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ABBREVIATIONS

CBO	Community Based Organization
EPA	Environmental Protection Agency
HDA	High Density Aerobic Landfill
ICT	Information, Communication Technology
ISWM	Integrated Solid Waste Management
MLGRD	Ministry of Local Government and Rural Development
MMDA	Metropolitan Municipal District Assembly
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NGO	Non Governmental Organization
PPP	Public Private Partnership
SWM	Solid Waste Management

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1. INTRODUCTION

ISWM considering all stages of the product from its generation till its disposal involves various stakeholders ranging from producers, manufactures, sellers, consumers and after disposal people and systems and organizations involved in its collection, recycling or final disposal. Overall legal framework, policies and laws existing as well socioeconomic factors, regional and cultural draw factors which lay a basis for a waste management system.

The following Report is focusing on technical and non technical requirements on ISWMS. The technical requirements include collection, storage and treatment of different waste, recycling-options, energy recovery, final disposal and operation and maintenance of waste treatment facilities.

The non technical requirements defined in this report include legal frameworks, policies, monitoring, awareness raising, informal and formal sector, governmental bodies, and non governmental bodies effecting solid waste management.

2. TECHNICAL AND NON TECHNICAL REQUIREMENTS ON MUNICIPAL SOLID WASTE

2.1. Residual waste

2.1.1. Logistics and transportation

1. Receptacles for collection and its requirements for proper waste collection

Waste is collected in receptacles such as waste bins, sacks, polythene bags, pans, wooden boxes and communal containers depending on whether it is urban, semi-urban center or rural. In urban and semi-urban centers, waste bins are used in the collection at both household and corporate institutions.

In high income and middle income settlements, waste bins of various sizes, mostly 240 liters and 120 liters, are supplied to various households for collection. Under the polluters-pay principle, currently introduced at the metropolitan areas, service providers are expected to supply households with waste bins no matter the economic status of households. Each sub-metro or locality is expected to register with the assigned waste service provider for the supply of the bins.

However, those households who are not able to register with the service providers enjoy the services of the informal sector which uses sacks, polythene bags, baskets, and buckets among other containers as pertain in rural communities.

Among corporate organizations (institutions, SMEs, industries), either waste bins of various sizes (120L, 240L, 1100L) or communal containers (skip, roll on/off of different sizes) are used in the collection.

The central communal collection system is used in low income urban areas where there is high population density, in market places, semi-urban or municipal areas.

Proper waste collection depends on:

- Collection areas and transport routes
- The number and type of the collection vehicles to be used
- Frequency of waste collection and the schedule for collection and transport.
- Collection vehicles shall be fully covered and leachate collection box shall also be prepared to prevent littering and leachate spill during transportation; similar requirement is expected of the storage containers.
- Heavily travelled roads should not be served or used during rush hours.
- Any infectious waste or hazardous waste should not be accepted into the normal waste collection vehicles (Pre-checking of waste before collection is needed)
- Daily records of the quantity of solid waste collected, the origin of waste, the quantity of solid waste transferred to disposal site shall be maintained.
- Design of the proposed structures and areas designated for unloading, storage, compaction and loading which are in an enclosed building or covered areas with all the instruments or devices must be installed for ventilation and controlling dust, litter and odor.
- The proposed unloading area in the transfer building shall accommodate at least two times of the hourly-average number of incoming collection vehicles of the normal weekday.
- Provisions may be made for weighing or measuring all incoming and transferred solid waste

2. Methods of collection

In rural areas, collection is done by the waste generators themselves. There also communal labor organized by the local authorities for cleaning of the streets and other public areas. The waste is mainly sent to the community dumpsite or is burnt at the dumpsite to reduce the volume. Also, individuals not able to send the waste to the dumpsite burn the waste or use organic waste to enrich their backyard farm or use agricultural waste to feed animals. In some villages there is a communal container system of collection. In this case it is worth to carry out information on proper waste disposal (No-burning) of waste and to offer waste collection and recycling options.

There are two main methods of waste collection in the urban and semi-urban areas; house to house collection and collection from the central communal containers (CCC). In the urban and semi-urban areas house to house collection is usually provided to high income areas whereas communal container collection system is pertained to low income and high dense populated areas.

In urban and semi-urban areas of low income levels, communal container system is widely used by the people. The waste is sent to these collection points for a fee (For an example in Ghana it is 50 pesewa[1]. However, in some of the villages there is a communal container collection system, but no money is paid for dumping; the responsibility is borne by the District Assembly. This is also the case in many semi-urban areas where the people have low income and the population density is high. In the urban areas communal container collection is also employed but the people are asked to pay. This is due to the fact that e.g. Municipal and District Assemblies (MMDAs) have different budget commitment towards waste collection or management. The collection at communal container site and also from house to house should be promoted at the low income urban and semi-urban area, but subsidies ought to be paid to waste contractor by government to ensure effectiveness and compliance by the people. Also activities of the informal service providers should be regularized for full participation in these low income areas (in the metropolitan areas of Ghana, activities of the informal sector is considered illegal since most of the areas are zoned for the registered private waste management companies). To avoid conflicts it is a good idea to consider the (past) informal sector to offer alternatives in employment in other recycling businesses.

With the introduction of the polluter-pay principle, the house to house collection is gaining grounds in all classes of settlements and since it is convenient, considering moving far a distance to a communal container site to dump and pay almost the same fee. In Ghana for instance, depending on the size of the waste bins and the income level of the locality, a fee of $2-$10 is charged. For the 240 L bin in a first class area a fee of $10 is charged per once a week lifting service whereas the same goes for $8 in middle and $4 in low income areas. The 120L is charged $6, $5 and $2 for the high, middle and low income areas, respectively. Collection of household waste is mainly accomplished by the use of trucks, tricycles, cart, wheel barrow, etc. Different types of trucks are used; the compaction truck, roll on-roll off truck and three wheeled truck (also called Borla Taxi).

Compaction trucks are used to collect waste from house to house, whiles roll on-roll off is used for lifting communal containers. However, tricycles and three wheeled trucks are used for house to house collection in low class areas where accessibility and road networks are poor. On the other hand, the informal service providers use wheel barrow, cart and motorized tricycles for house to house waste collection.

3. Maintenance of equipment and collection trucks

There are two methods of maintenance schedule followed; responsive and regular maintenance. Responsive is done when unexpected breakdown happen to the truck whereas the regular maintenance (Servicing) is as on a schedule. Servicing is done according to the mileage covered by the truck. Servicing of the truck is basically divided into three parts - cleaning, replacements and checking.

[1] Foreign currency one Dollar ($) = 1,50306 Ghana Cedi (GHC),1 Ghana Cedi = 100 Pesewas (p)

Cleaning- When the truck covers every 5,000 km, among other checks the engine is cleaned thoroughly and properly maintained. Other parts cleaned are the oil –water separator and the air-elements.

Replacements- Oil filter is replaced on every service after every 5,000 km. Both the oil-water separator and the primary and secondary fuel filters are replaced after every 10,000 km. Air cleaner element is replaced after every 20,000 km.

General checks- The fluid levels (ATF/Radiator/oil level) are all checked and necessary top ups made. Belt tension is adjusted after every 10,000 km covered. Other general checks comprise, the greasing of parts, checking of brake pads and adjusting the clearance.

4. Availability of logistics for maintenance

Spare parts for maintenance of trucks and other vehicles are not readily available or repairs of broken trucks or vehicles, thus delay the period with which these trucks spend at various workshops. The spare parts are ordered abroad and quite little time is spent for shipping. Also some of the part are expensive and need time for funds to be raised to purchase these spare parts. Mechanics and tools though are available for repairs, specialized equipment or vehicles require trained mechanics.

2.1.2. Treatment options

1. Waste Generation and composition

Waste generation rate in urban areas, where waste management is about 0.5kg/cap/day and depending on the socioeconomic status. The rate is however about 0.30kg/cap/day for rural areas. The highest component of the waste is the biodegradable fraction. Research work over the years suggests that about 60 to 70% of organic waste is recoverable if source separation is practiced. These values are similar with waste generation rate and composition in other developing countries. The treatment options being considered are mechanical separation, land filling and waste incineration. Regarding the waste generation, a good tool is to assess the waste generation from time to time to monitor and evaluate measures in solid waste management systems covering from generation, collection, segregation habits and the according public awareness effectiveness.

2. Mechanical separation

This method is a first pre-treatment process which precedes the hierarchy of waste management. Separation of valuable fraction is either done at source or the final disposal site. For public health reasons separation at source is highly preferred. Also source separation helps to generate better quality materials for recycling. The waste fraction in the West African regions is dominated by organic waste followed by plastics, metals, glass, textiles and e-waste. A separation at source would help to reduce the volume of waste and represents resource recovery.

The waste can undergo

- Cleaning: This helps to remove dirt from materials that are contaminated, example plastics.
- Cutting: Helps to reduce size and shape materials for easier transportation and use.
- Grinding: This reduces the size of materials for easier handling and recycling at industries. It also eases transportation and increases surface area of the material for faster processing.
- Shredding and compacting: This reduces the volume drastically for transportation and handling at the processing sites. Plastics, paper and metals can be pre-heated in this manner.
- Bailing: Papers, plastics, metals can as well be bailed for other use or processing into waste-to-energy facility or recovery.
- Conveying belts, industrial magnets and eddy current separators

2.1.3. Final Disposal methods

1. Waste incineration

In an Integrated Waste Management approach, incineration occupies the next to last priority, after waste prevention, reuse, recycling and composting have been undertaken (Tchobanoglous et al, 1993). Incineration is the burning of waste under controlled conditions, usually carried out in an enclosed structure. Incineration, the combustion of organic material such as waste, with energy recovery is the most common Waste to Energy implementation. Incineration may also be implemented without energy and materials recovery; however this is increasingly being banned.

2. Waste supply

Wastes generated in developing countries, however, usually do not allow energy recovery, due to their high moisture and high content of organic matter (Akankeng, 2003; Hui et al, 2006). Municipal Solid Waste (MSW) in a typical low-income country is wet with low calorific values, so waste incineration is less suitable.

3. Technology

The technology is very complex and capital intensive. The method of using incineration to convert MSW to energy is a relatively old method of waste-to-energy production. Incineration generally entails burning garbage to boil water which powers steam generators that make electric energy to be used in our homes and businesses. Incinerating MSW to make electrical energy is that the pollutants are put into the atmosphere, when burning the garbage that powers the generators. For pollutants such as ash or particle matter filters have to be used. Very high temperatures provided in incineration plants can assure that the majority of the pollutants were destroyed and filtered.

4. Economics

The capital outlay for equipment installation and plant maintenance costs are very high that the energy benefits accruing may not suffice to offset incineration in developing countries but could be envisaged in mega-cities.

5. Environmental issues

There are a lot of public and environmental health concerns with respect to the quality of emission from incinerators which include fine particulate, heavy metals, trace dioxin and acid gas emissions. Other concerns include toxic fly ash and incinerator bottom ash. These by products could have adverse effects on public health and natural resources. These pollutants are acidic and have been reported to cause serious environmental damage by turning rain into acid rain. Ash or slag from incinerators needs to be disposed in sanitary landfills or can be used for construction (streets).

2.1.4. Land filling

At the end of the integrated waste management hierarchy is land filling of slag from incineration plants or treated or recyclable waste. Sanitary landfills were designed to collect and treat leachate. Several West African nations do not have engineered landfill sites, but controlled disposal sites.

In most cases this is the final disposal site. All types of waste are dumped in the final disposal sites being it industrial or municipal waste.

1. Technology

There are different ways of going about sanitary landfills with increasing complexity as well as capital investment and operational cost. Open dumps/ uncontrolled dumpsites do not follow a technology – this type of disposal and should be banned due to its bad effects on the environment. Existing open dumps needs to be controlled, closed and remediated if possible, when sanitary landfills were established.

2. Economics

In landfills capital investments can also be very large. However getting land for such activities is very difficult. Encroachment has been one of the problems associated with landfill site. Due to increasing population after a few years of operation landfill sites become habitable areas with the attendant problems of public displeasure leading to their closure in most cases. Getting buffer areas around landfill is an ideal but adds on to the capital investment.

3. By-products of the landfill

Main products from landfill sites include recycled products through the activities of waste pickers before compaction or treatment of waste is practiced. In sanitary landfill methane gas can be captured in closed landfills for use as energy or flared.

4. Environmental issues

The main environmental problems from open dumpsites activities is the production of methane gas which causes odor; also it serves as a place for greenhouse gas such as methane. Leachate from disposal sites pollutes underground and surface water if not collected or treated separately. However in sanitary landfill sites collecting gases, methane gas can be captured and used as a source of energy. With the right operations as in engineered landfill site, like dumping in cells and covering of the waste on daily basis as well as lining of the site to collect and treat leachate, the problem of vermin breeding and leachate run offs can be prevented.

2.1.5. Classification of disposal sites

Four types of disposal sites are identified based on the level of controls, location, management requirements, scale and complexity of operations, equipment employed, and types of waste handled and also by their potential environmental impact.

1) Open Dumpsites are illegal disposal sites without any controls like fencing, supervision, and leachate management. They are normally found close to water bodies, beaches, undeveloped lands within or close to communities. These dumpsites evolve from small heaps into big uncontrollable waste heaps when the local authorities fail to intervene early. They exist mainly in peri-urban as well as urban communities where waste collection services are nonexistent or where members cannot afford services. The absence of drainage, fencing and supervision exposes communities to multiple environmental problems from littering, surface and groundwater pollution as well as air pollution due to frequent burning of refuse.

2) Controlled dumpsites are sanctioned by MMDAs as official disposal sites of their jurisdiction; these facilities normally co-host liquid waste as well. Over 90% of disposal sites fall within this category. These sites are areas identified and developed with or without permission from the Environmental Protection Agency (EPA) to run as disposal sites and periodically bulldozers are hired to push and spread refuse for the site to accommodate more waste. Access to these sites during the rainy season is very problematic due to the absence of equipment and maintenance of internal and external roads.

3) High density aerobic (HDA) landfills in Ghana and as may pertain in other West Africa States were developed with donor funding under the Urban Environmental Sanitation Program. They are co-disposal sites for both solid and liquid waste. These landfills reduce odor, produce methane gas and leachate by allowing aerobic decomposition of the bulk of the organic waste. Their locations are carefully considered in order to avoid pollution of important ground and surface water resources. HDAs are fenced, with gate houses, offices and washroom for personnel and well demarcated roads within the facility. Technical support in terms of capacity building, waste management personnel and equipment were made available to the beneficiary MMDAs. Currently, these facilities and equipment have run down due to poor maintenance. Liquid waste disposal points are also not maintained regularly hence the flow of liquid waste directly led into nearby water bodies with pollution implications. Continuing and regular maintenance, capacity building without financial support from donations is important.

In Ghana, for example donor funding for sanitary engineered landfill facilities have been developed in the sub regions Tamale and Kumasi, another two are still in their development stages in Takoradi and Tema. These facilities have multiple liners; weigh bridges, and gas vents for methane management and facultative ponds for leachate treatment. Poor operation and maintenance have degraded these facilities but significant quantities of waste generated in their catchment areas still end up in illegal dumps due to poor collection services and coverage, attitudes and inadequate support from central government. Therefore it is important to plan and carry out good waste collection coverage and expect support from governmental institutions (Good governance).

Operation and maintenance of final disposal sites continues and remains a big challenge to all regulatory bodies across the sub region. In regional capitals and municipal areas, high waste generation rates challenges local authorities to maintain presence at disposal sites with personnel and equipment. In this order the following requirements needs to be taken into account:

- Appropriate equipment
- Skilled personnel
- Cost recovery system to maintain operation costs
- Operation and maintenance
- Land acquisition and suitable land
- Leachate and gas treatment
- Compaction
- Environmental Awareness

In many metropolitan areas for instance, availability of land for the establishment of landfills is a challenge that city managers fall on abandoned stone quarries to fill with municipal solid waste. These sites are not protected, fenced and waste is not well compacted; gas and leachate management is always a challenge because of the absences of liners.
Covering of waste is not regular and leachate management basically involves the construction of a sump a few meters downstream of the dump to collect leachate which is de-sludged and hauled to the waste water treatment sites.

4) Dumpsite aftercare

Dumpsites after its exhaustion are simply abandoned, rarely are these sites covered, this situation leads to high leachate volumes, fires, littering and bad aesthetics for the host communities.

Lack of capacity of governmental agencies to deal with decommissioned landfills. To ensure a good dumpsite aftercare, its closure, fencing, controlling, monitoring of the environment and possibly bio-remediation have to be taken into account.

2.1.1. Policy, legal and institutional framework for solid waste

Waste laws must ensure the regulation of waste generation, collection, reuse, treatment, and disposal. Laws that regulate all aspects of solid waste should explicitly contain clauses that deal with the following issues:

- Waste generation (Producers responsibility) e.g. packaging of waste
- Source separation and recording of waste streams
- Documentation of waste collection and its final disposal
- Licensing of dumping sites and landfills
- Land filling of various types of municipal waste
- Regulation of waste recovery activities
- Regulations on disposal of animal by-products
- Proper and responsible storage and disposal of waste
- Punishment for offenders of waste laws and sanitation bye-laws
- Rules for collection, handling and disposal of special waste – hazardous, animal by-products and e- wastes.
- Clear-cut responsibilities of everyone who is involved in the waste management chain

- Measures, procedures and guidelines for prevention/reducing pollution of surface water, ground water, soil and air.
- Enforcement activities
- Landfill taxes
- Private Public Partnerships

A successful implementation of ISWM requires strengthening of institutions that regulate all aspects of waste management. The following institutional requirements to ISWM are outlined: Adequate staffing of local authorities, regulatory bodies and other institutions are needed for:

1. Inspection of households, institutions and industries for abuse of waste and sanitation laws
2. Environmental compliance monitoring
3. Resolution of conflicts related to SWM among households, institutions, industries, and the informal sector
4. Enforcement of legislations on SWM
5. Awarding and negotiation of contracts
6. Dealing with complaints from stakeholders
7. Awareness creation of environment effects of improper waste management
8. Monitoring and evaluation of landfill leachate and groundwater quality analysis
9. Monitoring of waste streams at landfill sites for traces of foreign materials such as hazardous waste and electronic components.
    - Development of clear-cut functions among institutions involved in SWM
    - Strengthening of environmental protection regulatory bodies
    - Strengthening of institutions involved in enforcement of bye-laws on waste management
    - Management of dumping grounds and landfill sites
    - Strengthening of traditional authorities and local councils

2.1.2. Financing mechanisms and economic aspects

1. Public and private support to economic incentives

These economic instruments include subsidies of different kinds that seek to directly reward the desired behavior (waste reduction, improved management, recycling or re-using practices) rather than penalize the behavior to be discouraged. Subsidies can be direct payments, reductions in taxes or other charges, preferential access to credit, or in-kind transfers like the provision of land or other resources. For instance, companies undertaking waste recycling activities such as the recycling of agricultural wastes or agricultural by-products, recycling of chemicals or the production of reconstituted wood-based panel boards or products might be eligible for tax exemptions. However, these instruments tend to reduce revenues available to the authorities so they must be carefully assessed.

Other kind of economic incentives aims at “internalizing” the externalities associated with the production, transportation and disposal of wastes. For instance, according to the Polluter-Pays Principle (PPP), the costs incurred during environmental impact mitigation should be borne by the entities whose activities are responsible for inducing the environmental impact at each stage of the product's life cycle. One way of doing this is to internalize the environmental costs into market prices.

2. Efficient tax systems

Cost recovery mechanisms are the main challenge to be faced in terms of SWM funding. In an era of decreasing aid and shrinking central government budgets, African countries must find new and innovative ways to draw upon local capital markets for financing waste management. It is therefore necessary to explore concepts to finance of environmental management services (e.g. waste minimization, import or sales tax on certain packaged products, collection of user service charges, deposit-refund system for recyclable materials, etc.). This should include making waste management activities more attractive to all actors through social marketing. The experience has shown that service users are prepared to pay for their waste to be removed when they agree with the service levels, when the charging system is transparent and when services are provided for locally acceptable prices. Even in slum areas, people are generally willing to pay for appropriate primary collection services. And this could be the way to follow in order to improve the efficiency of cost recovery mechanisms; moving from a position where solid waste management is paid through general revenues, to one where it is paid entirely from user charges. It is likely to be a gradual transition; so, at least in the medium term, a significant proportion of the total cost will still have to be paid by the municipality or the national government as part of its public health and environmental protection responsibilities. Moreover, it may be suggested that waste management laws incorporate highly strict punitive measures, effective fines for those who infringe the laws on this matter and service fees agreed with stakeholder associations through participatory processes.

3. Inclusion of budget headings for SWM

Solid waste management is given a very low priority in the targeted countries. As a result, very limited funds are provided to the solid waste management sector by the governments, and the levels of services required for protection of public health and the environment are not attained. The creation of a separate budget heading for solid waste management will consolidate funding and help draw attention to the needs of solid waste management.

4. Capacity Building

The number of suitably trained experts, level of capacity-building and training resources in general environmental problems and the specific issue of the collection and management of waste are insufficient in the target countries. Moreover, background studies and surveys of the solid waste management situation are required to assure that the use of means is best suited to the capabilities of the countries and their people. Financial setbacks prevent officials from being adequately paid. This makes undertaking such assignments unattractive, meaning that many people do not aspire to work in this area. Governments and other stakeholders in waste management need to find financial support for the training of inspectors and other officers.

5. Contributions to infrastructure and technology

Government must also be willing to support with necessary infrastructure. There is a need for Western African governments to intensify their efforts in the provision of modern equipments and personnel for removal of SW, ensure compliance with existing laws and regulations on waste management.

6. Harmonization of external funding

Better coordination for effective implementation of solid waste management initiatives is also required by the various agencies involved in solid waste management. External donor support from international donors (WB, EU, USAID, UN, etc.) through bi-lateral and multilateral agreements is one of the most important sources of funding for waste management activities in the targeted countries. However, many solid waste management projects in developing countries suffer from the lack of coordination, which often results from the lack of clear roles defined for agencies in solid waste management. The roles and responsibilities of the various agencies involved should be clearly defined by the national government and a coordination mechanism should be established.

Harmonization of external initiatives with national policy and actors will improve the impact of SWM initiatives and avoid overlapping and solutions not adapted to local necessities achieving a more efficient distribution of funds. In this sense, Action Plans to harmonize different donors and agencies initiatives are needed.

The Paris Declaration on Aid Effectiveness, agreed in March 2005, establishes global commitments for donor and recipient countries to support more effective aid in a context of a significant scaling up of aid. The intention is to reform the delivery and management of aid in order to improve its effectiveness. The reforms are intended to "increase the impact of aid […] in reducing poverty and inequality, increasing growth, building capacity and accelerating the achievement of the MDGs". The Paris Declaration outlines five principles which should shape aid delivery:

- Ownership: Developing countries will exercise effective leadership over their development policies and strategies, and will coordinate development actions;
- Alignment: Donor countries will base their overall support on recipient countries' national development strategies, institutions, and procedures;
- Harmonization: Donor countries will work so that their actions are more harmonized, transparent and collectively effective
- Managing results: All countries will manage resources and improve decision-making for results
- Mutual accountability: Donor and developing countries pledge that they will be mutually accountable for development results.

7. <u>Transparent tendering processes which reach cost effectiveness</u>

Open and transparent tendering procedures will lead to a more efficient use of resources reducing costs and improving the quality of SWM services. Public procurement regulations must be clear, widely disseminated and enforced. Lessons learnt in Europe show that transparent tendering procedures required under EU public procurement rules result in more competition, stronger safeguards against corruption, better services and good value for money.

8. <u>Increase the efficiency in the SWM system</u>

Tough financial constraints faced by the sector in Senegal, Côte d'Ivoire, Ghana and Nigeria are an incentive to design more efficient policies, which make the best uses of available financial resources available locally. Authorities should evaluate the performance of the SWM system and identify those aspects hindering its efficient functioning. This analysis will allow authorities to select the most adequate improvement strategies for their communities. There are numerous cost-cutting strategies to improve SWM efficiency, including reducing the frequency of collection, implementing dual collection of solid waste and recyclables, automating collection practices, increasing employee's efficiency, well designed competitive procurements of services, etc. Collection costs typically represent between 40 and 60 percent of a community's solid waste management system costs, so even small changes in collection programs can yield big results. In addition, intangible benefits can be achieved, such as increased customer satisfaction.

9. <u>Sustainability plans that ensure enduring financing for waste management activities</u>

In many cases, environmental policy has not been effective in Western African countries due to the lack of systematic planning. For instance, excessively ambitious plans to extend the coverage and level of infrastructure services need to be replaced by more realistic programs, tailored to provide appropriate operation and maintenance, essential repairs and rehabilitation of critical elements of the municipal waste infrastructure, and building needed new elements in order to ensure cost-effectiveness, within the limits of what households and public budgets can afford. The local/municipal authorities may have to turn to *self-financing* policy reforms and initiatives that show promise for sustainable financial security for waste management.

10. Involvement of the private sector

Involvement of the private sector can bring several advantages:

- The private sector has shown that it can provide a more efficient or cost-effective service.
- The private sector often has better access to capital financing and it is able to use more efficient equipment.
- The private sector may have easier access to specialist skills. For example companies can form joint ventures with international specialist firms.

However, the private sector must not be seen as the automatic solution to all problems. In many cases, where the public sector (local government) has failed, private enterprise also fails to deliver the required service. The activity of bringing in new arrangements is not enough. Only if the arrangements are carefully designed and implemented, private sector involvement can be expected to bring improvements. Public sector must be able to monitor the private sector in a satisfactory way. Competition is also a key requirement for satisfactory private sector participation. There should be real competition in the tendering process to ensure good prices, but also ongoing competition.

2.1.3. Stakeholder participation

1. Creation of demand for ISWM

Demand for systems of SWM is created when end-users have motivation, opportunity and ability to implement systems of SWM which suit their needs. Demand creation is an on-going activity throughout the planning and implementation processes and beyond.

In order to create demand for sustainable solid waste management within any locality or community, it is necessary to identify what the community members actually desire, as well as to identify what aspects of the system will be of most interest to them. Once key actors in the SWM are identified, they should be used to convince the community to adopt sustainable systems of SWM.

2. Awareness raising campaigns targeting stakeholders.

Raise awareness is a strategy to involve different stakeholders in the process of planning and implementing SWM systems in order to incorporate those actors who are usually left outside the decision-making process and promote good practices that can improve the efficiency of the SWM services provided.

Awareness raising should focus on ISWM promotion and hygiene education and should take the form of dissemination and information campaigns aimed at positively influencing attitudes, behaviors and beliefs. Attempts to educate and mobilize society to segregate recyclables have not yet produced satisfactory results. Society's awareness in this field needs to be raised.

3. Promoting participatory processes.

The need for participatory planning and decision making approaches in SWM is widely recognized. The involvement of stakeholders, their problems, priorities and points of view should be used to increase the opportunities of success of a project. The purpose of this requirement is to bring together stakeholders and unite them under a common goal. It is important to identify and involve all directly or indirectly affected stakeholders such as waste collectors and processors, local municipalities and policy makers, government agencies, companies providing Waste Management services, recycling and waste treatment industry and business sector, local NGOs representatives, rural associations of women and indigenous, rural cooperatives, and stakeholders from the informal sector (CBO organizations, waste pickers associations, etc), etc. Their involvement will facilitate acceptance of the project and ensures the success of the participatory planning approach.

4. Increase the information regarding stakeholders in the target countries.

The collection of data for a national waste information system could, through a process of learning, change the way that waste is managed. Information can make people aware of the consequences of their behavior and influence their opinions, attitudes and knowledge. In South Africa, there is a successful story with the creation of the South African Waste Information System (SAWIS). Information could be extended by conducting surveys and identification of organizations, institutions, or associations affected by SWM policies so that interests of different actors are taken into account.

5. Involvement of the informal sector.

The informal sector represents a significant part of the economy in some Western African regions, and waste recuperation and recycling is an important economic activity. Community based organizations (CBOs) collect waste from informal settlements where local authorities do not provide a collection service.

There is a need to develop an integrated approach where the public, private and community sectors work together to develop local solutions promoting sustainable solid waste management. The informal sector must be included in the participatory processes in order to ensure an interdisciplinary co-operation at several levels and among key actors so that scavengers or informal waste pickers are incorporated into the formal sector and provided with sanitary working conditions.

2.1.4. Education and Training

The successful implementation of Integrated solid waste management (ISWM) in the target countries depend on the quality and frequency of technical training given to all persons along the entire chain of Solid Waste Management (SWM). Training is required for various stakeholders such as waste generators (households, industries, and municipalities), waste collectors, local authorities, sanitation officers, waste treatment and recycling companies, central authorities and policy makers, Non Governmental Organizations (NGOs) and Community Based Organizations (CBOs) involved in SWM.

Training in the form of awareness creation on the benefits of efficient SWM is required for all persons since each individual generates waste. The training requirements are classified with regards to the various stakeholders involved in waste management: generators, collectors, regulatory institutions, waste treatment companies, and authorities.

1. Waste generation (producers responsibility)

In order to implement ISWM in the target countries, all waste producers should be educated to:

- reduce waste generation by purchasing items that contain less waste per unit quantity
- reuse waste as much as possible
- appreciate the benefits of sorting waste before collection
- avoid dumping of waste in unapproved places
- cooperate fully with service providers such as waste collection companies
- make prompt payments for services such as waste collection
- understand the important of ISWM and its contribution to sustainable development

2. Waste generators (consumers responsibility)

Training requirements should highlight the following awareness creation issues as well as benefits to be derived from practicing ISWM;

- Education of all people in target countries on waste and environmental sanitation policies and laws through print or electronic media.
- Avoidance of waste: Patronage of goods that generate relatively low amount of waste or goods which wastes are reusable or recyclable
- Purchase of goods which show a long longevity
- Re-use of items (plastic bags, bottles, textiles)
- Patronage of goods produced from recycled materials
- Practicing waste segregation: source separation of organic waste, plastics, glass, paper metals.
- Education and awareness rising on effects of electronic waste and toxic materials on the environment
- Avoidance of indiscriminate dumping of garbage in unapproved places including drains and water bodies, pathways, playing grounds, lorry parks, road sides, etc.
- Cooperation with sanitation officers and waste collectors
- Observance of rules and regulations on sanitation by-laws of local authorities
- Reporting unscrupulous people and institutions that disregard sanitation bye-laws to authorities
- Payment of appropriate fees to waste collectors for their services
- Use of organic waste in composting for agricultural applications in both urban and rural communities; this could boost backyard farming and improve food security in the target countries if practiced by households and institutions.
- Avoidance of improper and unapproved waste treatment systems such as open burning and burying of waste.

3. Training of institutional heads

Training is required of heads, staff, and students of institutions such as schools, universities, prisons, orphanages, health centers, prayer camps, among others, to:

- Practice proper SWM: avoidance of waste, reuse of waste, sorting of waste, collection of waste, practicing of composting, etc.
- Inclusion on ISWM in curricula of all educational institutions
- Spreading information available on ISWM at the university level
- Training courses for teachers and graduate students in higher institutions aimed at spreading knowledge on ISWM.
- Training courses for professionals
- General education, including online training on ISWM for various segments of society – students, local authorities, sanitation officers, environmental engineers in industries, and informal sector; online courses.

- Practical (on-site) training of approved SWM practices for different segments of society
- Institutions especially schools and universities can obtain purchase recycled items such as books produced from recycled paper

4. Waste collectors

Technical training required of waste collectors should include the following:

- Comply and follow waste collection routes and schedules
- Pre-checking of waste and inform the waste producer on correct waste disposal if applicable

Training in administration regarding waste collection

- New ways of raising capital to augment revenue from existing sources
- Effective customer service systems
- Use of ICT to improve data management
- Capacity building in financial management and priority setting

5. Waste recycling and treatment companies

Technical training required for companies that are into waste recycling and treatment should include:

- Effective collection and assembling of waste for recycling; for example, plastic recycling companies could provide special bins for households and institutions
- Application in new and cost-effective treatment options
- Capacity building in financial management and priority setting
- Sanitation officers and local authorities
- Operation and maintenance of waste recycling and waste treatment facilities

Requirement of technical training and education for sanitation officers and local authorities should include:

- Retraining of officials in new ways of enforcing by-laws
- Use of ICT (Information-Communication- Technology) to improve data management
- Recognition of corruption issues

6. Traditional authorities

- Involvement of traditional authorities to cooperate with all stakeholders to educate people on proper disposal of waste and be a role model
- Need for traditional authorities to join hands with local authorities to enforce laws on sanitation
- Need for traditional authorities to demarcate land for use as dumping grounds and landfill sites

2.1.5. Planning, monitoring and evaluation of the Integrated Solid Waste Management System

1. Planning

Beside monitoring and evaluation the aspect, planning is the first step in designing solid waste management systems to ensure its success. Planning should involve all stakeholders in solid waste management. During the planning phase, the baseline must be properly identified and defined. This will enable the team to set specific targets, choose appropriate technologies and prepare an implementation plan which includes monitoring and evaluation.

2. Monitoring

Policies and programs initiated in Africa are not properly monitored to ensure its success neither are they evaluated to see to what extent they were able to achieve their set goals and objectives and if there are any lessons to be drawn from its implementation. Monitoring and evaluation of solid waste management systems is a very important segment of any integrated waste management system. From generation to collection, recycling, and disposal, there should be effective monitoring measures put in place to ensure its success.

For instance, on the generation side, there should be the need for the implementation of sorting waste at source; the local authorities must put in place effective monitoring measures to ensure that waste generators are doing the right thing by sorting their waste correctly at source. Measures to be employed could include, but are not limited to, snap checks of waste bins by city authorities or ‘sanitation police’, checks by waste collectors and neighbors who can report their colleagues if they see waste material being put into the wrong collection bin. Others include ensuring that waste generators do not dump waste indiscriminately as they were doing previously. Waste collection business has been privatized in most African countries leaving the state authorities which hitherto were the collection body in charge of supervision and monitoring. This is often not carried through to the latter leaving the waste collectors enough room not to do the right thing. One way of monitoring the activities of the waste collectors is to liaise with the public or beneficiaries to measure their level of satisfaction with the service providers. In this order, non performing service providers can be rooted out. Also an effective dialogue channel should be opened between the service providers, the beneficiaries and the city or district authorities to resolve conflicts between service providers and beneficiaries that may arise and also ensure that each party is playing his role well.

3. Occupational health aspects

Waste collection workers are often not properly dressed. Clothing such as gloves, aprons, industrial safety boots and nose mask are not given to them raising issues of occupational health hazards. State authorities must ensure that all waste collector companies must provide and ensure that their workers are properly dressed. Moreover, workers in such areas should be subjected to the same strict occupational health and safety rules. This will ensure that the workers are working in a safe environment and do not end up with injuries, diseases which will affect their health chronically or acute.

4. Environmental aspects

One area of waste management that needs monitoring especially is the dumping section. State authorities have in the past fallen foul of their own laws by sitting dumping sites close to water bodies and dumping on so called degraded land without any engineering works taking place to ensure the removal and treatment of the leachate. This notwithstanding, now that private entities have been given the license to operate their own landfills and dumpsite, the monitoring wing of the departments must ensure strict adherence to the laws and status. Sitting of dumpsite and landfills should not fall within the specified radius of inhabitants (community), water bodies and playing grounds for children. Also, engineers must ensure that all leachate are collected and treated before being discharged in water bodies. Aside this, landfill managers must ensure proper compaction of the waste by bringing in the right equipment.

5. Evaluation

Evaluation is very essential, in that it is able to tell you the success or otherwise of a project or program and most importantly if carried out well can lead to very useful lessons being drawn which will lead to the formulation of new policies or help modify existing ones to enhance their effectiveness.

Surveys are one option which can be used to evaluate a program as well as structured questionnaires can be applied to gather data from beneficiaries on things, such as:

- satisfaction with the waste collectors
- ability and willingness to pay fees
- frequency of waste collection
- Ability and willingness to sort waste at source.

This data can be used to evaluate the service provider and also measure the success or otherwise of a program like sorting of waste at source. Another tool to be used in the evaluation of the solid waste management system is waste characterization:

- quantity of waste generated
- quality of waste generated

Daily data collection of waste generated in terms of quantity, quality and type can also be used to evaluate the success of a policy or program. Apart from surveys, authorities can also conduct snap check – visit the sites to see at firsthand the kind of service being rendered by the service providers (collectors and dumpsite managers).

6. Health aspects

Waste management and the health of the people cannot be decoupled. Improper waste management is challenging the health sector and affecting the health of its inhabitants. Talk of infectious diseases such as diarrhea or malaria can be traced indiscriminate dumping of refuse leading to choked gutters which serve as breeding grounds for mosquitoes or spread of germs in polluted drinking water resources. Any evaluation of waste management program or project should be therefore considered as part of the health sector. This is clearly a very important criterion since any integrated waste management program should improve the health of the people. Collection of health data and an assessment of the health sector are required to monitor, plan and evaluate ISWM programs.

2.2. Organic Waste

The section below discusses different methods from treatment and recycling, such as feeding animals, composting, anaerobic digestion for biogas production and incineration with energy recovery. Requirements for all of them are also described below with focus on the more common systems.

The organic content of municipal waste in the target countries vary from 40-70%. The waste stream is of high value if recycled back to nature in the form of compost through controlled aerobic decomposition. This practice is the most recommended in African nations due to its simplicity and convenience. In rural areas it is usually preceded by prior use of the organic waste for animal feeding. Composting recycles the nutrients back to the soil, may suppress plant diseases, and improves water retention. This practice often also implies avoiding adverse environmental impacts that would otherwise occur[2]. Utilization and treatment options are not only feeding animals and composting, but also anaerobic digestion for biogas production and incineration for energy recovery.

A careful study of local conditions may reveal that large portions of this waste are already being sorted out upstream the collection system to feed the animals of the local community as mentioned earlier. The means of collection and effectiveness also vary widely. This depends on the socio-economic nature of the community, and is less common in urban areas. An ex-ante socio-economic study is therefore a fundamental requirement and at times the most important element of the project.

2.2.1. Primary collection and transport

Requirements for Primary Collection and Transport are as follows:

Primary Storage:

- Store in separate containers from other types of waste if possible or at least in separate bags.
- Choose durable containers, covered with a lid to avoid pests.
- Containers should preferably not to consist of valuable or reusable material or components as much as possible, and possibly be chained to their location (e.g. to avoid thefts to re-sell, or use for storing goods).
- Locate the containers in areas easily accessible to those disposing and those collecting.
- Ensure that a person of below average height can easily dispose a bag in the container to avoid disposal around the container.
- It is preferable to use pure organic waste fractions, if they can be collected, e.g. from markets, in order to avoid impurities.

Primary Collection:

- Encourage separation-at-source (e.g. at the household, or restaurant, etc) to better make economic use of the organic waste and avoid contamination, separation at source is a recommended goal, where sorting-into-two (organic and non-organic) is a recommended starting point to simplify matters in practice and start the trend (CEDARE, 2005).

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[2] Examples of adverse impacts are: odors and methane emitted from poorly managed wastes, seepage of leachate into ground water, and noxious emissions from open burning, soil degradation and excessive use of the energy-intensive chemical fertilizers, among other impacts that eventually threaten public health and the environment.

- Avoid littering during waste handling and transportation by training personnel and properly equipping them, with special consideration of the liquid (leachate) generated by organic waste. The primary collection system should take into account that the waste is wet, dense, odorous, and attracts insects and animals.
- The number of containers per location should be sufficient (equivalent to the quantity disposed) and evenly distributed.
- Collect often, preferably at least once per day to avoid odor from excessive decomposition and to avoid self-ignited fires (Hoglan et al., 2007).
- Establish operational procedures and train the collectors to follow all the environmental and health measures throughout all the recycling operations.

2.2.2. Treatment options

The purpose of treatment of organic waste, either in the collection process, during final treatment, and during product transportation and storage, is to reduce weight and volume to facilitate further transport and to stabilize the waste to avoid odor generation and to maintain the waste qualities for further uses if any.

In final treatment, the purpose is to recover the nutrients, organic matter, and energy as much as possible and to safely dispose the remaining waste if any. It must be noted that all treatment requires land and water.

The requirements for treatment of organic waste are as follows:

- Separate the waste before treatment if it is not separated at source already. Sorting before treatment is better for the quality of the end-product.
- Process the waste on a continuous basis to avoid its decomposition which generates offensive odors, attracts flies and rodents and poses threats of self-ignited fires.
- Ensure the recruitment of sufficiently skilled labor and provide training for them.
- Ensure enforcement of environmental and safety procedures through an effective monitoring and reporting system, and conduct regular evaluation of performance.
- Ensure that the product, whether compost or animal feed, meets the relevant quality requirements of the relevant authorities (e.g. some countries require that samples of compost are analyzed for contents and contaminants, and the same for animal feed). If no regulations are available, then regulations should be introduced as necessary, but should be simple and realizable.
- In composting and anaerobic digestion, co-treatment with fecal sludge should be considered if possible. Fecal sludge management is a major sanitation challenge in many West African cities[3], and co-treatment with fecal sludge may be beneficial technically as well as economically (Cofie et al., 2009). The nutrient content in fecal sludge improves the fertilizer value of the compost. The main complication with co-treatment is the pathogen content in fecal sludge. Odor may also be a concern.

One important steps in organizing and designing treatment for organic waste is to know the rate of solid waste generation, as well as the waste characteristics and components. These facts are important both for the waste collection system and for the treatment. Characteristics to investigate include moisture content, organic matter content, nitrogen content, biodegradability, density, amount of recyclables with a market value and inorganic residual waste (Westendorf, 2000).

[3] The cities are largely not connected to a sewer system and human excreta are managed through decentralised on-site systems. These produce faecal sludge that needs to be removed, treated and preferably recycled (Koné and Strauss 2004).

Any treatment can be performed with a variety of technical solutions and at various scales. Selection requires consideration of many aspects, consultation of experts or literature such in Rothenberger et al., (2006).

Production of fuel briquettes made from organic waste, could play a significant role in managing organic waste, improving the energy security for the urban poor, generate income, acquire self employment, and enhance food and nutrition security by providing low cost cooking fuel. Fuel briquette-making involves collection of combustible materials that are not directly usable as fuel because of their low density and compressing them into a solid fuel product of any convenient shape that can be burned like wood or charcoal. Urban combustible wastes that are useful as raw materials for fuel briquettes are charcoal particles, sawdust, wood chips, waste paper and manure from urban livestock. The documented experience of fuel briquette making from urban waste is still limited, but there are experiences from Kenya and Uganda that could be valuable to consult in planning of this type of recycling.

2.2.3. Recycling and recovery

Energy, organic matter and nutrients are resources that can be recovered from biodegradable waste. Organic matter is a soil improver and contributes to carbon sequestration (USEPA, 2008). Biodegradable waste contains both macro and micro nutrients, and therefore acts as a fertilizer. By aerobic treatment (composting) it is possible to recover organic matter and nutrients, while anaerobic treatment (digestion) further recovers energy from the waste in the form of biogas, but the process tends to be more complicated (DANIDA, 2000). The investment costs are higher than for composting, and it requires more skilled personnel.

Reuse of organic waste as animal feed is very resource efficient. It recovers energy (carbohydrates) and nutrients (protein, micro nutrients) from the waste (Westendorf, 2000). It should be allowed as long as contamination and quality is controlled (e.g. organic waste that has been exposed to leaking batteries due to bad waste handling should not pass unnoticed through the quality control procedures, etc). Considerations to treat human pathogens and harmful bacteria should also be considered in the quality control measures. For example, in certain countries, there are legal requirements that farmers boil any food scraps containing meat before they can be used as livestock feed (USEPA, 2011).

With the aforementioned background in mind, the requirements for recycling and recovery should be as follows:

- Have an appropriately designed recycling facility which matches the quantities and nature of organic waste that have to be recycled.
- Maintain continuous operation to avoid generating offensive odors and attracting flies and rodents.
- Monitor the compliance with the standard procedures for operation and maintenance to ensure safety and efficiency.
- Recruit sufficiently skilled labor and provide necessary training.
- Assess the market of competing products and make a marketing strategy (Rothenberger et al., 2006).
- Support marketing and conducting quality control for the products. For example, in Egypt, a dedicated organization, the Central Lab for Organic Agriculture (CLOA), provides a label to certify the quality of compost after sampling and testing (Dorghamy, 2009).

2.2.4. Disposal

According to the technology used, there might yet be waste remaining, both organic and non-biodegradable (e.g. impurities). A method for disposal of non-biodegradable waste (impurities) is needed, which can simply be landfilling, or whatever disposal method of the rejects is used for the overall SWM system.

2.2.5. Policies

A policy framework enabling composting, biogas production, reuse as animal feed, or other treatment methods is needed. Also decentralized treatment should be enabled by the policy where appropriate, since this reduces transportation costs and generates more job opportunities.

Quality control of the product is important in order to build trust in the market. That can be arranged through legislation (some countries have legal restrictions on metal concentrations in fertilizers applied to agricultural land), or through voluntary systems, such as third party certification of compost. Legislation is probably not necessary in West Africa (this can be compared to Europe, where the only legislation at EU level concerns reduction of disease transmission).

Policies should be coordinated with agricultural, energy and wastewater/sanitation policies. In its formulation, the following priorities are required:

- Participatory planning*:* Plan the policies in consultation with all the stakeholders, including both the beneficiaries and the affected parties.
- Segmentation in planning: Ensure that the policies and the participatory planning are geographically and culturally sensitive since every area and community has different needs, priorities and practices.
- Formalization in existing communities: Aim to transition toward formalization of the industry. This is done through awareness, training, and institutional capacity building, in consultation with the stakeholders in every step. Formalization should not be looked upon as replacing the formal with the informal, but rather as capitalizing on the informal sector and the indigenous know-how and experience to become part of an empowered formal industry and to improve the livelihoods of these stakeholders in the process rather than "policing" the informal sector and taking sweeping measures against them (CID, 2008).
- Formalization in new communities/expansion: Integrate adequate ISWM in the urban planning of new communities, in advance, in order to avoid repeating mistakes and inefficiencies.
- Cultural change: Encourage minimization and Sorting-at-Source. This can be done through campaigns, monetary incentives, non-monetary incentives, etc.
- Entrepreneurship: Facilitate marketing of products (organic compost, digestive, or animal feed) with non- bureaucratic and simple quality-control procedures/guidelines. This is needed to add value of the product to encourage recycling and recovery and to facilitate formalizing the industry.

2.2.6. Institutions

Quality control of the product is important, in order to build trust in the market. That can be done either informally, through government, or through voluntary formal institutions (third party certification, etc.).

- Link waste management with agricultural institutions. Since organic waste can be used as animal feed or transformed into fertilizers, it is important to coordinate with agricultural professionals and organizations, especially stakeholders in urban agriculture (Hofny-Collins, 2006).

- Link with energy institutions, in case incineration or biogas production is considered, especially in the case of electricity production.

In Ghana, solid waste and wastewater is managed in the same municipal department, which is an advantage if co-treatment of fecal sludge and solid waste is considered. In case solid waste and wastewater are managed by different units, coordination is needed if co-treatment is considered.

The following institutional capacity requirements are recommended for a sustainable ISWM system:

- Establishing one overruling entity to plan for organic waste management, and approve policies and programs on the short and long terms. It would be responsible for self-financing and empowering stakeholders.
- Availability of regional and/or local organizational structure which is responsible for projects implementation / management – through third parties, especially the private contractors - , monitoring and evaluation.

2.2.7. Financing mechanisms

Investments are needed, so funding must be secured before operations can start. Considerations for planning the project financing are as follows:

- It is essential that funding for maintenance is included in the financing of the treatment facility
- Other income generation is typically from collection fees. Creative ways to facilitate collection are possible, in some countries, the collection fees are charged through the electricity bill.
- A market strategy for making the best use of the compost (or equivalent) is needed. Practical guidelines on this can be found in Rothenberger et al., (2006).
- In most places, the revenue from selling compost is not enough to cover all costs of treatment and primary collection, but it can cover part of the costs. Other financing is also necessary, for example waste collection fees (Cofie et al. 2009, Sundberg et al. 2006).
- For large projects, Clean Development Mechanism (CDM) funding is an opportunity that should be investigated, such as through methane avoidance or through energy recovery to displace fossil fuels. Energy recovery on its own may also provide extra revenue or cost savings (Friedrich and Trios 2011, Boström, 2010).

2.2.8. Stakeholder participation

In additions to stakeholders normally involved in waste management:

- Potential sellers and users of the compost/fertilizer should be involved. That could include urban and peri-urban farmers, extension services, real-estate developers, nurseries, fertilizer wholesalers and retailers.
- Government institutions in the food and agriculture sector
- Actors involved in excreta management: waste water treatment, fecal sludge management
- Involvement of researchers can help in preventing and solving problems with operations and marketing.
- If energy products are produced, energy market and policy stakeholders need to be involved.

To ensure maximum acceptance from stakeholders and the most beneficiaries, labor-intensive systems of waste management should be considered as a priority in developing countries. Such systems are often more cost-efficient than the capital-intensive systems anyway, and result in more recycling and recovery while providing job opportunities (GTZ, 2005).

2.2.9. Education and Training

The requirements for education and training are as follows:

- Labor of all stages of the system should receive training on health, safety, and environment, and should have basic understanding of the entire system in order to appreciate the upstream and downstream operations relating to their respective function.
- Training should preferably be based on a well planned and written curriculum, and delivered in a formal training setting (e.g. lecture halls/spaces, field visits, etc). The relevant rules and regulations should be included in the training program. Apart from the general training, specialized training is needed, such as:
- Training on the technical and biological processes involved and of product quality and use for the staff involved in the treatment operations.
- Training on operation and maintenance of mechanical equipment, etc.
- Cooperate with research institutions. This has been a success factor in many composting operations, whether for research and development, or for quality control, monitoring, and possibly assistance in product- and process certification.
- Furthermore, public awareness is necessary:
- Public: In case waste is separated at source, training of the general public is needed. Public education should target women and children, who most often manage waste in the household. Potential users of compost and fertilizers need training on the effects of fertilizers, the uses, and how to evaluate quality. Demonstration in practice is effective.
- Schools: The waste-handling requirements should be mainstreamed into school and university education.

2.2.10. Impacts of separate handling of organic waste

Separate handling of organic wastes enables recycling of nutrients back to soil, reduces dependence on synthetic chemical fertilizers, saves water due to improved water retention, avoids methane emissions that might otherwise be emitted from landfilling, and improves organic waste quality (when maintained separate from contaminants) for all uses, whether composting, anaerobic digestions, animal feed, or other uses. Furthermore, the mere expansion of a new industry also creates additional job opportunities.

By treating organic matter in processes other than landfilling, the negative environmental effects of landfilling, open dumping or open burning are avoided. Negative effects of landfills include leakage to ground- and surface water of leachate, as well as greenhouse gas emissions. Under anaerobic conditions, as in landfills, organic matter is microbiologically decomposed to methane, which is a strong greenhouse gas, 20 times stronger than carbon dioxide. Avoidance of greenhouse gas emissions is thus a major benefit of a treatment process that diverts biodegradable waste from landfills (Friedrich and Trois, 2011). In composting, organic matter is decomposed aerobically instead, i.e. with exposure to oxygen (air), and therefore avoiding methane emissions, while producing the compost product which recycles nutrients back to soil. 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 digest, which is also used to recycle nutrients back to soil. Other methods for avoiding emissions from landfills are capture and combustion of landfill gas, and incineration, which are described in (chapter for land filling). The benefit of reducing greenhouse gases is that it can create a source of revenue to finance organic waste management through the Clean Development Mechanism (CDM) of the Kyoto protocol through the sales of certified emission reductions (CERs) (UNFCCC, 2009, LLDA 2007).

Another benefit of treating and recycling organic waste instead of land filling it is that less landfill space is used, and the life span of current landfills is prolonged. This can be very beneficial to city planning and waste management budgets.

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).

Waste management has occupational health risks, and precautions should be taken to prevent negative effects on health. Workers should wear uniforms, boots, and gloves. In areas where composting is taking place, face masks should be worn, and good ventilation is crucial. High concentrations of carbon monoxide and carbon dioxide, as well as hydrogen sulfide and ammonia are potentially toxic.

There is a risk for odor from any process treating biodegradable waste. Precautions should be taken already at the planning stage of treatment facilities and the selection of the site location. Keeping the premises clean and good management of the composting process is also fundamental for odor reduction (Sundberg et al., 2009).

2.3. Recycling and Recovery from plastics

2.3.1. Primary collection, transfer stations and transport

The separate collection is based on recovering the different fractions of recyclable plastic and metal waste separately from other waste, so that they can be recycled.

With this aim, a good suggestion for targeted African countries would be the containerization of industrial estates and urban areas, in order to provide the population with different containers so that several wastes can be selectively deposited.

1. Selective waste collection models

Two generic models for selective collection of waste regarding the disposition of the containers could be suggested for targeted countries.

The first is the selective collection in waste collection points (transfer stations) where high-capacity containers are generally used, as igloo (see **Error! Reference source not found.**) or lateral loading (see **Error! Reference source not found.**) container, which have a mouth at the top adapted to introduce the waste. For the targeted countries this type of container must be useful because they are not expensive (comparing with metallic ones) and made of plastic so when their end of life comes, they can be considered as a raw material for plastic recycling industry.

Fig. 1: Igloo type container

Fig. 2: Lateral loading container

Construction and location of collection points is quite crucial to avoid adverse effects due to odor, breeding of vectors such as flies and mosquitoes, and entry of birds or other animals. In terms of location, taking into account the situation of targeted African countries in which waste collectors can only use little chart carriers and roads are small, containers must be placed in specific collection points with spacious places and where the access is easy for collection vehicles. Therefore, collection points should be located and constructed in such a way that it is convenient for small carts to unload solid waste and for bigger vehicles to collect and transport that waste.

In this system, the citizen has to separate the materials at origin and then deposit the waste in the containers located in collection points. The containers are often emptied depending on the needs.

The material collected in the containers by this system is usually good quality one, since this makes difficult to have errors when depositing waste due to the identification of each waste depositing container by its corresponding color or label.

The second collection system is called selective collection system by sidewalk container.

In this case, the containers would be smaller than those cited above. These containers would be located next to traditional rubbish containers and very close from homes.

This method offers more comfort for citizen, due to their proximity, ensuring a high turnout, although there is some risk that the rate of "not appropriate" materials that do not correspond to the container is greater than in cases of collection points.

In order to get environmental benefit from waste selective collection, in a reasonable cost, it is necessary citizen participation not only by separating their waste at home, but depositing waste in the corresponding container.

The waste collection system choice will be one of the most important decisions for local authorities, when implementing a recovery of wastes as plastics or metals. Issues such as the availability of physical space for containers, the already implemented urban solid waste collection system, the urban typology, future investments or collection services conditions, are determining factors for the choice.

The decision regarding the collection system to be implemented, not only influences the result of the collection stage, but determines the rest of operations that are included in a recycling program: sorting, recovery and final recycling. Therefore, its correct choice is the key for a successful recycling program, and there should be promoted environmentally and economically efficient collection systems.

2. Type of containers

The container type choice will depend on the waste collection system to be used, so it is necessary to consider several aspects:

- The collection system already implemented for other fractions. To use the same system allows some symbiosis, such as the possibility of sharing the material and aesthetic consistency of the collection points.
- Urban typology. Some systems require a certain size of the streets (side loading) or a certain minimum height (top loading).
- The waste collection performance.
- The population size where the waste collection will be developed. Each system requires a different population size to be viable (the concept of critical mass).
- Flexibility in the location of collection points.

Fig. 3: Containers for selective collection (Source: Ecoembalajes España, S.A)

Each of these types of container can be found on the market made of different materials with different benefits in terms of durability, aesthetics, ability to repair and purchase price. The materials commonly used in the manufacture of containers for collecting municipal and industrial wastes are steel, plastic (polyethylene) and fiber (polyester reinforced fiberglass). As it was previously mentioned, for the targeted countries the most interesting are plastic containers because of their lower cost and the possibility to be recycled.

As a summary next **Error! Reference source not found.** shows the following references:

Table 1. References for waste collection containers.

<table>
<tr><th>Container type</th><th>Material</th><th>Capacity (Liters)</th></tr>
<tr><td rowspan="4">Lateral Load</td><td rowspan="2">METALLIC</td><td>2,400</td></tr>
<tr><td>3,200</td></tr>
<tr><td rowspan="2">PLASTIC</td><td>2,400</td></tr>
<tr><td>3,200</td></tr>
<tr><td rowspan="3">Back Load</td><td rowspan="3">PLASTIC</td><td>800</td></tr>
<tr><td>1,000</td></tr>
<tr><td>1,100</td></tr>
<tr><td rowspan="4">Igloo</td><td>METALLIC</td><td>3,000</td></tr>
<tr><td rowspan="2">THERMOSET</td><td>2,700</td></tr>
<tr><td>3,000</td></tr>
<tr><td>PLASTIC</td><td>3,000</td></tr>
</table>

To determine the allocation of containers it should be taken into account the collection system (selective collection in collection points or selective collection system by sidewalk container), the type of municipality and its population and urban factors.

3. <u>Collection vehicle</u>

In the collection system to be applied in the targeted countries, the decision of the collection vehicle to be used must take into account the particular characteristics of the municipalities or industrial areas where the service will be implemented.

Regarding the size of the collection vehicle and its waste collection capacity, due to the low marginal cost of each cubic meter of cargo capacity, the benchmark will be always to try to use the largest possible. However, the real situation in the targeted countries indicates that it is usual to have small not pathed roads and many not accessible areas so the urban characteristics will not allow its movement and handling. Therefore, it must be taken into account next criteria:

- The lower the amplitude of the ways where the vehicle will move, the lower should be its size to navigate with ease. However, containers must be installed in areas where access for collection vehicles is viable so as industrial estates or waste collections points.
- Furthermore, the choice of the capacity of the vehicle, it should be considered the optimization of the number of trips to the waste discharge in transfer stations or recycling plants.

- Collection by little chart carriers or motorized vehicles, very usual for waste collection in the targeted countries, should be continued as they would be an essential part of the logistical structure of the SWM systems to be implemented.

Most usual capacities for collection vehicles are:

  - Lateral Load: 25 m^3
  - Back Load: 22 m^3
  - Top load: 20 m^3

In order to ensure the quality of the collection system, it is suggested to take into account the following considerations regarding bigger collection vehicles:

- The box of the top loading vehicle should have a system to cover the collected material so that the blowing possibility during transportation is avoided. The system should not unnecessarily slow harvesting.
- If it is necessary to share the collection vehicle for different waste collection services, it should be tailored to the needs of each service.

4. Other suitable solid waste collection options

Another suitable option would be to try and target valuable solid waste stream as metals or plastics before they get mixed with the general waste – creating hundreds of informal jobs in the collection of waste (oneself collection in return for payment, regular collection from stores, restaurants, hotels and other places), which would need to be backed up by a guaranteed off-take market at a standardized best-industry-price.

Materials recovery at landfills or dumps could divert what gets through the primary collection. All waste would then be processed centrally where profit-sharing options would be redirected to the collectors. Unusable and contaminated plastics could then be processed as Refuse Derived Fuel (RDF) for cement kilns, or incinerators.

2.3.2. Treatment options

In response to the strengthening of environmental laws and the growing environmental requirements, industry is being forced to change the way they manage waste. Faced with regulations, public pressure, landfill shortages and the need for increased resource efficiency, companies are moving away from the waste treatment approach and towards waste prevention.

The 3R's, reuse, recycling and recovery, are a hierarchy of sustainable waste and resource management practices. It outlines a very sound principle for how we should deal with the waste materials that we produce as a society.

First priority is to REUSE the product before throwing it away. Reusing saves the energy and resources that would have been used to make a new product and means to use the same item more than once, avoiding the product incineration or disposal in landfills.

Second priority is to RECYCLE the waste materials. Recycling means to return a waste product to a factory where it is remade into either the same product or something different.

Third priority is RECOVER, referring to the energy recovery from the waste materials through various technological processes such as incineration, pyrolysis etc. As a viable alternative to fossil fuels or nuclear power, clean energy from waste can contribute to reducing use of the non-renewable resources. The low heating value or net heating value of a substance depends on the composition of its organic fraction (C, H, S and O), moisture and ashes contents. Cellulose $(C_6H_{10}O_5)_n$ with 4,000 kcal/kg and polyethylene $(CH_2)_n$ with 10,000 kcal/kg are considered as typical low and upper limits of heating value for organic solid fractions when related with their compositions.

Error! Reference source not found. illustrates the general approach covering the recycling and recovery options for plastics materials.

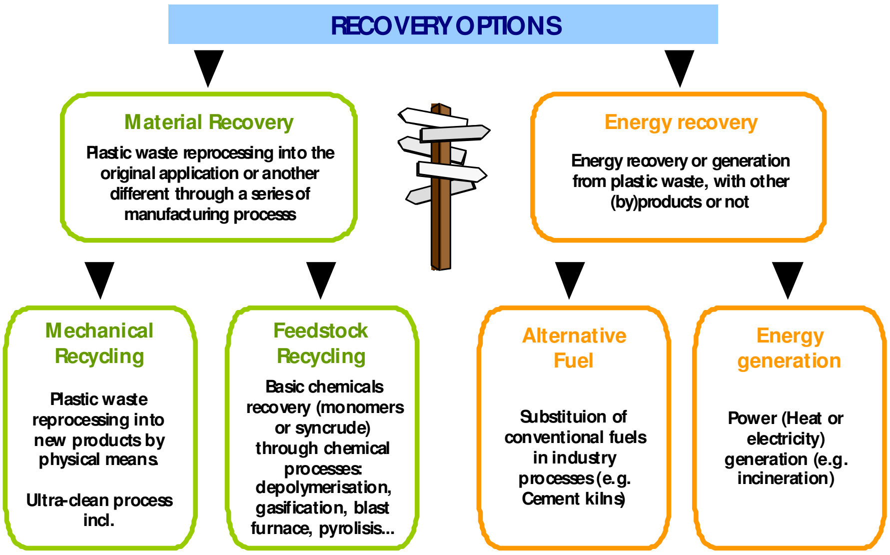

Fig. 4: Recycling and recovery option for plastic materials

2.3.3. Plastic materials

Plastics are polymers and hence large organic molecules formed by combining many, hundreds or thousands, smaller molecules, the monomers, in a regular pattern. The basic units that link each other in a chain usually contain carbon and hydrogen and sometimes nitrogen, oxygen, sulfur or silicon.

Polymers are divided into two distinct groups: thermoplastics and thermo sets. The majority of polymers are thermoplastic, meaning that the polymer can be heated for soften, reformed and cooled for harden reversibly. That property allows for easy processing and facilitates recycling. The other group, the thermo sets, cannot be re-melted since they harden irreversible through chemical cross linking reactions between polymer molecules. Once those polymers are formed, reheating will cause the material to scorch.

Usually the thermoplastics are divided into commodity or standard plastics (PET, HDPE, PVC, LDPE, PP, and PS) and engineering or technical plastics (SAN, HIPS, ABS, PA, PC, PMMA POM, PBT and blends of them). Thermo sets group comprises alkyd, phenol and amino resins (melamine and urea resins), epoxides, unsaturated polyesters, polyurethanes and allelic.

Almost all polymers come to the processing stage as compounds, in which the polymer often acts largely as a matrix, allowing the valuable properties of other materials to be harnessed. Additives used in plastics include pigments, colorants, heat-stabilizer, ultra violet stabilizers, flame retardants, plasticizers, lubricants and processing aids. Fillers and reinforcements such as glass, carbon or another fibers and minerals, such as calcium carbonate, talc or mica are also used.

The method of processing or hardening has a direct influence on the ease with which plastics can be recycled, using reprocessing methods. Applications for recycled plastics are growing every day and recycled materials can be blended with virgin plastic without sacrificing properties in many applications. Mixed recycled plastics can be used to make polymeric timbers or selected plastics bottles can be spun into fiber for the production of carpets. Another option for plastics that are not recycled can be energy recovery.

2.3.4. Recycling and recovery

1. Mechanical recycling of plastics

The majority of polymers are thermoplastic, meaning that once the polymer is formed it can be heated and reformed over and over again. This property allows for easy processing and facilitates recycling. The thermo sets cannot be re-melted, once these polymers are formed, reheating will cause the material to scorch.

Available recycling technologies for plastics are selected depending on the levels of mixture, dirtiness, contamination and deterioration of the materials. Mechanical recycling technologies based on material separation and cleaning operations are adequate for almost pure plastics like the HDPE (high density polyethylene); PVC (polyvinyl chloride), PBT (Polybutylene terephthalate), PP (polypropylene), PET (polyethylene terephthalate), PA (polyamide) and other thermoplastics found at industrial scraps and sorted post-consumer wastes. Mechanical recycling technologies based on material joint processing for the production of plastic lumber are more adequate for commingled, dirt, contaminated and deteriorated plastics as in the targeted African countries. Other alternatives to landfill to be considered are feedstock recycling, energy recovery and incineration technologies although they are supposed to be economically not available for targeted countries.

Pure plastic recycling activities are related with the treatment of post-consumer wastes like bulky or selectively collected plastics containers and films and like dismantled parts or intermediate streams and fractions generated during the end of life treatment of complex goods as electric wires and cables, end of life vehicles (ELV) or waste from electric and electronic equipment (WEEE). In a wider sense plastic recycling activities also comprise, and many times mix with the above mentioned categories, plastic from other sources like out of specification pellets, production scraps generated during plastic processing activities and plastic product rejections. Activities on mechanical recycling of plastic are mainly focused on thermoplastics

Additionally to these different origins there exists a broad plastic material variety to be recycled since together with the commodity plastics, used for containers and other low demanding applications, like PET, HDPE, LDPE (low density polyethylene), PP, PVC or PS (polystyrene), also appear many engineering plastics, like SB or HIPS (high impact polystyrene), SAN (styrene-acrylonitrile), ABS (acrylonitrile-butadiene-styrene), PA, PC (policarbonate), PMMA (polymethyl methacrylate), PU or PUR (polyurethane), and some plastics alloys and blends that need to be applied in the manufacture of high performance automotive or electric and electronics parts. A brief summary of uses for virgin and recyclates are shown at **Error! Reference source not found.**.

Generally speaking plastic industrial scraps have better quality and are less dirty or mixed than post-consumer plastic wastes. The recycling of post-consumer plastic wastes require either manual or automatic identification and sorting operations in the beginning of the scheme when dealing with manually dismantled big plastic parts or products like bottles that will be conditioned (shredded) and cleaned (washed), in order to obtain intermediate products like clean flakes or pellets after the compounding and extrusion of those flakes.

When shredded or grinded materials are mixed different separation operations (density, shape, size or any other property based) are required for the concentration of target materials. The products from any of these plants are plastic fractions, in the form of shreds or granulate, that fulfill some given purity or property levels.

Table 2. Sources and uses for recycled plastics

Plastic	Common Uses	Major end uses for recyclates
PET (Polyethylene terephthalate)	Packaging (bottles) Soft drink bottles, peanut butter jars, salad dressing bottles, mouth wash jars	Fibre, strapping, sheet, bottles and other packaging, injection moulded components (electrical and automotive parts) Liquid soap bottles, strapping, fibrefill for winter coats, surfboards, paint brushes, fuzz on tennis balls, soft drink bottles, film
HDPE (High density polyethylene)	Rigid packaging (bottles, crates, pallets) Milk, water, and juice containers, grocery bags, toys, liquid detergent bottles	Soft drink based cups, flower pots, drain pipes, signs, stadium seats, trash cans, re-cycling bins, traffic barrier cones, golf bag liners, toys Construction items, pipes, ducts and fittings, film and sheet, other packaging, bins and boxes, pallets and cases, lumber, street furniture, plant pots
PVC (Polyvinyl chloride)	Clear food packaging, shampoo bottles, cable sheathing, piping, window frames, credit cards	Floor mats, pipes, hoses, mud flaps Pipes, ducts and fittings, film and sheet, noise barriers, flooring, traffic signals
LDPE (Low density polyethylene)	Agricultural and packaging film Bread bags, frozen food bags, grocery bags	Garbage can liners, grocery bags, multi purpose bags Packaging film and sheets, construction film and DPMs (Damp Proof Membranes), agricultural film, street furniture and lumber
PP (Polypropylene)	Ketchup bottles, yogurt containers, margarine, tubs, medicine bottles Packaging (trays and tubs, vending cups)	Manhole steps, paint buckets, videocassette storage cases, ice scrapers, fast food trays, lawn mower wheels, automobile battery parts Plant pots, street furniture and lumber, pipes, ducts and fittings, wheel arch liners and injection moulded parts in automotive sector, pallets, crates and cases, coat hangers
PS (Polystyrene)	Packaging, EEE casings, automotive parts, video cassette cases, compact disk jackets, coffee cups, cutlery, cafeteria trays, grocery store meat trays, fast-food sandwich container	License plate holders, golf course and septic tank drainage systems, desk top accessories, hanging files, food service trays, flower pots, trash cans Packaging and building insulation (EPS), coat hangers, plant pots, miscellaneous injection moulding applications
ABS, SAN, HIPS (SB), PC/ABS	EEE casings, automotive parts	Miscellaneous injection moulding applications in multiple sectors (EEE, automotive, consumer)
Others	Various	Miscellaneous injection moulding applications in multiple sectors, fillers, etc.

2. Separation technologies for plastic recycling

Handling of material mixtures in order to sort and upgrade target fractions involves the use of the following operations and related equipment, that can be separated in high or low technologies.

Low tech means technologies which are suitable and adaptable in the targeted countries. However, high tech means technologies that are suitable but difficult to be adaptable considering the situation of targeted countries.

Low Tech Separation technologies for plastic recycling

- Size reduction technologies, produce stress in a particle leading to breakage and employ three basic types of forces shear, grinding and crushing (also folding, bending and traction forces can occur)
    - Shredders: blades rotate in different directions forcing two parts of an item in different directions and crush it, see **Error! Reference source not found.**
    - Granulators: blades apply friction to the surface of an object and cut it, see **Error! Reference source not found.**
    - Hammer mills: impact forces on compressive materials cause size reduction
- Size separation, the separation of solids is based in their different size and shape, shredding or milling devices are used previously in order to pre-conditioning the solids
    - Rotary screens (trommel): basically a horizontal cylinder rotating over its axis, a coarse and a fine fraction are separated
    - Vibrating screens: basically a grid with vertical movement, several size ranges could be obtained
- Density separation, the separation of solids is based in aerodynamics or hydrodynamic properties and density
    - Sink/float separation: the solids heavier than liquid media sink and the ones lighter than liquid media float, two fractions are separated, see **Error! Reference source not found.**
- Sorting and separation by hand washing of plastics if required. Plastic hand washing could be carried out for the removal of heavy contamination and also for the separation of mixtures of plastics and contaminates using water as a medium to float out the fractions of plastics with specific gravity

High Tech Separation technologies for plastic recycling

- Density separation, the separation of solids is based in aerodynamics or hydrodynamic properties and density
    - Dens metric tables: basically a table surface inclined that has vibrating movement in which particles are fluidized by pressurized air that stratify the light material to the top that cause the heavy fraction moves up hill, see **Error! Reference source not found.**
    - Hydrocycloning: heavy and light fractions are separated using centrifugal forces, geometry can be modified in order to get better purity
    - Pneumatic classification: an air jet is used to remove light materials (like foams) and laminar materials (like films) form other solids
- Magnetic separation: ferrous metals are separated from other solids using either electro or permanent magnet in belts or drums, see

- .
- Eddy current separators: a method based in magnetic induction to separate non ferrous metals from other materials, see **Error! Reference source not found.**.
- Electrostatic separation: separation method based on electrical conductivity values (insulating or conductive materials) that are charged by discharge, induction or friction and are separated by attraction or repulsion.
- Flotation: two fractions are separated when surfactant agents are added to a liquid, usually aqueous, media in which solid are immersed
- Spectroscopic methods (infrared recognition for polymer, laser induced plasma emission for elements)

Fig. 5: Oldenburg stamler MVT Twin Roll Sizer

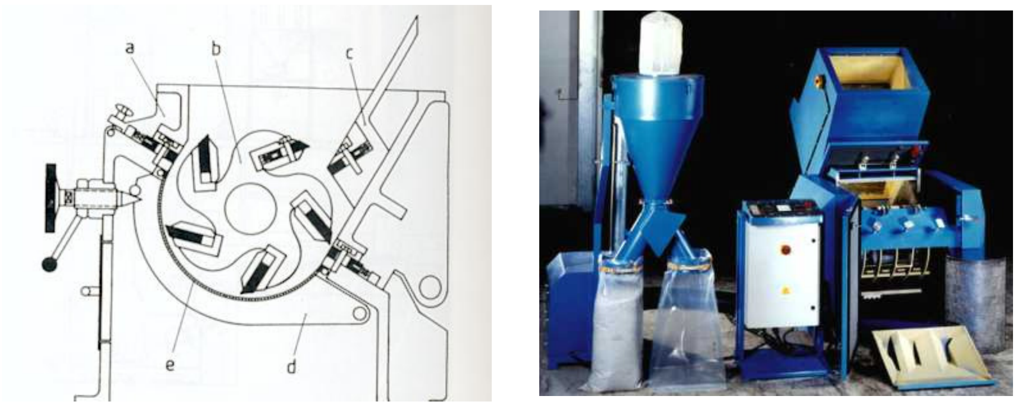

Fig. 6: HERBOLD - Blade granulator with material extraction

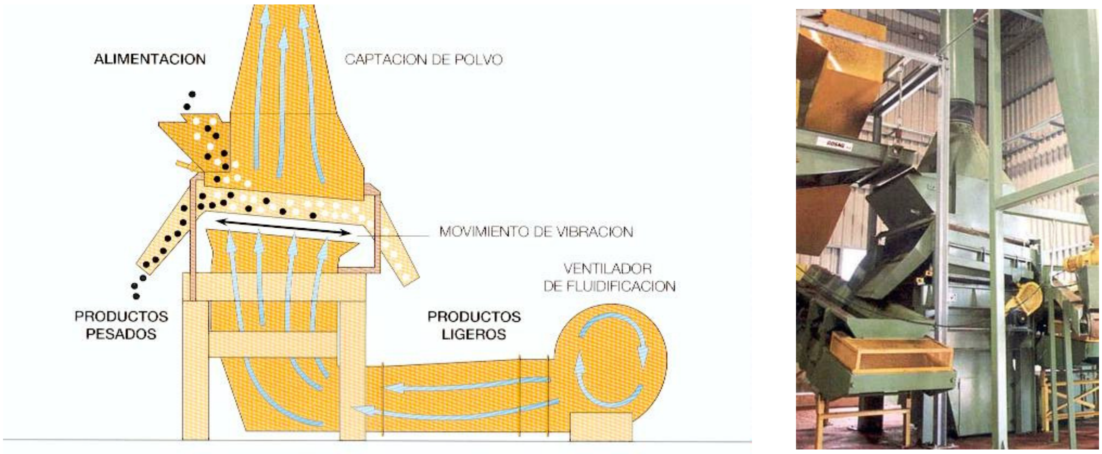

Fig. 7: Dens metric table

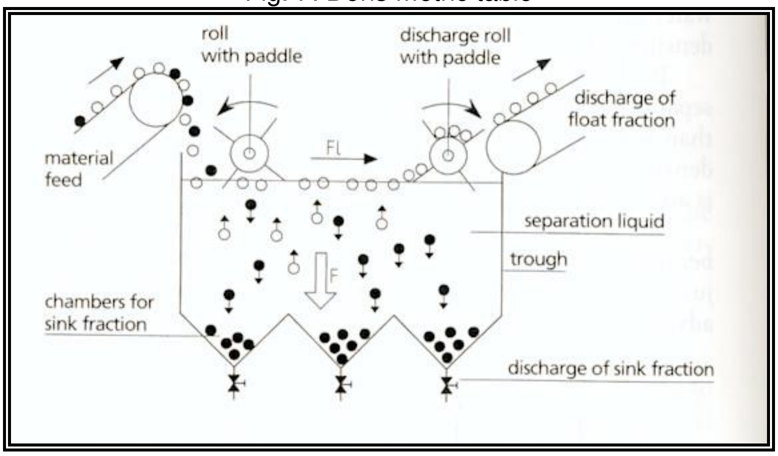

Fig. 8: Sink/Float separation

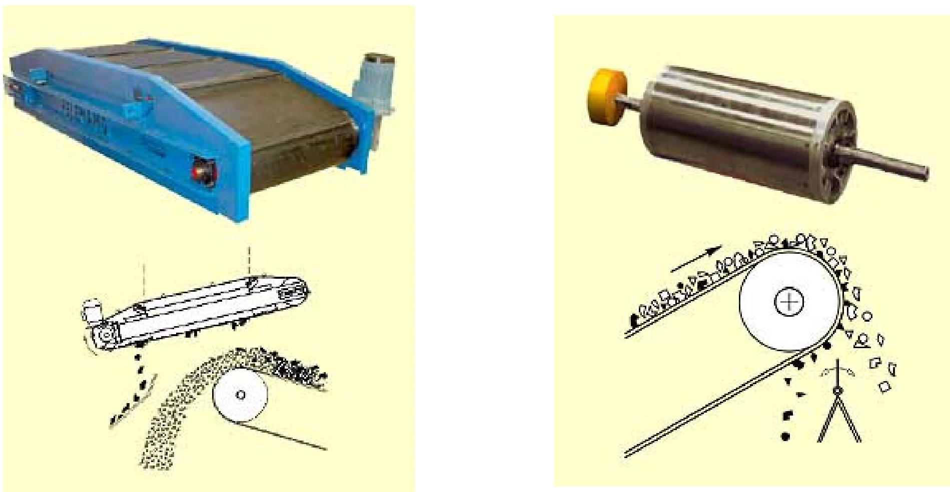

Fig. 9: FELEMANG - Magnetic separators
Overband SFI-RC (left) and Electromagnetic drum SF-T (right)

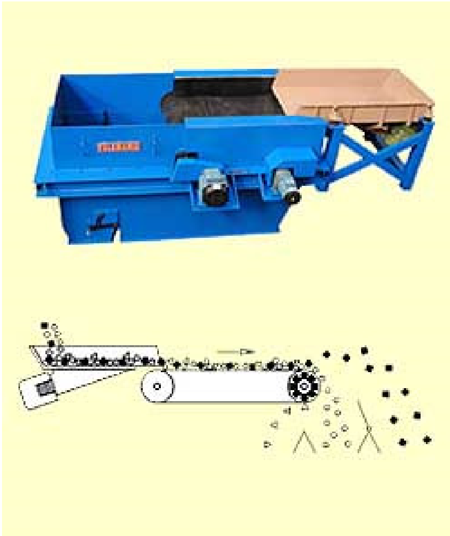

Fig. 10: FELEMNG- Eddy current separator

3. Plastic processing (high tech)

Plastic recycling industry consider shredded and washed plastic pure fractions as high value final products, plastic recycling industries in the targeted countries should indentify that as their principal final product. However, plastic processing technologies, which can be considered as high tech, are now described as they get considerable higher value for the recycled plastic final products.

The choice of technology used for processing plastics depends on whether the material is thermoplastic or thermo set and on the product required. For thermoplastics, the conversion of pellets, flakes and powder in various shapes usually implies melting, moulding and solidification. In the case of thermosets, liquid components are mixed and transformed in a mould, where they suffer a chemical reaction and become 3D shaped structures. Plastic processing techniques fall into two broad categories:

- Extrusion for 2-dimensional, unlimited length products
- Moulding for 3-dimensional, discrete parts

4. Extrusion

In the case of thermoplastics, the extrusion process produces a variety of shapes such as tubing, rods, sheet and complex profiles. Extrusion involves plasticizing a polymer compound in a long heated machine barrel with one or two screws, and continuously forcing the melt through a die to produce the desired final shape, and finally cooling under controlled conditions to maintain the desired shape. Depending on the type of product required, extrusion can take many forms as follows: sheet extrusion (in that case wire extrusion passes a copper wire through a die and sheathes them with plastic insulation), co-extrusion (it combines the output from more than one extruder into a single die to produce sheets or profiles made up of layers of two or more polymers) and calendaring (it is used mainly for processing PVC into sheet).

For their processing plastic pellets are introduced throughout a funnel into the extruding cylinder. The granules are gradually melted with the energy generated by a spinning lathe and the heaters placed around the cylinder. At the extrusion processing at **Error! Reference source not found.** the melted polymer is pushed through a nozzle that shapes the material into pipes, bars, rods, drainpipes, etc. At the extrusion blowing processing at **Error! Reference source not found.** the melted polymer goes through a pipe where it is inflated in the shape of a balloon with a gush of air which ascends inside the bubble. The bubble goes through some rollers

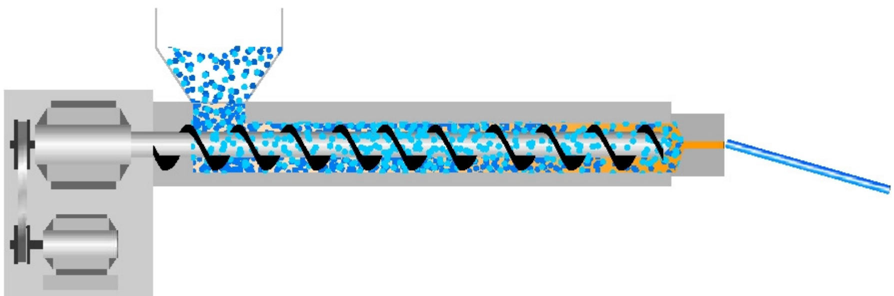

Fig. 11: Plastic profile manufacture by extrusion (source: www.anaip.es)

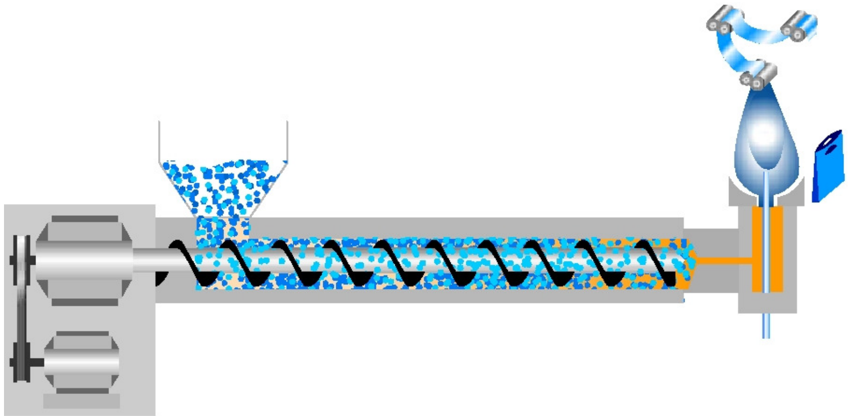

Fig. 12: Plastic bag manufacture by extrusion blowing (source: www.anaip.es)

The thermoforming process follows to either a calendaring or an extrusion process in which plasticized state of the respective plastic is produced, it is not possible to threat granulate form of a plastic directly. In a thermoforming process thermoplastic polymeric materials are heated (infrared radiator) in the plasticized state, thermoformed under slight pressure and cooled while maintaining the deforming force. This force can be applied by vacuum, a mechanical punch or compressed air. In the case of thermosets, there are also analogous processes for production of similar shapes in fibre-reinforced plastics, such as centrifugal casting, filament winding and continuous sheet lamination processes.

5. Moulding

In moulding, the plastic is formed by heat and pressure into the shape of a mould. Each grade of plastic has its own optimum moulding conditions of temperature and pressure.

For thermoset plastics, there is essentially only one moulding technique: compression moulding. The plastic moulding compound which may be pre-heated is placed in a heated metal mould where, as it heats up, it begins to flow. The mould is closed, pressing the softened material to the shape of the mould, and the plastic sets or cures. The moulded part is then removed, hot, from the mould. Variations on this process aim to improve the efficiency with which the charge of material can be introduced into the moulding press, within the limitations imposed by the chemical reaction that occurs with heat.

For their processing plastic pellets are introduced through a funnel into a cylinder melting machine of reciprocal injection. The pellets are gradually melted with the energy generated by a spinning lathe and the heaters situated along the cylinder. At the injection moulding processing at **Error! Reference source not found.** the cylinder is shifted forwards and it injects the plastic into a mould. Once the plastic becomes solid, the mould is opened and the piece is expelled. At the extrusion blowing processing at **Error! Reference source not found.** the melted polymer goes through a pipe where it is inflated in the shape of a balloon with a gush of air which ascends inside the bubble. The bubble goes through rollers Plastic pellets are introduced through a funnel into the extruding cylinder.

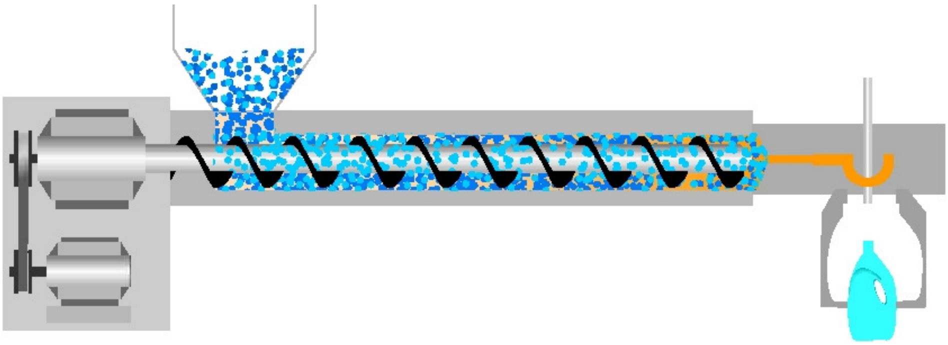

Fig. 13: Plastic bottle manufacture by injection (source: www.anaip.es)

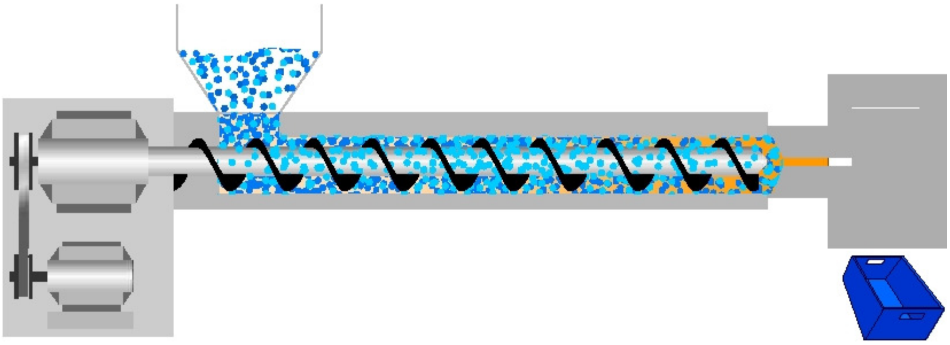

Fig. 14: Plastic box manufacture by blow moulding (source: www.anaip.es)

Reaction moulding (RIM) is used for moulding polyurethanes, which are thermosets but in the form of two liquids that react rapidly when mixed, to form a solid material.

6. Applications for recycled plastics

The production of plastic lumber is a compromise between some expensive separations of a mixed plastic stream into purified homogeneous plastic fractions and the possibility of an almost direct use of a commingled plastic stream in an application able to give products of satisfactory quality and for which there are a potential high demand.

Plastic lumber is available in a number of profiles such as planks, rails, slats, tongue-and-grove board as well as circular profiles, see **Error! Reference source not found.**. Plastic lumber has numerous park and recreation uses such as public walkways, marine structures, fences, etc.

The use of a commingled plastic stream for the production plastic lumber is relatively inexpensive since products generally have a large cross sectional area and can tolerate a high degree of contamination but the resultant products have lower performance and aesthetic properties compared with the ones produced from pure plastic fractions. Several processing technologies like intrusion, profile extrusion, compression moulding, can be applied for producing plastic lumbers.

Fig. 15: Different profiles and end products made of plastic lumber

The composition of a commingled plastic stream has a significant influence on the resultant physical properties of the plastic lumber. For instance a high proportion of LDPE can give a product with a low flexural modulus which may be too flexible for use in load bearing applications. An excess of PP in the mix can produce a product which is quite brittle, especially at temperatures below zero, while a high level of PVC can cause problems due to its decomposition and gas and vapors release at the temperatures used to process polyolefins.

The commingled plastic streams are required to be free of abrasive materials like stones, glass and metals and of polymers that melt at low temperature like PVC and decompose below the processing conditions. Grinding in the 4-6 mm range helps to minimize negative effect of high melting point plastic like PET or PC and allows handling them as fillers.

Compared with wood plastic lumber have some limitations:

- Pure plastics streams are more expensive than natural wood
- Despite plastics do not have anisotropic properties they are more flexible than wood and are inappropriate for primary structural purposes
- Plastics are heavier than wood in a density comparison
- Plastics have lower resistances to creep than wood
- Plastics have lower friction coefficients than wood and turn slippery when wet

- Commingled plastic streams are generally dark or black color and are very difficult to paint

Compared with wood plastic lumber offer some benefits:

- Protective and safety: reduction in damage to shipped product and injuries to workers (pallets without protruding nails, screws or broken boards)
- Cost-effective: considerable reduction in needed storage space (nestable pallets for space saving in trailer transportation costs and longer trip life)
- Consistent: products are moulded to be uniform in size, shape, and weight and will not warp, shrink or change mass over time (plastic do not absorb moisture, do not support the growth bacteria, fungus, insects or rodents)
- Clean and stable: plastic products may be cleaned by water jet, steam or chemical bath (stable to most chemicals, solvents, acids and salt sprays)
- Waste free: plastic products are fully recyclable and after their useful life can be returned to the process

2.3.5. Energy recovery

Plastics are almost all derived from oil and plastics waste is a waste with a high calorific value. Energy recovery from plastic waste can make a major contribution to energy production. Plastics can be co-incinerated with other wastes or used as alternative fuel (e.g. to coal) in several industry processes (cement kilns). Pelletized or fluff plastic waste can be used as *refuse-derived fuel* (RDF) in dedicated RDF boilers or co-incinerated with coal or oil in a multi-fuel boiler, see **Error! Reference source not found.**. The energy content of plastic waste can be recovered in other thermal and chemical processes, such as pyrolysis, gasification, liquefaction and coke oven feedstock recycling.

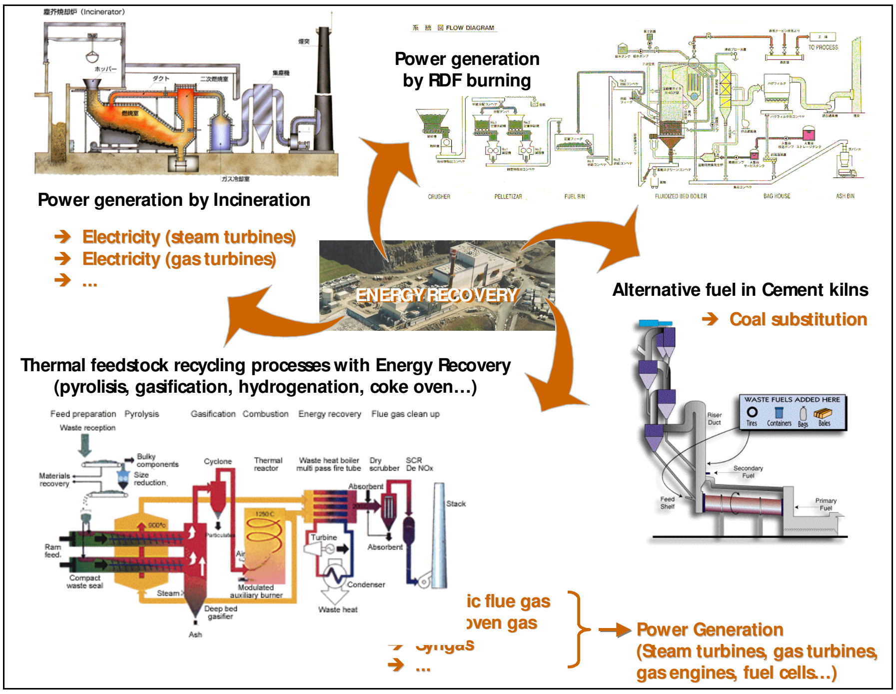

Fig. 16: Energy recovery options for waste plastic

Legal and institutional aspects

2.3.6. Financing mechanisms and economic aspects

2.3.7. Stakeholder participation

2.3.8. Education and Training

2.3.9. Occupational health and hazards

2.4. Recycling and Recovery from metals

2.4.1. Primary collection, transfer and transport

2.4.2. Treatment options

2.4.3. Metal types

2.4.4. Recycling and Recovery

Metal waste in this study is originated from producers and households. Besides plastics, several metal types currently have a high value in the target countries from the project. Therefore, their collection from various stakeholders (private and informal sector, industries) and increasingly for export purposes can be observed and is described as a major problem for local recycling business in Ghana and Senegal as well as the resulting resource depletion. As scrap metal, mainly aluminum, iron and copper can be regarded as relevant in this study. Partly these metals are originated from e-waste and can be found in the chapters dealing with e-waste. Other metal waste not originating from e-waste will be discussed briefly in this chapter.

In general big metal industries follow an oligopoly-business. Only a few companies are scattered and located in industrialized and transition countries. Smaller companies can also be found in the target regions.

For metal recycling it is of advantage if the metal is clean or not accompanied with different metals, which makes the recycling more difficult. For example, aluminum's purity has to be at least 90%. Also it has to be considered that the emissions of recycling of metals need to be held by purification systems as well as any possible heavy metals.

The major technical requirement in terms of metal recycling is the transfer of know-how within the target countries and the establishment of low technology options. From the non technical side it is of advantage to assess the streams of metals coming in and going out of the country.

For economical reasons creating an environment which makes it attractive to work with this resource in the target countries would benefit local companies. At the same time it needs to comply with the requirements to protect human and environmental health.

2.4.5. Legal and institutional aspects

The analysis of legislative, regulatory and institutional frameworks for waste management reveals many shortcomings related to, amongst others, a lack of synergy between different texts (definitions, standards), lack of expertise in the application of existing legal provisions (weak response capacity, staff), lapse of certain provisions and absence of a strategy to involve the actors involved in waste management programs. As a result, the limited impact of laws and regulations and the technical structures in charge of their implementation, should lay the grounds for the reorganization of institutional aspects, the renewal of legal tools and the development of action plans for waste management. From now on, we should work on the more limited concept of recovery, as opposed to that of management, of a more compassing nature.

In Senegal, for example, a review of provisions made by legislative and regulatory texts shows a focus on waste management rather than recovery. Some provisions even hinder the practice of recovery.

As such, steps should be taken towards the regulation of recovery activities. To this end, it would be helpful to:

- revise any provisions that impede the practice of valuation;
- provide legal matter for the concept of a recovery actor and the field in which he works;

- see provisional frameworks for recovery activities (environmental requirements, social security for actors);
- Secure the business environment to attract investors.

2.4.6. Financing mechanisms and economic aspects

Smelters from metal recycling and other recycling actors are faced with many financial constraints. In Senegal, a study carried out in 2009 on the different recycling sectors showed that the artisans find it increasingly difficult to withstand the surge in prices of nonferrous metals (copper, aluminum), especially with the presence of Indian and Chinese exporters, who have access to more financial resources. This leaves them in a precarious situation. This strong competition of raw materials exporters dealing with Asia and Europe is threatening the breakthrough of local processing industries such as foundries.

The public and private partnership which depicts the possible relationships between public and private sector to ensure close collaboration in the delivery of services could be a tailored solution for financing the sector. Private actors may include private companies, non-governmental organizations and also community organizations. This type of partnership would grant informal actors direct access to the international market and the ability to sell according to market rates. The introduction of a tax on products with their subsequent recovery in mind could also help partially in the financing the sector.

2.4.7. Stakeholder participation

Some actors hold key seats and roles. It is necessary to develop a synergy of actions between the actors.

1. The State

The state has an essential role to play in the conduct of reforms (review of provisions which impede recovery activities), the definition of national policy on recovery and the support of recovery actors. In practical terms, it is about collaborating with the recovery actors concerned to carry out an inventory of all the provisions that disadvantage recovery activities and to reduce them through their revision.

In addition, the definition of a national recovery policy is needed to create the economy of scale and the reduction of waste management costs. The state via its services could oversee effective organization of waste recovery by following the beginnings of recovery practices in terms of social security (recovery actor exposure to multi-form risks, the education and training of those involved in recovery).

Finally, in the context of environmental conservation, incentives for good management practices can be applied including tax exemptions for collectors or industries who have taken this ecological dimension most into accounts.

2. Local authorities

They can be seen on two levels: externally, through decentralized cooperation, and internally, particularly through the strengthening of support frameworks for recovery actors.

Thus, the first level is seen when a local authority (or several) develops partnership relations with one (or several) foreign local authorities. In the case of the recovery of solid waste and industrial waste, the technical assistance from more experienced local authorities could be applied and beneficial for local recovery actors.

On the internal aspect, local authorities are required to prepare a comprehensive program including a strategic plan for waste recovery. This plan covers many aspects.

On the technical side, taking into account the issue of waste recovery implies integration from the beginning, sufficient provisions for collection, transportation and disposal in line with industry practices and requirements.

Therefore, instead of uncontrolled collection, a national network of separate household bins as well as waste reception centers developed and integrated into neighborhoods could be considered. This logistic model, accompanied by a comprehensive outreach and public information program, would enable them to pre-sort their waste.

At the organizational level, local authorities are expected to play a key role in the supervision of recovery and recycling practices. To this end, they can influence the allocation of sites; determine their role, the material to be exploited, the security conditions to be met and compliance with certain environmental requirements. These are clauses that local authorities may set out by using by-laws through a partnership agreement signed with the recovery actors. Through this, local communities are involved in promoting the local economy, in reducing risks associated with the practice of recovery, but most importantly in reducing the quantity of waste, and the costs of treatment and disposal as well.

3. Informal actors

Recovery actors should lean towards better structure and strengthen existing organizations by encouraging the creation of support frameworks through which to bring together the various actors involved in waste recovery.

This structure could take the form of grassroots organizations represented by groups for each sub-sector (recycling group for scrap metal and plastics) and then grouped together as a federation. It would allow easier supervision, exports in large quantities, reduction of transaction costs linked to the search of information, negotiation and decision-making as well as better visibility for recovered products. Once established, these federations could have a real capacity to be accepted as an interlocutor on issues related to recovery.

1. NGOs

Their role in waste recovery remains important because of the technical support they can provide, the support to grassroots actors, applied-research or even advocacy targeting the State or local authorities. Their presence on the ground alongside informal actors gives special weight to their policy positions.

2. National private sector

These are primarily employers' organizations, whose involvement is largely restricted to seeking a secure business environment (legal framework regulating the practice of recovery) and incentive policies (exemption on taxation, energy, VAT, patents for local authorities). All of which should contribute to the beginning of local transformation of solid waste and materials. This transformation has larger added value and allows work savings in bulk.

2.4.8. Education and Training

This subchapter refers to the building of human and technical capacities which belong to actors involved in the waste recovery system, including formal businesses, recovery actors, local authorities and populations. Education should also focus on the development of policies for communication and awareness on the challenges and prospects for waste recovery. This appears to be an unavoidable factor in improving the organization of the system. In fact, improving the recovery sector cannot be achieved without a good policy for communication and awareness-raising of all actors in the system. This must be done not only via the media (radio, television or print media), but also through localized awareness campaigns in the sites where waste pickers operate.

2.4.9. Occupational health and hazards

Waste pickers and other recovery actors may be exposed to manual risks such as injuries from broken glass, traps, shocks and drops while loading or lifting heavy materials. Smelters operate potentially dangerous activities with the handling of materials subjected to high temperatures, heat sources, and risk of fire and release of gas or potentially toxic fumes.

Unlike the European Union countries where legislation requires the use of protective clothing, tools and tailored to meet local safety standards, in West Africa the smelters are not subject to any safety requirements. With the exception of a tiny minority, the smelters do not use any protection (protective clothing, gloves, appropriate footwear). They work with their bare hands and wearing sandals, if not barefoot. Foundry work performed under such conditions is of a dangerous nature, which artisans offset by working in a highly ordered and optimized manner.

Chemical hazards are linked to the handling of containers of hazardous chemicals (toxic, irritant, harmful, corrosive, etc.) Residues from paints such as aerosols can be inhaled, ingested or penetrate the skin, affecting the health of actors working without protective equipment. The use of protective equipment and improved recovery practices could reduce these risks.

3. TECHNICAL AND NON TECHNICAL REQUIREMENTS ON E-WASTE

3.1.1. Primary collection, transfer stations and transport

Collection, transportation, treatment options, recycling and recovery and final disposal in the integrated E-waste management should meet some requirements so as to avoid uncontrollable co-dumping of E- waste along with municipal solid waste or indiscriminate dumping at authorized dumpsites. Some of these requirements will be needed for successful management of E-waste as highlighted below.

1. Primary collection, transfer stations and Transport

There are two major E-waste collection channels which have been successfully used, municipal collection points, and producer/retailer take-back. The means of collection will vary, depending on distance, rural or urban patterns, and the size of collected appliances. The collection opportunities must give priority to convenience and accessibility, preferably at existing transfer stations, recycling center, or other municipal facility. An efficient E-waste collection and transportation system will ensure reuse, recycle and adequate E-waste management including avoiding damage or breaking components that contain hazardous substances. The major factors, which determine the efficiency of collection system includes accessibility, efficient collection facilities, minimal movements of the waste products, minimization of manual handling, separation of reusable appliances, adequate and consistent information to the users. It is also important that E-waste is collected, sorted, stored and transported under controlled conditions since it is hazardous in nature. Collection and transportation system has been described in terms of collection channels and infrastructure required to support it. Requirements for primary collection and transport are:

- Identify refurbishment shops/workshops, recondition facilities, e-waste recycling centers, influx of illegal used electronics goods, existing used electronic market
- Identify different kinds of e-waste collected and managed by the selected centers
- Collection of e-waste from households which are considered as the largest consumers of electronic products
- Create official collection points that are accessible to the E-waste generators especially households and businesses. A number of sorting/segregating containers can be provided at the collection sites according to the E-waste product groups such as Refrigeration equipment, other large household appliances, equipment containing CRTs e.g. TVs and computer monitors, IT and telecommunications equipment (laptops and mobile phones), Lighting (bulbs and fluorescent tubes) and all other WEEE or as required by the transporters. This collection mechanism is usually free for household E-waste, but charges sometimes may be applied for commercial companies. These collection points must comply with the conditions of the national waste laws and regulations.
- Producers/ retailers take back system of electrical and electronic equipment. In this collection mechanism, consumers can take back E-waste to retail stores that distribute similar products or directly to the producers or their designing collection centers. Where available, this service is usually free to private households.
- Other officially registered points. Consumers and or businesses can drop off E-waste at specially created sites/centers which can be specialized sorting centers controlled by registered companies whose operators may be remunerated for the provision of space. A number of sorting containers are provided according to the E-waste scope and logistical

arrangements with recyclers and transporters. This is usually free for household E-waste, but sometimes charges apply for commercial E-waste products.

- Financial collection incentive to officially approved collectors and collection sites that collect, sort and prepare E-waste for transport according to official requirements.
- Appropriate measures should be adopted to minimize the disposal of E-waste as unsorted municipal waste and to achieve a high level of separate collection of E-waste.
- Availability and accessibility of the necessary collection facilities should be ensured taking into account the population density of the community.

2. Requirements for retail Collection Points

Retailers can provide convenient and accessible collections for some residents. In order for a retailer to be the sole or primary component of a municipal or regional collection plan apart from meeting the legal requirements for collecting the waste must also do:

- The retailer must be within a convenient driving distance (estimated at 20 minutes driving time in one direction) from all residential points within a municipality.
- The retailer must be willing to accept and separate household e-waste from business electronic devices.
- The retailer must not charge the residents of the community for collection of the waste.
- The retailer must sign an agreement certifying that they are aware of, and agree to abide by the requirements for participating in the program.
- The municipality or region must have a contingency plan should the retailer decide to no longer participate in the program.
- A retailer may decide to serve as an auxiliary component of the collection plan without having to meet the requirements of the program other than applicable national waste law provisions.

3. Transfer points and Transportation

In the municipal system, dustbins are utilized for e-waste disposal while waste pickers use hand carts for transportation of E-waste. Further, vehicles from municipal solid waste transportation company pick e-waste

Residues from the bins for disposal at waste dump site. Dismantling in the informal sector, use vehicles to transport E-waste from the point of generation to the junkshop or for the place of dismantling the following recommendations are required for collection points/storage areas and transport of E-waste:

- Transfer points and transport of separately collected E-waste shall be carried out in a way, which optimizes reuse and recycling of those components or whole appliances capable of being reused or recycled.
- Sites for storage (including temporary storage) of E-waste prior to their treatment should have impermeable surface for appropriate areas with the provision of spillage collection facilities and where appropriate, decanters and cleanser-degreasers.
- Sites for storage (including temporary storage) of E-waste prior to their treatment should have weatherproof covering for appropriate areas.
- Document the length of time the waste has been accumulated on-site.

- Label waste to clearly identify the type of waste. Containers of broken or processed CRT glass, batteries, lamps and mercury containing devices should be labeled
- Safe handling and management standards are to be followed by the transporters.
- Transportation of waste that is destined to be disposed may require a solid or hazardous waste transportation license.
- Transporters to comply with all applicable national transportation regulations, including, packaging, labeling, marking and pleading requirements.
- Transport E-waste to a licensed, approved, legitimate recycling facility, or a licensed hazardous waste facility
- Ensure that containers are not damaged during on and off-loading and that waste containers are secure during transport.
- Respond to spills and manage any resulting residues promptly and appropriately

3.1.2. Treatment options

The major E-waste treatment options include sorting and repair or disassembly. E-waste treatment options starts with sorting of reusable and non-reusable separately. The reusable can be repaired or refurbished. Non-reusable E-wastes undergo size reduction, separation and recovery of different material such as metal and plastics which can serve as raw materials in the production process of new products, while the remaining E-waste fractions are disposed of either in landfills or incinerated.

3.1.3. Recycling and recovery

Organized recycling centers that must comply with all environmental performance requirements and with applicable municipal, provincial, and federal regulations and requirements

- Infrastructure build up for recycling: Facilities employing mechanical material processing and separation activities which are equipped with a dust collection system/apparatus (engineered to reduce environmental emission of and worker exposure to; toxic substances and particulate matter), an emergency shut-off system and fire suppression equipment
- Provision of guides to recyclers to ensure that WEEEs are managed in an environmentally sound manner that safeguards worker 's health and safety and the environment from the point of primary processing to the point of final disposition
- Provision of Environmental Management System to identify and control the impact of the recycler's activities, products and services on the natural environment. The system will include an environmental policy to provide guidance to the recyclers on controlling environmental matters as well as procedures outlining how environmentally significant tasks are to be conducted to ensure compliance with applicable environmental legislation.

  All recyclers shall:

- Document the downstream flow and handling of WEE from receipt at the recycler's facility to each point of final disposal, including details on how the goods are recycled at each point, and the percentage of recycled materials sent to each downstream recycler
- Ensure that whole units and separated components of electronics goods are stored and/or processed at minimum in a fully covered area that conforms to all current applicable legislation and where (1) Unauthorized access to the premises and storage areas is

controlled or otherwise prohibited through security measures (2) Any electronic scrap that are stored outside must be covered to prevent exposure to environmental elements (3) Any substances of concern are protected from exposure to weather and leaching into the surrounding natural environment through indoor storage

- All recyclers shall implement and maintain an Occupational Health and Safety (OHS) program
- Possess comprehensive or commercial general liability insurance including coverage for bodily injury, property damage, complete operations and contractual liability
- Provide Personal Protective Equipment (PPE) to reduce injury or exposure to dusts and metals that may contact the skin and/or lungs either through airborne dusts or handling materials, and enforce the use of this equipment.
- Conduct a documented annual risk assessment of hazards and worker exposure to lead and other toxic substances through air, absorption, ingestion, or other means.
- Maintain a process to identify health and safety training needs and provide regular documented refresher training, information from the risk assessment required, safe material handling, spill prevention, engineering controls and equipment safety
- Conduct air sampling and analysis for airborne contaminants such as metal content and dusts and ensure compliance with applicable exposure requirements at a frequency determined through the risk assessment
- Conduct annual facility sampling to detect worker exposure to lead and other toxic substances through medical examinations, air sampling, and sampling of surfaces in communal areas
- Implement policies and procedures for hygiene, eating and drinking to reduce worker exposure to lead and other toxic substances.

3.1.4. Final Disposal

Unwanted parts of E-waste can be disposed of through

- Engineered landfill with leachate treatment
- Engineered incineration with waste air purification
- Other environmentally sound methods

3.1.5. Legal and institutional aspects

E-waste has been identified as an environmental issue in this century. E-waste is an emerging environmental problem in Africa and the rest of the world. At the Second Session of the International Conference on Chemical Management (ICCM-2) held in Geneva, Switzerland in May 2009, e-waste was one of the emerging issues proposed and discussed extensively by the African Group at the Conference. It was a battle that the African Group led by Nigeria, fought to ensure that the issue was included in the International Agenda. Since then, the subject has occupied a major point for discussion in many international fora.

4. Regional trends in e-waste policy and legislation

Basel Convention on the Control of Tran boundary Movement of Hazardous Wastes and their Disposal: On the global level, the most prominent international initiative stemming against e-waste trade is the Basel Convention on the Control of Tran boundary Movement of Hazardous Wastes and their Disposal, which entered into force in 1992.

Solving the E-waste Problem initiative (StEP)

Another global effort in tackling e-waste problem is StEP (Solving the E-waste Problem). StEP is an initiative of various United Nations Organizations with the overall aim to solve the e-waste problem.

Restriction of Hazardous Substances Directive (RoHS Directive)

Also at global level is the Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (2002/95/EC) commonly referred to as the Restriction of Hazardous Substances Directive (RoHS Directive)

5. Policies, Laws and regulations related to e-waste management

This provides an institutional framework for their implementation. Extended Producer Responsibility" or "Product Take Back" now forms the basis of policy framework in developed countries. WEEE directives provide a regulatory basis for collection, recovery and reuse/ recycling targets in EU. The fundamental principle of the WEEE directive is "Extended Producer Responsibility", where producers are responsible for WEEE/ E-waste take back.

In many countries in Africa, there has been an improvement in waste legislation over the past few years. E-waste, however, has not received significant attention. Most African countries do not have a specific policy on e-waste in place. However, there is recognition of international conventions regulating chemicals and hazardous waste. Among them are the Basel Convention on the Control of Tran boundary Movements of Hazardous Wastes and their Disposal and the Bamako Convention. These Conventions aim at introducing preventive measures and guaranteeing appropriate disposal of hazardous waste in Africa. However, there are several grey areas in the convention, which are open to interpretation, making the implementation less effective than expected.

Some of the other Multilateral Environmental Agreements (MEA's) relevant to e-waste management includes, the Stockholm convention on persistent organic pollutants, the United Nations Framework Convention on Climate Change(UNFCCC) and the Montreal Protocol on Substance that Deplete the Ozone Layer.

Although many African countries are signatories to the Basel Convention, this means e-waste should be one of their policy priorities. In spite of this, African countries do not have specific regulations of e-waste. There are provisions instead found in other laws governing the environment, air, water, public health, waste and hazardous substances.

From the foregoing studies of the target regions, it can be said that none of them have specific legislations for management and regulation of e-waste. However, Policies and laws addressing e-waste management are efficient instruments of intervention for ensuring environmentally sound management of e-waste in Africa. It is therefore important that governments focus on developing policy, legislative and regulatory frameworks at the national and regional level.

These policy interventions should:

- Evolve as a result of a legal analysis of the e-waste problem that would culminate in the development of appropriate national, regional and global modalities for addressing e-waste;
- Include both regulatory and operational component covering all aspects of e-waste management;
- Encourage an effective import and export regulatory regime;
- Ensure that the provisions of international conventions – Basel and Bamako – are implemented and followed.
- Include amendment of national environmental laws to include specific provisions for control of e-waste import with diligent compliance monitoring and enforcement in collaboration with other security agencies at the national level and international cooperation with regulatory agencies in other countries and regions including information sharing,
- Incorporate the Extended Producer Responsibility as is done in developed countries;
- Include outright prohibition of electronic appliances, which are broken and cannot be repaired for further purposes
- Designate responsible parties/roles for different stakeholders,
- Incorporate performance target and recycling standards;
- Mandate practice of Environmentally Sound Management (ESM);
- Should be Incentive based to encourage voluntary compliance'[s]

6. Enforcement of policies and laws for e-waste management.

E-waste has been identified as a global problem, but is a new challenge for the African region as such it would require a global approach for its effective management. Lessons learned from developed countries could serve as a platform for effective enforcement of international, regional and national e-waste management policies and laws in the target regions particularly, the extended producer responsibility.

On the national level however, E-waste policies and laws can be enforced by:

- Collaboration among stakeholder institutions not limited to MDAs, agencies, with the Ministry of Environment as the key player and its relevant enforcement agencies. Also State and Local governments and their various relevant agencies should also be involved.
- Agreement with police and customs for enforcement is also very important.
- Setting up of an inter-ministerial committee comprising of key stakeholders to brainstorm on the strategies for solving e-waste problems in the country;
- Setting up of National Toxic Waste Dump Watch Program with relevant enforcement authorities as members (Ministries and Agencies of Environment, Customs, Police, Ports Authorities etc).
- Commencement of registration of importers of EEE in the country with the aim of stemming down the indiscriminate importation of e-waste into the country will also enhance enforcement.
- On the international and regional level, networking with international environmental organizations is crucial; this paves the way for unique access to intelligence through collaboration, agreements and MOUs. These organizations include Network for Environmental Compliance and Enforcement (INECE) Seaport Environmental Security

Network (SESN), EU Network for the Implementation and Enforcement of Environmental Law, the International Criminal Police Organization (INTERPOL). The key enforcement agents are the various countries Ministries of Environment and relevant agencies, Basel Centers, Customs, (An example of a sub-regional network is the East African Environmental Compliance and Enforcement Network (EANECE) which was established in 2010 by the governments of five East African countries Kenya, Tanzania, Uganda, Rwanda, and Burundi, in partnership with INECE -to promote the rule of law, good governance, and sustainable development through efficient and effective implementation and enforcement of environmental legislation and policies.

- African Toxic Waste Dump Watch Program should be established and reactivated at the Regional/Sub-regional levels, to monitor importation and dumping of near-end-of life electrical/electronic equipment and e-wastes.

7. Challenges to effective enforcement

Some of the key issues to look out for which have hindered the effectiveness of e-waste legislation and enforcement in other countries are;

Various legal and implementation issues hamper the legislation's overall effectiveness. These include inadequate capacity on the part of the authorities involved, for instance to pursue inspections more proactively; gaps in national law for enforcement in case of non-compliance; and legal grey areas concerning the classification problems regarding waste, particularly the difficult distinction between functioning second-hand and waste products, among other things; The lack of criteria for distinguishing new, used and waste products is one of the main reasons for illegal exports.

The existence of many export points, i.e. many different ports in the case of trans boundary shipments, and a huge number of goods exported with a relatively low specific value make it impossible to check all containers or even control the reusability of second-hand EEE. Economic forces ultimately limit the effectiveness of these means even if they are combined with joint enforcement and awareness-raising projects. These forces, driven by a huge demand for EEE in non-OECD countries and a significant price difference for the recycling/dismantling of e-waste between OECD and non-OECD countries, constitute the strongest incentive not to comply with export regulations.

Experience from the EU indicates that clear legal provisions, including those for monitoring and enforcement, the need to raise awareness of existing regulations among all relevant stakeholders and the recognition of e-waste's potentially hazardous nature in conjunction with a more sustainable use and reuse of EEE are necessary for effective handling of e-waste.

The fragmented laws and allocation of responsibility under existing legislation may hinder effective enforcement. Sometimes, responsibility for monitoring some activities falls to the states, while the federal government is responsible for others and may cause difficulties in enforcement and monitoring in an environment where capacity is both limited and strained.

Unnecessary administrative costs caused by legislative and monitoring contradictions and overlaps add to the financial burden of enforcement activities.

Finally, in developing countries, the lower compliance burden shouldered by the informal WEEE recycling sector and the latter's ability to externalize significant environmental costs create an incentive for e-waste to bypass the legal framework.

Table 3: Institutions involved in e-waste management and their roles, traditional authorities

Type of service	Regulator	Service Provider			
		National Government	State Government	Local Government	Private
Collection	Ministry of Environment & Enforcement Agencies (National & State),		Waste Management Authorities	Street Sweepers and Cleaners	Informal Collectors, Private Sector Participants (PPP)
Transport			Waste Management Authorities		Informal Collectors, Private Sector Participants (PPP)
Treatment	Ministry of Environment & Enforcement Agencies (National & State),				Private Sector Participants (PPP)
Disposal	Ministry of Environment & Enforcement Agencies (National & State),		Waste Management Authorities		Informal Collectors, Private Sector Participants (PPP)
Recycling	Ministry of Environment & Enforcement Agencies (National & State),				Informal recyclers, Private Sector Participants-Formal Recycling (PPP)

3.1.6. Financing mechanisms and economic aspects

Some financing modes that can be adapted for use in developing countries are as follows

a. User charges:
    a. In many countries, user charges are being introduced. They are still
    b. Low for municipal sectors but for commercial and industrial sector, the charges could be high to meet the costs in accordance with the polluter's pay principle. However, these charges also motivate waste generators to reduce the waste. Volume-based charges for municipal waste are quite common in some countries.
b. Penalty, fine and levy:
    a. This form of direct income is also becoming an important financing tool for governments to finance SWM. The terminology and rate of the penalty/fine/levy may vary from country to country.
c. Direct Loans:
    a. Local governments may take direct loans either from domestic or International financing institutions.
d. International Cooperation:
    a. There is an increasing trend of a direct multilateral and bilateral cooperation with local governments. International agencies are providing support to local governments to improve the local environment. Various bilateral initiatives, including sister cities, are also helping local governments to seek assistance for financing their development projects including SWM.
e. National subsidies: This is still a major source for many local governments to finance environmental infrastructure and services.
f. Annual budget: Local governments allocate substantial portion of their development budget to finance SWM. This is usually cross-subsidized from the profit-making avenues of local governments.
g. Private Sector Participation (PSP): There is an increasing trend of private sector participation in solid waste management. Experiences from developed countries indicate that, for effective management of e-waste, external financing is required to fund collection and recycling. However, some issues to be considered for organizing a secured financing ranged from who should be financially responsible, whether it should be visible to consumer or not. A recycling fee on the product was considered the most viable alternative because it internalizes environmental costs in the price of the product in keeping with the Polluter pays principle and is much more equitable than municipal waste taxes. The consumers can be charged at two points – at the time of purchase, or at the Time of disposal.

3.1.7. Stakeholder participation

The description of stakeholders and what their roles should be in e-waste management in developing countries is given below;

a) Manufacturers/ Importers

Manufacturers and importers should bear any responsibility of their products for their post consumption treatment.

b) Retailers

The retailers should play key role in the collection of e-waste, not only limited to a few products with high resale values. This should be in form of exchange offers and the buyback of goods sold at an attractive value to encourage consumers to return their old EEE.

c) Consumers

Given the low level of environmental awareness and that most African countries are highly price sensitive markets; consumers are unwilling to pay a market premium for environmentally friendly products. Consumers, be it institutional, commercial or individual users should be encouraged to pay for the recycling of old appliances and play an important role in keeping the appliance out of the waste stream, by preferring to repair or hand-down the appliance than dispose it. Or be compensated for its material value, through auctions or pick up by door-to-door collectors.

d) Recyclers

The collectors and recyclers form the backbone of the e-waste management in Africa. They bear both the physical as well as financial responsibility of the end-of-life product. The collectors and recyclers, and a host of intermediaries, must work together on the basis of informal business contracts.

e) Government

The Ministry of Environment is the national authority that is responsible for drafting legislation regarding waste management and environmental protection. National hazardous waste management laws should be revised to include regulation of e-waste. The local governments, who are responsible for the collection and disposal of the municipal solid waste, should also play a role in the collection or disposal of e-waste.

f) NGOs

The environmental NGOs in Africa should continue to play the important informational role, in creating awareness regarding e-waste.

g) Raw material producers

Environmentally sound method of materials recovery should be practiced, as a lot of the material recovery, such as gold and copper, is done in the informal, workshop-based environment, using highly toxic substances such as cyanide solutions for gold recovery, and open burning for recovery of cooper.

h) Disposers

The landfills, which are run by the municipal corporations, should be designed for hazardous waste and therefore equipped with preventive linings to stop the leaching of toxins into the soil and ground water accumulated in illegal dumps. And incineration should be discouraged.[14]

3.1.8. Education and Training

As environmental awareness and compliance is a new concept in many parts of Africa it is necessary to develop the skills, training and education amongst the people to be able to enforce and comply with legislation.

E-waste management involves several stakeholders and education and training for some of these stakeholders is the key to the success of its management, these trainings are to acquire the required skills to enable certain stakeholders effectively and efficiently perform their roles, some of which are highlighted above.

- Consumers/ households need to be informed of their role in e-waste management and encouraged to adopt responsible consumerism. For example, while buying electronic products, they could opt for those made with recycled content and few toxic components, or those that are energy efficient, with minimal packaging and that offer take-back options. Furthermore, donating electronics for reuse could extend the life of valuable products and keep them out of the waste management system for longer. Households should also be encouraged to practice waste segregation and not dispose of e-waste with municipal solid waste. Consumers/ Households should be made aware of and encouraged to practice the 3-Rs (reuse, reduce, recycle) of EEE.

- Governments will also need to ensure that there is adequate capacity and skills, including institutional capacity building. Build capacity and formalize the informal recycling sectors so that there is a protective protocol for workers dealing with e-waste disposal. Intense capacity building in environmentally sound management of e-waste is essential, in the areas of collecting, sorting and disposal of e wastes, for this sector because of its economic benefits to countries.

- Also, there should be intense promotion of public awareness on hazardous substances in EEE and e-waste and the need for national, regional and global control actions for all stakeholders especially policy makers, lawmakers, regulatory authorities and the Customs, women and youths and the media.

- Increase Capacity building for regulatory authorities particularly, Customs agencies in developing countries and countries with economies in transitions to be able to revise import entry codes to accommodate electronic and electrical articles that potentially contain e-waste so that they are flagged at the point of import.

- NGO/Civil society must be encouraged to be very active in increasing public, scientific and business knowledge on e-waste and continue to play a very important role of awareness creation.

- The opportunity provided by a IMPEL TFS (-Implementation and Enforcement of Environmental Law - Transfrontier Shipment Network (European Task force whose activities are focused on inspections of waste shipments through non OECD countries) in capacity building through exchange of knowledge and best practices facilitating inter-agency, cross-border collaboration and operational enforcement activities on Trans frontier waste shipments should be exploited by African countries.

- School curricula in African countries also need to be adjusted to include e-waste to reflect the realities on ground.

3.1.9. Effects on the environment and human health

Improper disposal of e-wastes is a particular problem faced in many regions across the globe. This leads to a number of negative environmental, economic and social consequences, some of which are:

a) Environmental consequences

- Air pollution, especially when e-waste is burnt
- Waste management problem of non-biodegradable equipment
- Toxicity and radioactive nature of e-waste to the human, water, soil and animals
- Blockage of water runoff channels
- Increased amount of waste
- Waste management disposal problem

b) Economic consequences

- Substantial public spending on health care
- Investments in complex and expensive environment remediation technologies
- Loss / waste of resources that can be recycled for re-use
- Opportunities for recycling industries and employment lost
- External costs trough damaged environment

c) Social consequences

- E-waste affects people's health (e.g. lead poisoning and cancerous mercury).
- Growth of informal waste disposal centers in the neighborhood
- Informal trade and management of e-waste
- Loss of appreciation for ICT

The main environmental concerns related to the management of electronic waste are the uncontrolled release of hazardous substances into the environment and the sub-optimal use of recyclable materials. Incorrect disposal can be extremely hazardous for the environment and health. Documented health hazards include various kinds of ailments from coming in contact with toxins such as cadmium, mercury, lead and dioxins and furans among others, emitted when land filled or incinerated.

There is little known of the impacts of e-waste on humans in Africa (since no studies or tests (as far as we know have been carried out on the African people, but only on the water, ground etc. and the environment in general)· But the impacts have been demonstrated through many studies made in western countries which raise the assumption that the impacts on human beings in Africa would be similar or perhaps greater owing to poorer health care systems and lower public health standards. With the knowledge of the potential damages from the hazardous substances in e-waste, it is scary to find that a lot of studies have shown that in developing countries, e-waste is usually processed by 'backyard' industries or small workshops using the most primitive methods (Osibanjo & Nnorom, 2007: 496).

An example of the negative effect of e-waste management is seen in the study carried out by Greenpeace "„Chemical contamination at e-waste recycling and disposal sites in Accra and Koforidua, Ghana" and „Poisoning the poor – Electronic waste in Ghana". Results of the Greenpeace studies confirmed the presence of "numerous toxic and persistent organic chemical pollutants, as well as very high levels of many toxic metals, the majority of which are either known to be used in electronic devices, or are likely to be formed during the open burning of materials used in such devices". The concentrations of copper, lead, zinc and tin were found to be in the magnitude of over one hundred times typical background levels. It is known that children, due to their hand-to-mouth behavior, are one of the most vulnerable groups in areas where soils and dusts are contaminated with lead. For instance, deaths of 18 children between November 2007 and March 2008 due to mass lead intoxication from informal used lead-acid battery recycling in Senegal, was attributed to inhalation and ingestion of soil and dust contaminated with lead. In this case, homes and soils in surrounding areas of lead-acid recycling activities were found to be heavily contaminated.

In China high levels of PBDEs have been reported in the blood of local residents around e-waste recycling activities. PBDEs have been known to cause abnormal brain development in animals and have endocrine disruptive properties.

Commonly, in unpolluted or lightly polluted areas, including urban and industrial soils in other countries, the values are below 1 pg/g TEQ and rarely above 10 pg/g TEQ (Zhu et al. 2008).

According to a recent survey done by EMPA, the total annual dioxin emissions from cable incineration in Greater Accra region were estimated to be about 5 g (EMPA 2010).

Compared to the European dioxin air emission inventory for 2005 (EU15 + Norway +Switzerland) this equals to 0.25%–0.5% of total dioxin emissions, 2.5%–5% of dioxin Emissions from municipal waste incineration and 15%–25% of dioxin emissions from Industrial waste incineration.

d) Effects to occupational health

In developing countries, inappropriate and crude techniques are usually adopted in material recovery from e-waste

This dangerous management practices include:

- Bashing open CRTs with hammers exposing the toxic phosphorous dust inside;
- Open burning of circuit boards to melt the lead solder hence breathing in of toxic fumes;
- Burning wire to melt the plastics to recover cooper;
- Open acid baths (nitric acid) for separating metals;
- Dumping pure acid and dissolved heavy metals into the soils, drains and rivers.

E-waste dismantling and disposal operations in Africa are extremely polluting and likely to be very damaging to human health.

A number of the workers involved in the collection of the scraps complain of aches, general weakness/ fatigue and irritation of the digestive system. A number of them sustain cuts and spinal injuries as a result of the rigorous working conditions. Particularly carrying the scraps on their back rather than pushing the barrows. A number of the workers involved in the dismantling and the repair/ refurbishing aspects complain of incessant cough that keeps coming and going, general weakness and irritation of eyes and skin.

Capacity building in ESM of electronic waste and the use of personal protective equipment will drastically reduce occupational health hazards. Provision of infrastructure needed for collection, recycling and recovery of e-waste. And provision of engineered sanitary landfills for safe disposal of e-waste. This will ensure protection of human health and the environment.

The EU legal framework on e-waste management, the laws were quite segmented in such a way as to cover e-waste collection, responsibility, economic instruments through the issuance of licenses (by a clearing house) for generation of e-wastes, specific environmental agency for the e-waste management, distribution, take-back system and recovery mechanisms for recycling these electronic wastes into fresh valuable items. Regulations amongst target countries must include the above segments to be able to achieve its desired end. As such the following recommendations may be considered in the target regions.

- A take-back mechanism by distributors from target countries free of charge from consumers and also ensure that producers take financial responsibility of the take-back mechanism to encourage consumer participation as was the case in the UK.
- Those voluntary agreements that are effective in Europe cannot be successful here without command-control measures in the form of legislation. Also, the Nigerian market possesses what maybe termed an imperfect inclination so that any agreement thereto must be complemented with effective laws.
- That the proper management of e-waste must involve the private sector actively and not just the government alone.
- Local legislation addressing import rules for used electrical and electronic goods must be developed in the target regions and existing related laws must be strengthened.
- National governments must provide an enabling environment that would support the restriction of e-waste imports. This could be in the form of lower import tariffs for new EEE.
- Roles and responsibilities of all regulatory authorities must be clearly defined. However, it is also important that they all work together to get the desired results.
- Adequate infrastructure must be put in place to facilitate all system processes involved.
- The private sector must come in and the industry must wake up to its corporate social responsibility to augment government inputs.
- The informal sector must be given its deserved recognition and interfacing with regulatory authorities must be improved and sustained.
- Technological and local capacity for collecting, transporting, processing and recycling the wastes must be built. Emphasis must be placed on harnessing human capital, away from acquiring technologies that are expensive and complicated.

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4. TECHNICAL AND NON TECHNICAL REQUIREMENTS ON HEALTH CARE WASTE

A possible outline!

4.1. Non Hazardous Health Care Waste

4.1.1. Collection, transfer, treatment

4.1.2. Recycling

4.1.3. Final disposal

4.1.4. Legislative framework

Financing mechanisms, role of stakeholder, measures in public awareness, etc.

4.2. Hazardous Health Care Waste

4.2.1. Collection, transfer, treatment

4.2.2. Recycling

4.2.3. Final disposal

4.2.4. Legislative framework

Financing mechanisms, role of stakeholder, measures in public awareness, etc.

5. TECHNICAL AND NON TECHNICAL REQUIREMENTS ON INDUSTRIAL WASTE

Since the industrial waste type is determined, it is of advantage to consider the waste itself. What are the technical and non technical requirements to offer appropriate collection, treatment, possible re-use, alternatives, achieve health and safety for workers during its treatment and protect environment. Which legislative framework would be from benefit in its according country?

5.1. Common industrial waste in Ghana

Mining industry

Petroleum industry

5.2. Common industrial waste in Nigeria

Example Oil/Petroleum Industry

5.3. Common industrial waste in Côte d' Ivoire

Example Sugar processing (UAA)

Paint and Chemistry Industry

5.4. Common industrial waste in Senegal

Example Sugar processing (MATAM)

Phosphate industry (ENDA)

Pesticides containers from pesticides industries (ENDA)

SUMMARY AND OUTLOOK

A well established Solid Waste Management system doing well in one country may not work in a different country where other conditions apply. Climate, infrastructure, geological condition, socio-economic situation, existing legal framework and mentality will influence and effect the establishment of such system. In the present report the involved consortium members have been working on the requirements needed from a technical and a non-technical point of view towards an integrated solid waste management system. The Waste such as residual waste, organic waste, plastics, metal and e-waste and its collection, treatment, recycling and final disposal have been taken into account.

Major findings were that in the collection and storage of waste, receptacles were seen as a hygienic option but suitable for well planned areas, asphalted roads and with access to regular waste collection. Other areas will need so-called transfer collection points in which residents or producers have to store waste till it is collected from a bigger vehicle. Bringing the waste to these collection points is ideally carried out by not motorized vehicles which can cross smaller roads. Bigger trucks can collect more waste at a time.

This leads to the next conclusion that the requirements are pending on the waste characteristics. The amount of generated waste in the target countries is still smaller in comparison with industrialized countries, therefore the application of big waste trucks would be too cost intensive. Regarding the content of the generated waste the organic fraction is the highest. It can be assumed that the amount is decreasing in more urbanized centers due to changing lifestyle and income. For organic waste composting remains as a useful and low technology option practiced from households, communities or small business operators. Obligatory for composting is segregation of waste.

Source segregation on the other hand is required to grab other valuable resources such as plastics and metal originated from households and industries. In terms of recycling plastics and metals small scale recycling exist but material were frequently exported due to economies of scale in industrialized and in transition countries. In this case it is from benefit for the target country that recyclables can be treated to that extend that it remains as a source in the country for further use or until other treatment methods are unprofitable or harming the health and the environment. For the recycling of plastics and metal, transfer of knowledge, low- technology options, and possible partnerships in further treatment is needed.

These requirements can be also applied for the recycling of e-waste. A growing problem since information technology is reaching every part of the world. Used and broken e-waste contains valuable parts which were recycled under very bad conditions in the target countries. Employment, on the other side, with huge external costs through damaged health and polluted environment leads to the same requirements as for plastics and metals. In addition, producers' responsibility has to be taken into account. The making of reusable parts and banning the use of hazardous substances would have a great impact.

Regarding the final disposal land filling is more suitable than other practices, since the composition of waste is less suitable for incineration, recovery of waste in nearer future may be possible and costs were lower. Nevertheless, requirements on land filling have to be leachate control and treatment, proper segregation of waste such as recyclables for recovery and organic waste to decrease biogas emissions.

After all, legal framework and policies need to be adapted towards a functioning Integrated Solid Waste Management system with its enforcement in daily business accompanied with environmental awareness for understanding ISWMS and its implementation.

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