitant from 2011 to 2015, then 0.6 kg/day/inhabitant from 2016 to 2020, 0.7 kg/day/inhabitant from 2021 to 2025, and finally 0.8 kg/day/inhabitant from 2026 to 2030. This would lead to a total of 7,418 tons of waste produced during the year 2030 which represent 2.3 times the amount of waste produced in 2011.

So, waste generation ratio is quicker than population growth which should attract local authorities' attention on the need to carry out campaigns not only on the proper disposal of waste but also on waste minimization.

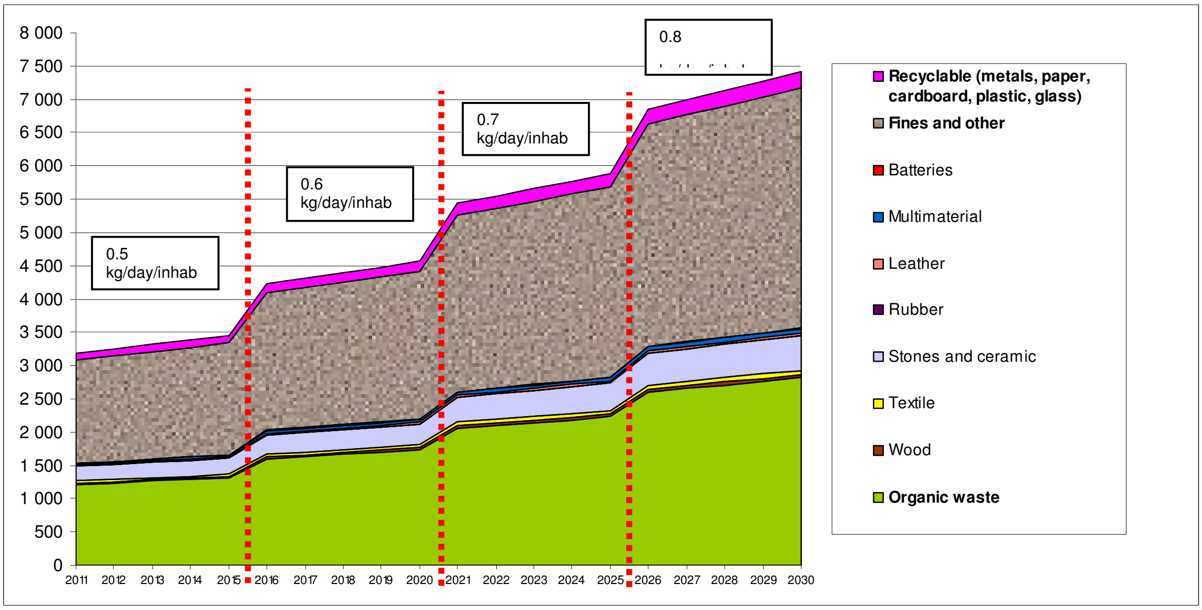

Figure 8 : Evolution of waste characterization in the next 20 years in the city of Matam

Concerning the changes in the nature of waste produced, IWWA project team did not have the resources in terms of prospective studies on social behavior, analysis of manufactured products arriving on the Senegalese market, etc. to produce a proper projection of the future proportions of recyclable materials, of organic waste, and so on. It is however very likely:

- that the proportion of sand and dust will remain quite high in the future, due to the local physical conditions ;
- that the proportion of organic waste will be reduced whereas the proportion of plastics and cardboard will increase (consumers will tend like everywhere in the world to buy processed and packaged food instead of cooking fresh meat and vegetables themselves) ;
- and last but not least, that e-waste and hazardous waste will appear; they probably already exist today but in small quantities that have not been detected by waste characterization studies carried out so far.

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