Grant Agreement number: 244188 (IWWA)
Project acronym: IWWA
Project title: Integrated Waste Management in Western Africa
Funding Scheme: CSA-CA

Task 6.3: Development of tools and activities for mass dissemination

Deliverable 6.20: Publication 2nd publishable scientific article on Solid Waste Management Practices in Western Africa

Due date of deliverable (6.10): 28.02.2012
Actual submission date: 08.05.2012

Start date of project: 01.06.2010 Duration: 24 months

Organisation name in charge of deliverable 6.10: EMPA and ENDA
Organisation name of lead contractor for Task 6.3: BIOAZUL
Project coordinator: ttz Bremerhaven, Germany
Project website address: http://www.iwwa.eu

Project funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1. INTRODUCTION

African countries are characterized by the world's highest urban growth rates (Achankeng, 2003). Lagos (Nigeria), the biggest city of Africa has a population of 9 Mio; Abidjan (Ivory Coast) reaches 3.7 Mio, Dakar (Senegal) 2.5 Mio and Accra (Ghana) 2 Mio.

In Western Africa, the rapid rate of uncontrolled and unplanned urbanization coupled with a high density of urban settlements and changing consumption patterns have accelerated the need for water supply, sanitation and waste management infrastructure. The lack of waste collection and disposal facilities results in deteriorated living conditions, affects the health of urban dwellers and increases environmental degradation.

Approximately 9 000 tons of solid waste is collected daily in Lagos/Nigeria, in Accra/Ghana the amount reaches 1 400 tons per day. The situation in medium-size cities and in semi-urban areas is not much different: regular waste collection only reaches higher income neighbourhoods and the proper disposal in adequate landfills is virtually inexistent. Discarded waste composed of paper, plastics, clothes and organics has become part of the urban living environment. Refuse bins that are not always emptied become miniature waste dumping sites. People living in the vicinity of these dumping sites are exposed to bad smells and smoke caused by the intended or unintended burning of the waste heaps. Waste lying in the streets is blocking the rain- and wastewater drainage system which leads to the flooding of the surrounding living areas and negatively impacts the water supply system and the water quality. Waste pickers living adjacent to the dump sites sort waste and try to make a living with revenues from recyclable goods. In the past, remedial efforts towards a functioning waste management system could not cope with these challenges, mostly due to the lack of finances and insufficient or inefficient public administrative capacities.

The situation has become dramatic in most towns and it is widely recognized by international organisations and policy makers that a functioning waste management system which copes with the specific urban challenges is a prerequisite for improving the living conditions of the urban population while decreasing the environmental degradation.

The public administration and the private sector are challenged in developing adequate waste management policies and in implementing environmentally, socially and economically sound waste management systems. The deficient waste collection scheme needs to be upgraded and adjusted to the waste quality and quantities. Waste separation, reuse and recycling should be improved, reducing the environmental impact caused by improper handling, recycling and disposal practices including open–air incineration. The informal sector, representing a significant part of today's waste collection, re-use and recycling system has to be fully integrated both economically and socially, while designing future waste management schemes.

The European Commission FP-7 financed programme on Integrated Waste Management in Western Africa (IWWA) has compiled and analysed relevant information on waste management practices and approaches from African and European countries with the aim to provide tools and build local capacities for future solid waste management planning and decision making. The present article summarizes the status of Solid Waste Management Practices in four countries of Western Africa: Ghana, Ivory Coast, Nigeria and Senegal.

2. METHODOLOGY

In order to get an overview on the current solid waste management practices a comprehensive survey was conducted by the IWWA Afro-European research team together with the partner institutions in the four project countries. Prior to the survey, characterization criteria for the solid waste management system were defined in order to retrieve comparable data. The criteria covered the areas of waste characteristics, collection and transportation practices and infrastructure, reuse and recycling practices and infrastructure, secondary markets, downstream processors and final disposal practices and infrastructure.

The survey was composed of four different questionnaires, which were completed by the partner institutions in the respective countries.

The municipal solid waste management and the plastic waste management practices were assessed through selected case studies. For each country, two towns that were considered to be representative for the country's respective waste management system were selected and documented; one for an urban area (>100 000 inhabitants, equals a large city) and one for a semi urban area (10 000-100 000 inhabitants, equals a medium-size city).

The management of electrical and electronic waste (e-waste) was assessed on country level. For each country, data was retrieved from e-waste country assessments which have been conducted within the framework of other projects (see (SBC 2011; Amoyaw-Osei et al. 2011; Messou and Rochat 2011; Wone and Rochat 2008)). Information on health care management was also collected at country level.

The questionnaires were completed based on existing information, previous studies and interviews with local experts. It turned out that some questions were difficult to answer without the existence of a functioning waste management system. If questions as regards to quantities could not be answered, the quantity was roughly estimated and/or the situation was described qualitatively.

All information contained in the questionnaires was compiled and analysed in order to give a comprehensive overview on the current solid waste management practices in the four countries with a special emphasis on similarities and differences of the considered systems.

3. WASTE CHARACTERISTICS

3.1. Municipal Solid Waste

3.1.1. Waste generation

The origin of municipal solid waste is mainly households, hotels and restaurants, market places and offices. In large cities such as Abidjan, Dakar, Accra or Lagos, waste also originates in significant quantities from slaughter houses, small businesses, smaller industrial estates, health care and schools.

The average volume and composition of municipal solid waste is displayed in Table 1. According to the statistics, the quantity of waste generated varies between 0.45 and 1.7 kg per day and inhabitant in the 7 areas studied. In Senegal, the average waste generation for municipal waste is 0.60 kg/(day·inhabitant) for cities with more than 100 000 inhabitants, and 0.33 kg/(day·inhabitant) for cities with less than 100 000 inhabitants (GRET, 2006).

Table 1: Generation of Municipal Solid Waste (MSW) in Ghana, Ivory Coast, Nigeria and Senegal

	Ghana		Ivory Coast	Nigeria		Senegal	
	Accra	Komenda-Edina-Eguafo-Abrem (KEEA)	Abidjan	Lagos	Ido	Dakar	Matam
Area covered km^2:	270	372	2 119	3 577	1011	550	3.75
Population	4 000 000	200 000	4 100 000	8 000 000	117 129	3 000 000	17 500
MSW generated per day (tons/day)	2 200	165	3 000	9 000	195	1 400	7.8
MSW generated per inhabitant (kg/(day·inhabitant))	0.55	0.83	0.7	1.13	1.66	0.54	0.45

Sources: (IWWA 2011; Burgeap 2011; LAWMA 2011; IAGU 2007; IAGU, 2005)

In large cities, a great variation in waste generation rates can be observed: from 0.45 kg/(day·inhabitant) in the poor areas to 1.23 kg/(day·inhabitant) in the richest neighborhoods in Abidjan, for instance (Sané, 1999).

Surprisingly, the waste generation rate per day per inhabitant in large Western African cities is well above the average rates of some industrialized European countries where the average level of income and consumption is much higher. For instance, Paris, with a population of 2 233 818 produces 3 192 tons per day, or 0.69 kg/(day·inhabitant) (City of Paris, 2011). This is due to the fact that in most industrialized countries, municipal waste covers waste generated directly by households and by small businesses. Large businesses usually have their own service providers whereas the public service provides (directly or by sub-contracting) the collection of domestic waste. However, in most Western African countries, a lot of waste is collected by the informal sector, including waste from large businesses. So, there is in fact some “industrial” waste included in the Municipal Solid Waste statistics of most Western African cities which makes comparison difficult.

The challenge for the public waste collection is huge in the urbanised and densely populated areas such as Abidjan and Lagos that have to deal with up to 9 000 tons of municipal waste per day (Table 1).

3.1.2. Waste composition

The waste composition is similar in all studied countries (see Table 2): 40-70% organic, 15-20% plastic, 4-13 % paper and cardboard, 2-5 % metals and 7-25% accounts for the rest (glass, textiles, other inert materials, ashes etc.). There are no differences in the waste composition between urban and semi-urban areas except for the region of Matam (Senegal), where due to its Sahelian location, a large amount of sand reaches the municipal waste stream. In all cases, municipal solid waste contains both toxic and valuable substances. Toxic materials for instance are car batteries, dry batteries from electronic devices, electronic components, pharmaceutical products, oils, chemicals and agrochemicals. Valuable substances include metal scrap, glass bottles, plastics, organics, and tyres.

Table 2: Municipal solid waste composition in Ghana, Ivory Coast, Nigeria and Senegal

Waste composition (%)	Ghana		Ivory Coast	Nigeria		Senegal	
	Accra	KEEA	Abidjan	Lagos	Ido	Dakar	Matam
Organic	67	40	49	45	n.a.	44	n.a.
Plastic	20	20	8	15		18	
Paper, cardboard	4	10	6	10		13	
Metals	2	5	2	5		4	
Glass	2	n.a.	2	n.a.		n.a.	
Textiles, inert materials, ashes etc.	5	n.a.	24	n.a.		n.a.	
Rest	n.a.	25	8	25		21	
Total	100	100	100	100	100	100	100

Sources: (IWWA 2011; MACOM 2010; EDE 2003)

3.2. Plastic waste

Plastic waste originates from households as well as offices, shops, little markets, schools etc. In Accra and Lagos, households account for around 25-35 % of the total plastic waste generated. More detailed information on the origin of plastic waste is provided for the city of Lagos, Nigeria (see Table 3). In the city of Dakar, plastic waste is mingled with household waste which makes it impossible to determine its origin. In Dakar plastic waste also originates from around 40 plastic processing companies.

For semi-urban regions, no specific data on plastic waste is available since plastic waste is neither collected separately nor further processed.

Table 3: Origin of plastic waste in Ghana and Nigeria

Origin of plastic waste (%)	Ghana	Nigeria
	Accra	Lagos
Households	35	25
Commerce	65	35
Shops		30
Offices		5
Schools		5

Source: (IWWA 2011)

Information on the quantity of plastic waste is available for Dakar, Accra and Lagos (see Table 4). The quantities, however, do not correspond to the total quantity of municipal solid waste generated and its respective plastic content (Table 2). It is therefore assumed that the quantities indicated in Table 4 are related to the plastic waste that is processed in a separate stream.

Table 4: Quantity and origin of plastic waste in Ghana, Nigeria and Senegal

Quantity of plastic waste (tons/year)	Ghana	Nigeria	Senegal
	Accra	Lagos	Dakar
Total	54 750	1 620	9 500*
Packaging	n.a.	810	n.a.
Agricultural films		486	
Bottles		324	

* Includes plastic waste generated and recycled by plastic transforming industries
Source: (IWWA 2011)

Plastic waste in municipal solid waste is not homogenous. It is composed of Polypropylene (PP), Polyethylene (PE), Polyethylene terephthalate (PET), Polyvinyl chloride (PVC), Polystyrene (PS), Low Density Polyethylene (LDPE) etc. In Lagos, LDPE accounts for around 60% of the plastic waste. According to available data from Senegal, more than 14% of the household plastic waste is composed of plastic bags and around 4% account for bottles and old plastic shoes.

The main plastic types reused are bottles made of PE, PET and PP. The main plastic types recycled into new products are PE, PET and PP. Some forms of PS and PVC are also processed in Ghana and Senegal. In Nigeria, there is also nylon and tyre recycling.

3.3. E-waste

The origins of waste electrical and electronic equipment (WEEE) or e-waste in short, are private households, corporate businesses, public institutions and repair businesses. In addition, in West Africa e-waste is also directly imported under the disguise of second hand electric and electronic equipment (EEE). In Ghana, households account for over 50%, repair businesses for around 30%, imports for around 10% and corporate and public consumers only for 6% (Amoyaw-Osei et al. 2011) of the total e-waste generation. The large share of e-waste generation in households is mainly due to the significant weight of large household appliances (e.g. refrigerators) and consumer electronics (e.g. televisions), which are less used by corporate and public consumer. In other documentations, the origin could not be determined but a similar split is expected.

The quantity of e-waste generated in the four project countries according to the assessment reports is summarized in Table 5 (Amoyaw-Osei et al. 2011; Wone and Rochat 2008; SBC 2011). E-waste in Ghana and Nigeria reaches around 7 kg per inhabitant and year. Ghana and Nigeria have, due to high amounts of second hand imports, a high availability of second hand equipment that can be purchased at comparatively low prices which makes such products available for a larger share of the population. Electronic equipment as second hand products, which have a shorter lifespan compared to new products, results in a high e-waste generation per year. In Ivory Coast, the e-waste generation is significantly lower with less than 1 kg per inhabitant and year. A comparison of e-waste from personal computers shows, that also in Senegal, compared to Ghana and Nigeria, e-waste quantities are still rather low.

Table 5: E-waste generation in Ghana, Ivory Coast, Nigeria and Senegal

E-waste quantities	Ghana	Ivory Coast	Nigeria	Senegal
All e-waste (tons/year)	179 000	15 000	1 100 000	n.a.
All e-waste (kg/(year·inhabitant))	7.52	0.72	7.11	n.a.
E-waste from personal computers (tons/year)	6 400	n.a.	70 000	900
E-waste from personal computers (kg/(year·inhabitant))	0.27	n.a.	0.45	0.08

Sources: (Amoyaw-Osei et al. 2011; Wone and Rochat 2008; SBC 2011).

The share of e-waste collected in relation to the total e-waste generated is difficult to estimate. Due to the informal door-to-door collection, it is assumed that in Ghana and Nigeria, up to 95% of the e-waste generated is also collected. For the Dakar region, it is estimated, that of all the e-waste collected, about 20% is reused as spare parts, around 78% is dismantled manually and 2% is disposed of without any treatment. In Ivory Coast a large share of obsolete equipment is stored and only a small amount is reaching the recycling sector.

E-waste that goes for recycling is dismantled manually into various components, including valuable fractions that can be sold such as ferrous metals, aluminium, and copper, brass, bronze, printed wiring boards, processers and rubber. Unsellable fractions which often contain hazardous substances are plastics (partly with brominated flame retardants), glass, leaded glass from CRT screens, batteries possibly containing mercury and cadmium, capacitors possibly containing polychlorinated biphenyles (PCBs).

3.4. Health Care Waste

Health-care waste includes all the waste generated by public and private health-care establishments, research facilities, and laboratories. It includes solid waste (sharps, non-sharps, body parts, medical devices etc.) and liquid waste (blood, chemicals and pharmaceuticals). Healthcare waste can be non-hazardous or hazardous, when it includes infectious waste (having the potential of transmitting infectious agents to humans or animals), pathological waste, sharps, and radioactive waste. Biomedical waste includes liquid / gaseous waste arising from health-care (Basel Convention, 2003).

The indicator generally used to express the quantity of healthcare waste is in kg/(day·bed).
Table 6 summarizes the health care waste generation in the four studied countries.

Table 6: Health Care Waste generation in Ghana, Ivory Coast, Nigeria and Senegal

Item	Ghana	Ivory Coast	Nigeria	Senegal
Number of healthcare facilities (private, public, pharmacies…)	1 439	2 610	64 (Lagos and Ibadan only)	2 236
Number of beds	22 127	n.a.	n.a.	2 576 (Dakar only)
Tons of healthcare waste /year	12 114	3 794	27 (Lagos and Ibadan only)	269 (Dakar only)
Kg/(bed·day)	1.5	n.a.	0.5 (kg/(patient·day))	n.a.

Sources: (IWWA 2011; Hueber 1992; IAGU 2005)

The average rate compares rather well with the amount reported in other countries such as 0.60 kg/bed/day in Limpopo, South Africa (Nemathaga et al., 2008) and 0.84 kg/(day·bed) in El-Beheira, Egypt (Abd El-Salam, 2010).

A survey conducted in Ghana estimated very hazardous waste (acids, solvents, chemicals, expired medicines, explosives, inflammable materials, photographic developer and fixer solutions, toxic substances, radioactive materials etc.) to represent about 3% of the total health care waste i.e. 0.05 kg/(day·bed) (Hueber, 1992).

WHO estimates that most of the waste produced by health care facilities is non-risk or "general" health care waste (75 - 90%), coming from the administrative and housekeeping functions of health care establishments (WHO, 1999). The remaining 25-10% is hazardous health care waste and is estimated at 0.5 kg/(day·bed) in high income countries and at 0.2 kg/(day·bed) in low income countries. But as hazardous and non-hazardous wastes are not always separated appropriately in Western Africa, the real proportion of hazardous waste could be much higher.

A cultural specificity is the low proportion of anatomical waste, for instance in Dakar, as placenta, foetus, body parts are often given to the patients' families.

4. PREVENTION, COLLECTION, RECYCLING AND DISPOSAL PRACTICES

4.1. Municipal Solid Waste

4.1.1. Organisation of MSWM

In Western African countries, as in many other low-income countries, waste management is generally organized as summarized in Table 7.

Public and formal private actors are mostly involved in - insufficient - collection and final disposal (landfills), whereas informal actors are involved in pre-collection and recycling.

Pre-collection is generally performed by the informal sector in low income neighborhoods that are not covered by the formal collection systems. So, informal actors or NGOs organize pre-collection and transportation until "transfer stations", where the waste is collected by trucks belonging to either public or private actors and brought to the municipal dumping site. Sometimes informal collectors also deposit the waste in illegal dumping sites, especially when there is no reloading site nearby or when waste is not collected regularly.

Conflicts between formal and informal actors have been observed, when zoning of waste collection started, especially in the metropolitan areas of Accra, Kumasi, Tema, Takoradi and Tamale. There is ongoing dispute about allowing the informal sector to continue operating, to be integrated or organized into the formal sector or to be stopped all together.

Formal and informal recycling practices are summarized in Table 8.

Table 7: Organisation of waste management in Western Africa

Step	Actors	Infrastructure and equipment available
Pre-collection (in low income areas)	Informal sector, CBOs, NGOs, cooperatives, SMEs	Very low. Wheelbarrows, handcarts, tricycles (in Ghana). Communal collection points or transfer stations.
Collection (in high income areas)	Municipality, formal private sector	Plastic bags, bins, barrels, skip containers.
Transportation	Municipality, formal private sector	Compactor trucks, skip trucks, tipper trucks and roll-on roll-off trucks, or in more rural areas tractors and carts. An important share of the vehicles is second hand vehicles (international donations) and is not in working order. Zoomlion Ghana Limited, the largest Ghanaian company has 50,000 collection trucks and tricycles.
Separation	Households, informal sector	By households (if they sell to the informal waste buyers), by informal workers in the street and on dumping sites.
Recycling	Informal and formal sector	Informal sector: manual metal smelting equipment Formal sector: plastic shredders, etc.
Final disposal	Municipality, formal private sector	70% - 90% of the municipal solid waste is disposed of in official dumpsites. The rest is irregularly or illegally dumped. On the official dumpsites, the waste is compacted with trucks. There are usually no installations for gas collection and treatment or leakage water drainage. The leakage water runs uncontrolled to the next river. Only in Lagos the leakage water reaches a leachate pond. Information on total and remaining capacities of official dumpsites could not be acquired. Open air incineration is very common for households and at irregular and official dumpsites, to reduce the volumes.

Source: (IWWA 2011)

Picture 1: Informal dumpsite, Nigeria
Source: Empa 2009

Picture 2: Formal waste collection, Ghana
Source: Zoomlion 2011

Table 8: Examples of formal and informal recycling/re-use practices in Western Africa

Type of material	Formal recycling practices	Informal recycling/re-use practices
Paper / cardboard	In Accra, production of toilet paper (1 company). In Lagos, production of recycling paper.	Cardboard collected at the dumpsite and sold to plants, drugstores (to protect glass bottles), poor households (as wind-breakers or housing), fruit and vegetable processers/sellers (secondary packaging), sheep breeders or sellers (APROSEN and IAGU 2009).
Metal scrap	In Accra, a state owned agency is actively involved in the recycling of scrap metal by buying it from informal collectors and recyclers. At least 6 steel melting companies process scrap steel. In Dakar, at least 5 companies recycle metal and non-metal scrap (Diawara, 2010).	Dealers located on the informal scrap yards tend to export most of the metal scrap to China. Many informal aluminium smelting activities (Ghana and Senegal). Many informal copper smelting operations, mainly for jewellery making. Most of the copper scrap and increasingly other metal scrap is exported because of the high prices.
Organic waste	In Accra, production of biogas. Zoomlion Ghana Limited is establishing compost plant in the Greater Accra region.	Composting activities and the use of organic waste as animal food or fertilizer are found in Accra, Dakar and Lagos. In rural areas, it is done directly by households.
Glass	No information	In Senegal, sold to plants producing solvents, glue or varnish, drugstores, food or cosmetic sellers, and sometimes to other Western African countries (APROSEN and IAGU 2009).
Textiles	No information	In Senegal, sold as rags to plants and car garages, mattresses producers, tailors and dyers (APROSEN and IAGU 2009).

Source: (IWWA 2011)

4.1.2. Final disposal infrastructure

The Accra Metropolitan Assembly is struggling to secure land for the construction of a sanitary landfill. Residents are against the idea of constructing landfills close by because of the fear of the unbearable stench that is likely to emanate from the landfill and also the possibility of flies invading their homes.

In Ivory Coast, after having provided an emergency support during the political crisis (4 SMEs have signed service agreements with Abidjan) the World Bank in its partnership strategy for 2010-2013 has committed to a funding to build 2 sanitary landfills in Abidjan and to support the government in conceiving a national strategy for solid waste management. The objective is to secure 9 000 permanent jobs (waste collectors) by 2013 and to collect and deposit in the landfills 80 % of the waste generated in Abidjan.

In Dakar, a sanitary landfill is built in the Region of Thiès next to Dakar, where Dakar's waste will be disposed in the future. The landfill will be operated by a private company. In addition, a transfer and separation station is being built in Mbao. There is currently a conflict regarding the geographical location of the landfill between the Ministry of the Environment, the National Agency for Cleanliness (APROSEN), the network of the main cities of the Region of Dakar (Entente CADAK-CAR) and inhabitants of neighboring areas in the rural communities of Sindia and Diass.

In the City of Matam, the NGO Lux-Development is implementing a project including 3 transfer stations and a sanitary landfill for the municipal waste. Prior to the project, the city administration together with the inhabitants has carried out an environmental impact analysis.

Picture 3: Mbeubeuss dumpsite, Senegal
Source: IAGU 2006

Picture 4: Metal scrap sorting at dumpsite, Ivory Coast
Source: Empa 2009

4.1.3. Collection and recycling rates

The collection rate in mayor town areas reaches the indicated levels in Table 9.

Table 9: Formal collection rates of Municipal Solid Waste in Western Africa

	Ghana		Ivory Coast	Nigeria		Senegal	
	Accra	KEEA	Abidjan	Lagos	Ido	Dakar	Matam
Waste collected / waste generated	75%	n.a.	70%	> 75%	n.a.	70%	n.a.

Sources: (IWWA, 2011; MLGRD/NESSAP 2010; Burgeap 2011)

Concerning recycling rates, there is no public monitoring of such figures as recycling is left to the formal and informal private sector. There is hardly any support from both local authorities and governmental agencies for companies and business people who intend to establish businesses that make use of waste materials. However, paper, cardboard, organic waste, plastics, e-waste and metal scrap are sorted by the informal sector on dumpsites or scrap yards and either recycled locally by formal or informal actors, or exported. Some fractions such as metal scrap have a very high recycling rate while less valuable fractions end up in the dumpsites to a large extent.

4.1.4. Jobs

The number of formal workers responsible for the collection and transportation of municipal solid waste varies from 0.003 (Abidjan) to 0.8 per 1 000 inhabitants (Table 10). The number of informal workers is high in all 4 countries.

Table 10: Jobs in municipal solid waste collection, transportation and disposal

	Ghana		Ivory Coast	Nigeria		Senegal	
	Accra	KEEA	Abidjan	Lagos	Ido	Dakar	Matam
Number of formal companies	17 in Ghana		7	10	n.a.	n.a.	n.a.
Number of formal workers	3 200	141	1 765	3 000	120	1 701	9
Number of formal workers per 1 000 inhabitants	0.80	0.71	0.0003	0.38	n.a.	0.57	0.51
Number of informal workers engaged in separation, re-selling of recyclable materials and recycling	On Abgog-bloshie scrap yard: 3 000 members of the scrap dealers association.	n.a.		Over 25 000 in the Kano metropolis			

Sources: (IWWA 2011; Sané 2002; Saleh 2008)

The informal sector is particularly developed in Nigeria and is structured in the following way (Adebola, 2006):

- **cart pushers**: house-house waste collection at a small fee,
- **scavengers**: involved in both on-site and off-site waste/ resource recovery, they recover re-usable and recyclables materials like plastics, aluminium, glass, paper, scraps metal, animal wastes like horn, bones etc.,
- **resource merchants**: traders involved in the purchase of all recovered recyclable and re-usable materials from the scavengers,
- **recyclers**: includes both the micro and the small scale recycling companies, they convert recovered waste materials like paper, aluminium, animal by-products, plastics scrap metals etc, to valuable materials and raw materials for the consumption of the industrial sector.

4.1.5. Costs and financing mechanism

It is generally assumed that the cost of MSWM in Africa is very low, an average of 2 €/(year·inhabitant), as compared to the high income countries where it can go well beyond 100 €/(year·inhabitant). The City of Accra is practicing full cost recovery and thus charging close to commercial rates, while waste management in the most Western African cities is subsidized. Moreover, households pay directly the service providers especially the informal ones for pre-collection services.

Table 11: Costs and financing mechanism of Municipal Solid Waste Management

	Ghana		Ivory Coast	Nigeria		Senegal	
	Accra	**KEEA**	**Abidjan**	**Lagos**	**Ido**	**Dakar**	**Matam**
Costs/ financing mechanisms for collection and transport-tation	4.5-7.5 €/ month (door to door)	1.5 € /ton, (token)	Fee included in the electricity bill	Households: fee. Businesses : 14 € / lift of waste bin or 322 € / lift of compactor truck	n.a.	12 € /ton (paid to private companies)	n.a.
Costs/ financing mechanisms for disposal	Communal dump grounds: 7 €/ton Public dumpsite: 3.7 €/ton	no charge		n.a.	n.a.	n.a.	n.a.
Proportion of SWM costs in the munici-palities' budget	40-50%		20-55%	SWM is a responsibility of State agencies.		n.a.	around 10% (Secondary cities)

Sources: (Boakye 20054; Burgeap 2011; GRET 2006)

4.2. Plastic waste

According to the survey results, separate collection of plastic waste only exists in Lagos, through separate collection bins, skips, or bags. The collection is organised by the Lagos Waste Management Authorities. In addition, plastic waste is also collected informally. The official collection rate reaches around 35% of the total plastic waste generated. More than 1 500 formal and informal workers are engaged in the plastic collection and transportation. For transportation, open trucks and compactor trucks are used. In all other cases, plastic waste is informally and formally collected within the municipal solid waste collection system. Therefore, the collection frequency as well as the collection technology is the same as for household waste.

There are informal waste collectors that sort plastic waste out of municipal waste and sell it to generate income. In Accra, about 8% of the total plastic waste generated is estimated to be recovered by private collection companies. There are groups that deal with plastic waste by operating collection points and by selling the collected plastic to bulk purchasers who collect it with trucks for further processing in the country or for export. Others operate at the landfill site where they sort out any useful material and sell it to prospective buyers. All these activities happen informally, though on an increasing scale.

Plastic reuse, mainly of plastic bottles, is a common practice. In Dakar there are many informally organized practices of plastic reuse. On the Mbeubeuss dumpsite nearby Dakar, groups of women wash and clean plastic bottles for re-use. They sell the bottles to women merchants. Other activities include the sewing of plastic sheets to produce roofs for rural houses, the recuperation of material to make cushions, or to refurbish handbags to sell them again. The Tolbiac Street in Dakar is the main area where plastics are recovered, collected, sorted and recycled by the informal waste pickers and recyclers. It is ideally situated to collect plastics from industrial waste, close to the port, the industrial free zone, and

various markets. In Ghana, few companies reuse PE, PET and PP bottles and bags are produced from discarded plastic materials. Information on plastic reuse is scarce. In Nigeria, reused plastic wastes are mainly bags, bottles, barrels and films so it is again focused on PE and PET products. There are around 2 500 formal and informal workers engaged in the reuse and recycling of plastics.

In Dakar, mainly PE and PP is collected. The plastic is directly brought to the recycling plant. The treatment processes are quite simple and include manual sorting (PE and PP from the others), washing and drying of the plastics. Mechanical recycling processes such as shredding or extruding exist in few cases. In Accra, a sorting plant is under construction. Only few companies are involved in plastic recycling. The recycling process includes sorting, shredding, washing, drying and extruding. The resulting pellets are usually sold to other plastic companies or exported. Products manufactured from recycled plastics are e.g. buckets or chairs. On a more informal scale, there are plastic recyclers who scavenge for plastic materials at homes or in dumpsites. Some of them melt the waste plastic to produce beads which are then sold on the local market. In Lagos, in addition to PE and PET, also nylon and tyres are recycled. The recycling technologies applied include sorting, shredding, washing, drying and extruding in order to produce pellets, flakes and nylon. The final products/applications obtained from recycled plastics are e.g. waste bags, shoes, chopping boards and hair extensions.

Final disposal practices are the same as for municipal solid waste. Plastic waste is disposed of in authorized landfills or on irregular and illegal dumpsites. It is also quite common that plastic waste, especially plastic bags or sheets, is openly burned in backyards, markets, at stadiums, railway stations, dumpsites etc. In Dakar, within the next 3 years, 3 industrial methanization plants should be operational. This implies previous separation of non-organic waste. As there is no incineration plant projected, this is a future opportunity to organize separate plastic collection and recycling.

Picture 5: Plastic waste sorting at dumpsite, Senegal
Source: IAGU 2006

Picture 6: Plastic waste sorting, Ghana
Source: http://www.trashybags.org 2012.

4.3. E-waste

In general, there exists no formal separate collection of e-waste. Collection is mostly in the hand of informal collectors who pick up or buy obsolete EEE from door to door and scavenge at official or irregular dumpsites. In Ghana and Nigeria, the informal collection is well organized due to high amount of e-waste generation and the ability of the collectors to pay for the consumer's e-waste since they in turn receive money from the informal recyclers for every piece collected. These practices lead to collection rates of up to 95% in urban regions in Ghana and Nigeria (SBC 2011). In Senegal and Ivory Coast, due to smaller amounts of e-waste generated, the informal collection is not very widespread and the collection rate is probably lower that in Ghana and Nigeria (Messou and Rochat 2011; Wone and

Rochat 2008). Informal collection is usually done with handcarts, e.g. made from boards and old car axles. Some collectors also use trucks. There is no regular collection period of the informal collection.

Formal collection of e-waste is done by formal recycling companies. They have arrangements with certain e-waste generators that enable them to pick up their e-waste for free.

Refurbishment and repair of obsolete EEE is very common. Nigeria features the largest refurbishment and repair sector with extensive markets where second hand products are repaired, refurbished and sold in the same or close by locations. These markets are informal but very well organized. In Côte d'Ivoire, Ghana and Nigeria, there are associations of repairers and technicians of EEE. The approximate number of repairer and refurbisher is summarized in Table 12. In Ivory Coast, repairers are the largest provider of e-waste to scrap dealers. They usually have a close relationship and are sometimes located next to each other, exchanging materials according to their needs. In all target countries, the refurbishing and repair sector is highly specialized and has high repair success rates of up to 70 %. It contributes significantly to the extension of the lifespan of EEE and thus to the reduction of e-waste generation.

Picture 7: E-waste refurbishing, Nigeria
Source: Empa 2009

Picture 8: E-waste recycling, Ghana
Source: Green Advocacy Ghana 2010

Table 12: Jobs in e-waste management repair, refurbishment, collection and recycling

	Ghana	Ivory Coast	Nigeria	Senegal
Number of workers engaged in repair and refurbishment (Formal and informal)	Accra: 10 000 Ghana: 14 000	4 000	Lagos: 21 600	n.a.
Number of informal workers engaged in collection and recycling	Accra: 4 500 – 6 000 Ghana: 6 300 – 9 600	n.a.	n.a.	Mbeubeuss scrap yard: 800

Source: (SBC 2011; Prakash et al. 2010; Messou and Rochat 2011; Wone and Rochat 2008)

The e-waste recycling sector is mostly informal. In Ghana, the hub of the recycling operations is the Greater Accra Region at the scrap yards of Agbogbloshie, Gallaway and Ashiaman, although smaller scrap yards where e-waste is also dismantled are spread all over the country. In Senegal, informal recyclers also do collection and repair, either in informal warehouses disseminated all over Dakar, or on the dumping site of Mbeubeuss. In Ivory Coast, the main scrap yards where the dismantling of e-waste takes place, are located in the municipalities of Kumasi and Marcory (Anoumabo). In Nigeria, in contrast to the large and well organised refurbishing and repair-sector, e-waste recycling activities are at rather small scale and spread over the large cities. In all countries, the informal recyclers work in numerous

small workshops within the scrap yards where a few recyclers work together or one recycler employs several workers. In few cases, recyclers deal directly with end-processing partners, such as refineries, by selling them the recovered metals. In many cases, middle-men are handling collection of recovered fractions from the recyclers, and bring them to end processing partners. In larger scrap yards, the workers are often organised in associations or unions. The local recycling activities are similar in all countries (see Table 13). First, if possible, spare parts are sorted out and sold to the repair or refurbishment sector. E-waste is manually dismantled, sometimes by crude methods such as smashing or treating with a chisel, sometimes with screwdrivers etc., and then sorted into metals and other fractions.

Table 13: Pre-processing and end-processing of different e-waste fractions

Local informal pre-processing	Resulting components and fractions	Local formal and informal end-processing	Foreign end-processing	Environmental impacts of informal practices
Burning of copper cables	Copper	Formal smelters, informal smelters	Formal smelters	High dioxin emissions from cable burning
Manual dismantling and sorting	Copper			
	Ferrous metals	Formal smelters	Formal smelters	
	Aluminium	Formal smelters, informal smelters (e.g. production of cooking items)		Toxic emissions during smelting processes
	Lead	Local informal smelters (e.g. production of sinkers for the fishing industry)	Formal smelters	Toxic emissions during smelting processes
	Printed wiring boards (PWB containing precious metals)	Disposal	Hydrometallurgical treatment in Asia	Contamination of water and soil
	Plastic	Disposal and burning		Plastic may contain brominated flame retardants. High dioxin emissions from burning
	CRT tubes (containing lead, beryllium, phosphor, etc.)	Crushing and disposal		During the crushing, the dust containing hazardous substances is set free
	Hazardous fractions (PCB in capacitors, mercury in backlights, batteries)	Disposal and burning		Contamination of air, water and soil

Source: (Amoyaw-Osei et al. 2011; Messou and Rochat 2011; Wone and Rochat 2008; SBC 2011)

Copper cables are often burnt to remove the plastic insulation. Insulating foam from obsolete refrigerators, primarily polyurethane and/or old car tyres are the main fuels used to sustain the fires. The CRT monitor screens and other ‘non profitable’ fractions such as plastic casings, keyboards, capacitors,

dry batteries, etc. are not recovered and usually dumped and eventually burnt in order to reduce the volumes at the dumpsites. The uncontrolled dumping and burning of hazardous fractions lead to significant negative impacts on health and environment (Brigden et al. 2008; Amoyaw-Osei et al. 2011) Table 13 summarizes the local and foreign recycling activities of various e-waste components and fractions as well as the resulting environmental impacts.

The amount of fractions produced is difficult to estimate. According to the general composition of e-waste, it can be assumed that about 40% of the weight can be recovered and around 60% is dumped or burned (Prakash et al. 2010).

In each country some formal recycling activities exist. The formal recyclers usually get e-waste from corporate consumers. Valuable fractions that cannot be further processed in the country itself are exported to Europe. However, only a very small share of all e-waste is recycled formally (in Ghana, it is estimated at a level below 1 ‰).

E-Waste can be found in disposed municipal solid waste in all countries but it is normally sorted out at dumpsites and brought to informal scrap yards for dismantling. Non-valuable or toxic fractions resulting from e-waste recycling such as plastic cases and leaded glass from CRT screens, batteries, capacitors etc. are disposed of together with municipal waste on illegal or official dumpsites, in garbage bins, on the outskirt of municipalities or in reservoirs, rivers, lagoons or lakes. Since there is no controlled sanitary landfill for municipal solid waste in any of the countries, there is no infrastructure for the environmentally sound final disposal of non-valuable or hazardous fractions available.

Picture 9: Burning of copper cables, Ghana
Source: Green Advocacy Ghana 2010

Picture 10: Informal dumping of e-waste, Ghana
Source: Green Advocacy Ghana 2010

4.4. Health Care Waste

Often, no proper separation of the different types of health care waste takes place and the waste gets mixed with household waste. Very few institutions separate their waste, predominantly large hospitals in major cities. They separate i) sharp waste, ii) infectious, but not sharp waste and iii) anatomical waste, sometimes using a color code system. In the healthcare institutions, waste is most often not transported adequately (containers without wheels, etc).

Infectious waste is sometimes treated with bleach, sterilized in autoclaves or incinerated. But most health care facilities do not have access to such treatment facilities, and if they exist, they are often dysfunctional (open-air incinerators) or out of operation. The most modern incinerators in Senegal are to be found in the Principal hospital, in the Dantec hospital and in the Pasteur Institute. Ash is put together

with household waste and brought to the dumping sites. Anatomic waste such as placentas is often delivered to the belonging families for burial.

Besides the few treatment options, most of the health care waste transportation is sub-contracted to the same companies that transport MSW. Consequently, it ends up at official or informal dumpsites together with the MSW without any prior treatment except in Lagos where the waste is shredded and the original volume is reduced by 80%. The shredded waste is heated at temperature of 135^0C and 4 bar pressure. The final products are then disposed of with other general waste (LAWMA, 2008).

Some structures such as the University Hospital of Yopougon (Ivory Coast) have their own dumpsite for the reception of wastes of all types.

A factory in Port Harcourt, River State (Nigeria) called BOSKEL Thermal Factory incinerates expired pharmaceutical products and antiretroviral drugs in a high temperature rotary kiln incineration (Iyortim et al., 2011).

Picture 11: Infectious waste bin in a healthcare facility in Lagos, Nigeria
Source: Oketola et al., 2011

Picture 12: A locally built incinerator at a healthcare facility, Ibadan, Nigeria
Source: Oketola et al., 2011

5. CONCLUSIONS

Municipal solid waste is composed of recyclable materials such as organic matter, plastic, paper, cardboard, metal, glass, textiles etc. but also toxic materials such as car batteries, dry batteries from electronic devices, electronic components, pharmaceutical products and agrochemicals. In Côte d'Ivoire, Ghana, Nigeria and Senegal, sorting at household level is conducted by informal waste buyers, that collect valuable fractions directly from households, small businesses etc. The rest is disposed of as mixed waste. The formal collection theoretically is well organized and includes both door-to-door collection and communal collection from central collection points. It is normally carried out by private waste service providers contracted by local authorities. In practice however, the formal collection reveals some difficulties due to service providers that do not attend to their duties, inefficiency of operations, bad road and weather conditions, old vehicles etc. Sorting and recycling of municipal solid waste fractions in significant quantities only exists in urban areas. Most of the sorting activities take place in the informal sector that is concentrated on the solid waste dumpsites or on specialized scrap yards. Formal recycling comprises metal scrap recycling, plastic recycling, paper and cardboard recycling as well as recycling of organic waste. The formal recyclers often receive their material from the informal sector. Although sorting and recycling activities are only driven by economic interests, they still contribute to generating secondary resources and therefore conserve primary (natural) resources. However, not much attention is paid to negative environmental impacts during sorting and recycling processes and information on recycling technologies, environmental impacts etc. is rather scarce. Municipal solid waste is finally disposed of mainly in official dumpsites but also in irregular or illegal dumps. None of the official dumpsites feature leakage water or gas control, leakage water often reaches the closest river or lake. In none of the target countries a sanitary landfill exists where municipal solid waste could be disposed of appropriately, although in some countries, such landfills are planned. Instead of dumping municipal solid waste, it is a very common practice for households to burn paper and plastic components of their waste. Also at irregular and official dumpsites, waste is often burnt in order to reduce the volumes. Burning of waste, especially plastics can lead to significant air pollution with dioxins and furans.

Plastic waste, which accounts for around 15-20% of municipal waste in the 4 countries, is rarely sorted at source but disposed of together with the remaining waste fractions. Separate collection is carried out by informal collectors that sort, reuse and recycle plastics themselves or work together with a formal plastic recycler. Both formal and informal plastic recycling exists that include sorting, shredding, washing, drying and extruding in order to produce pellets or flakes. There is little documentation on recycling processes and its resulting environmental impacts. There are plans to intensify sorting and recycling of plastics in some cities.

Waste electric and electronic equipment (WEEE) or e-waste originates mainly from households, corporate businesses, public institutions and repair businesses. There is no formal collection of e-waste, but due to its valuable content (iron, aluminum, copper etc.) it is often bought or collected by informal e-waste collectors who go from door to door but also sift through waste bins, visit landfills and other waste dumping grounds to search for e-waste. The quantity of e-waste is difficult to determine due to different product scope of existing studies. Ghana and Nigeria, which have received large quantities of second hand equipment in the past years, have showed a significantly higher e-waste generation than Côte d'Ivoire and Senegal.

Obsolete EEE is often refurbished or repaired before it is disposed of. These activities in general do not lead to negative environmental impacts but contribute to the extension of the lifetime of equipment and therefore to a reduction of WEEE generated.

Recycling of e-waste mainly takes place at informal scrap yards where devices are manually dismantled and valuable substances are extracted, sorted and then sold to local smelters or exporters. Copper cables are often burnt to remove the plastic casings. 'Non profitable' fractions such as plastic casings are not recovered and usually dumped and eventually burnt in order to reduce the volumes of the dumpsites.

Besides valuable substances, e-waste also contains many toxic substances (lead, cadmium, mercury, plastics with brominated flame retardants) that are released during the dismantling and burning process and lead to serious environmental impacts.

Final disposal of e-waste fractions often takes place on irregular or illegal dumpsites next to the scrap yards. There are no appropriate disposal options for hazardous substances resulting from e-waste recycling in none of the target countries.

Health care waste constitutes a problem in all four target countries. Most often, no proper segregation of health care waste takes place and it is often mixed with household waste. Very few facilities segregate their waste, mostly large hospitals in major cities. But most health care facilities do not have access to treatment facilities and if they exist, they are often dysfunctional or out of operation. Besides the few treatment options, most of the health care waste ends up at official or informal dumpsites together with the municipal waste.

In conclusion, solid waste management practices in Western Africa are characterized by a high participation of informal actors, remarkably frequent re-use, sorting and recycling practices (which is particularly remarkable given the absence of support from public bodies to these actors) but also persistent inappropriate practices such as open-air dumping and burning of all types of waste including hazardous waste. A sustainable solution to these challenges could consist in measures for the social and economic inclusion of the informal sector (for collection, re-use, separation and recycling) and for the industrialization of disposal practices, especially sanitary landfills and treatment plants for hazardous waste.

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