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COMMUNITY BASED SOLUTIONS FOR URBAN MINING AND THE CIRCULAR ECONOMY IN AFRICAN CITIES : CASE OF YAOUNDÉ

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Engineering (MEng) in ***Environmental Engineering***

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DEDICATION

I dedicate this work to my parents

TOUKO Jean Baptiste and

ENGWAPI WAKO Claire Ange

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I was able to complete this endeavour because I was lucky to be surrounded with many wonderful people.

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ABSTRACT

All around the world, especially in developing countries, scavengers move from place to place searching for recoverable waste materials in the midst of immense piles of waste discharged in open dumps. Waste, once diverted from the dump is sold at a very low price (less than US$1) to intermediaries who in turn resell them to recycling companies and earn 10 times more than the scavengers. In a framework like that, where work conditions are also very poor, this kind of economic activity, is not improving the state of extreme poverty of the scavengers. The main objective of this work was to propose a formal solution to give dignity to the recycling activity of the poor, by designing an appropriate eco-center in Yaoundé in order to improve economic and health conditions of the workers involved. More specifically, the project will evaluate the state of open dumps in Yaoundé, assess the participation of scavengers in waste recovery, and design an effective eco-center in Yaoundé. After selecting and studying eight open dumps inside the city, a survey involving 39 informal recyclers was conducted. The survey focused on quantities, price of waste collected and on the recovered products sold daily, on the recovery processes, on final residues after recovery and the impact of the activity on the health of the informal actors and environment. People who recover waste work mainly in the Mokolo market: the main waste fractions recovered are plastic bottles, glass bottles, metals (mostly aluminium) and waste from electrical and electronic equipments (WEEE). The informal sector gets an average monthly revenue of 50 000 FCFA from plastic and glass bottles, 150 000 FCFA from WEEE and 300 000 FCFA from the recycling of aluminium. Approximately an eco-center receiving 30 000 kg of waste daily could be constructed with an initial investment of 30 675 384 FCFA with a payback period of 6 years. The eco-center has been designed considering an adequate workspace for scavengers that can sell directly to waste recyclers. The facility also provides more adequate workspace to the reusers/recyclers.

Keywords: Circular economy, Urban mining, Community-based solutions, Eco-centre, Informal sector.

RESUME

Partout dans le monde, en particulier dans les pays en développement, des récupérateurs de déchets se déplacent d'un endroit à l'autre à la recherche de matériaux récupérables au milieu d’immense piles de déchets déversés dans des décharges à ciel ouvert. Ces déchets, une fois détournés de la décharge, sont vendus à un prix très bas (moins d'un dollar) à des intermédiaires qui les revendent à leurs tours à des entreprises de recyclage et gagnent dix fois plus que les récupérateurs. Dans un tel cadre, où les conditions de travail sont également très mauvaises, ce type d'activité économique n'améliore pas l'état d'extrême pauvreté des récupérateurs. L'objectif principal de ce travail était de proposer une solution formelle pour donner de la dignité à l'activité de recyclage des pauvres, en concevant un écocentre approprié à Yaoundé afin d'améliorer les conditions économiques et sanitaires des travailleurs impliqués. Plus précisément, le projet évaluera l'état des décharges ouvertes à Yaoundé, évaluera la participation des récupérateurs dans la récupération des déchets, et concevra un écocentre efficace à Yaoundé. Après avoir sélectionné et étudié 08 dépôts sauvages dans la ville, une enquête a été menée auprès de 39 recycleurs informels. L'enquête a porté sur les quantités, le prix des déchets collectés et sur les produits récupérés vendus quotidiennement, sur les processus de récupération, sur les résidus finaux après récupération et sur l'impact de l'activité sur la santé des acteurs informels et sur l'environnement. Les personnes qui récupèrent les déchets travaillent principalement au marché Mokolo : les principales fractions de déchets récupérées sont les bouteilles en plastique, les bouteilles en verre, les métaux (principalement l'aluminium) et les déchets d'équipements électriques et électroniques (DEEE). Le secteur informel tire en moyenne un revenu mensuel de 50 000 FCFA des bouteilles en plastique et en verre, de 150 000 FCFA des DEEE et de 300 000 FCFA du recyclage de l'aluminium. L'écocentre a été conçu en tenant compte d'un espace de travail adéquat pour les récupérateurs qui peuvent vendre directement aux recycleurs de déchets. En recevant 30 000 kg de déchets par jour cet écocentre peut être construit et exploité avec un investissement initial de 30 675 384 FCFA et a une période de retour sur investissement de 6 ans. De plus, l'installation offre également un espace de travail plus adéquat aux recycleurs.

Mots-clés : Économie circulaire, Mines urbaines, Solutions communautaires, Ecocentre, Secteur informel.

SUMMARY

LIST OF ACRONYMS

CBO	Community Based Organisation
CBSWM	Community Based Solid Waste Management
CE	Circular Economy
GHG	Green House Gases
GPS	Global Positioning System
HYSACAM	Hygiene and Sanitation Cameroon
Inh	Inhabitant
Inh/km²	Inhabitants per square kilometres
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NBO	Neighbourhood Based Organisation
NBWM	Neighbourhood Based Waste Management
SDG	Sustainable Development Goal
SWM	Solid Waste Management
WEEE	Waste of Electrical and Electronic Equipment

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GENERAL INTRODUCTION

Background

An increasing world population and the urgent need to promote global sanitation, good health and improve living conditions of the population especially that of the most vulnerable (poor people) call for determining efficient actions and strategies to ensure sustainable and profitable municipal solid waste management (MSWM). With the world's global population increasing from 3.1billions in 1960 to 7.8billions in 2020 and expected to rise to about 9.8billions in 2050 (Kaza, 2018), waste management becomes one of the main challenge for the present and the future generations. In addition to this increase in population, increase in urbanisation and industrialisation will also increase the rate of waste production. According to Belgiorno & Cesaro, (2017), 2.02 billion tonnes of waste were produced worldwide in 2016 and this amount is expected to grow to 3.40 billion tonnes by 2050 under a business-as-usual scenario. Still under the same scenario, it is important to note that waste is growing the fastest in Sub-Saharan Africa, South Asia, and the Middle East, where, by 2050, total waste generated is expected to approximately double.

With this high rate of waste production, conventional waste management methods and finance affected to waste management at the national and local levels become insufficient leading to global anarchy especially in developing or low-income countries. This has led to the creation of open dumps in most cities in developing countries. Globally, most waste is currently dumped or disposed of in some form of a landfill with only eight percent of these having a landfill gas collection system. 33% of the waste produced worldwide is discharged in open dumps (Kaza, 2018). Waste management affects the well-being of vulnerable populations and the relationships between governments and citizens. Solid waste management influences how a society lives on a daily basis.

According to Medina (2010), about 1% of the urban population in the world (more than 15 million people), earn their living informally in the waste sector. This is well observed in Asia where in urban centers in China alone, about 3.3 million to 5.6 million people are involved in informal recycling (Linzner and Salhofer 2014). Waste pickers are typically women, children, the elderly, the unemployed, or migrants. They generally work in unhealthy conditions, lack social security or health insurance, are subject to fluctuations in the price of recyclable materials, lack educational and training opportunities, and face strong social stigma. According to Keohanam (2017), the number of female waste pickers can often exceed the number of male waste pickers and examples are observed in Vientiane, Lao People Democratic Republic, and Cusco, Peru, where 50 percent and 80 percent of waste pickers are female, respectively.

It is important to recall that this informal sector has a high environmental and socio-economic impact and provides basic needs to millions of vulnerable people around the world. For example, waste pickers in Mumbai, India; Jakarta, Indonesia; and Buenos Aires, Argentina, are estimated to have an economic impact of more than US$880 million annually (Medina 2007). In Jakarta, waste pickers are estimated to divert 25 percent of the city's waste to productive use (Medina 2008). With this high impact, it is a necessity to provide good working conditions and environment to people involved in waste picking. Some of the more successful interventions to improve waste pickers' livelihoods are formalization and integration of waste pickers, strengthening of the recycling value chain, and consideration of alternative employment opportunities. Therefore, promoting circular economy and in this case urban mining through a community-based approach will be an important component towards a holistic approach to sustainable management of MSW in developing countries. When properly supported and organized, informal recycling can create employment, improve local industrial competitiveness, reduce poverty, and reduce municipal spending on solid waste management and social services (Medina 2007). The objective of urban mining is to safeguard the environment and promote resource conservation through reuse, recycling, and recovery of secondary resources from waste (Arora et al., 2017). Initially carried out by the informal sector to earn a living, urban mining has gained interest from the formal sector due to its economic benefits. Apart from this economic benefit, urban mining is an efficient tool for waste management as it promotes waste segregation, reduces waste volumes and closes the linear loop of materials thereby fostering the circular economy.

The potential of urban mining as compared to conventional mining lies not only in its cost but also in the amount of minerals recovered; one tonne of gold ore yields about 5 grams of gold, but one ton of phone circuitry yields about 150 grams, 30 times as much[1].

Problem statement

In Cameroon, as in many developing countries, waste management is facing numerous problems such as lack of sustainable management strategies and adequate investments on waste.

[1] https://thediplomat.com/2013/11/the-potential-of-urban-mining/

Despite the existence of policies concerning waste management such as the decree n°2012/2809/pm of September 26th 2012 laying down the conditions for sorting, collecting, transporting, recovering, recycling, treating and final disposal of waste, the effectiveness of sustainable municipal solid waste management (MSWM) remains a challenge. This has led to improper collection of waste, resulting in the proliferation of open dumps in cities. According to Lavagnolo & Grossule, (2019), Yaoundé produces about 840 tonnes of waste daily. Less than 50% is collected; the rest is abandoned on the road or in water channels and often burned in the open air. Less than 5% of this waste is recycled by the informal sector. This can be explained by the low collection frequency for the curbsides, absence of drop off centralised points in areas where the curbside is not possible and unconventional bins in areas where the drop off points exists. All these, coupled with the ever-growing population leads to the creation of open dumps. Lack of coordination between the different stakeholders limits an effective action of urban miners who consider the mountains of waste as a possible way for an income. Despite the economic potential of urban mining, no sustainable MSWM strategies and policies have been implemented until now in Cameroon based on an effective community-based solution of waste recovery, focused on the promotion of a healthy and profitable solution, avoiding the proliferation of open dumps and upgrading the working condition of the pickers.

Research question

To study the situation presented above and propose adequate solutions, our research will try to answer to the questions:

- How can we ameliorate the centralised drop-off points to protect the environment?
- How can we organise and improve - from the point of view of health and economic conditions - the working activities of the informal sector?

Objectives

Main objective

Design a proper eco-center in Yaoundé to improve economic and health conditions of the informal sector involved in waste recovery and protect the environment.

Specific objectives

- Evaluate the state of waste management in Yaoundé (quantity and quality of waste, recyclable fractions, collection schemes, and open dumps).
- Assess the contribution of scavengers in waste recovery in Yaoundé.
- Design the eco-center.

Thesis structure

This work is composed of four (04) chapters preceded by a general introduction and followed by a conclusion:

chapter 1 - generalities and literature review;

chapter 2 - materials and methods employed to carry out the research;

chapter 3 - results obtained from research;

chapter 4 – design of the eco-centre and its sustainability analysis.

CHAPTER ONE : GENERALITIES AND LITTERATURE REVIEW

Introduction

The objective of this chapter is to present different terminologies related to our topic (e.g.: waste, sustainable waste management, waste disposal, etc.) and the literature review run through some keywords like urban mining, circular economy, community based solutions, and others.

1.1. Waste terminologies

1.1.1. Waste

The Cameroonian Law No. 96/12 of August 5, 1996, in the Framework Law on Environmental Management, defines waste as "any residue from a production, processing or utilization process, any substance or material produced, more generally, any movable and immovable goods abandoned or intended to be abandoned".

Waste can be considered, as those materials no longer required by an individual, institution or industry (UNESCAP 2000). "There is nothing as absolute waste" (Achankeng, 2004), hence, waste can also be viewed as something which is no longer of use to one individual or for a specific purpose, which therefore gives an opening for the idea that it might become useful again, for someone else, or for a different purpose (Uriarte, 2008). As such, what is waste to one individual is not necessarily waste to another.

These definitions suggest that waste depends on time (e.g. new products, war/shortage), location (e.g. rural/small town vs. urban, climatic differences), culture (e.g. food-wise), and social conditions (e.g. poor vs. rich)[2]

Waste can be classified either by their state (solid, liquid, gaseous) or by their origin: processing, household, packaging, or cleaning wastes; demolition and construction waste; emissions treatment waste; energy conversion waste. Or they are classified by some of their characteristics, such as inert waste, combustible waste, bio-degradable waste, hazardous and/or, nuclear waste (Pongrácz & Pohjola, 2004).

[2] Maria Christina Lavagnolo, Course on Solid Waste Management and Technology; Module 1a, Solid Waste Management: an Introduction, ENSTP/ University of Padova 2019.

Solid waste specifically, is distinguished as non-gaseous and non-liquid waste resulting from a wide range of community, industrial, commercial and agricultural activities. Being Non-gaseous and non-liquid implies that solid waste could be semi-solid. Semisolid or solid matter that are created by human or animal activities, and which are disposed because they are hazardous or useless are known as solid waste (Eleanor et al., 1998; Esone, 2016 cited by Eko, 2017). The main categories and types of wastes are illustrated in figure 1.

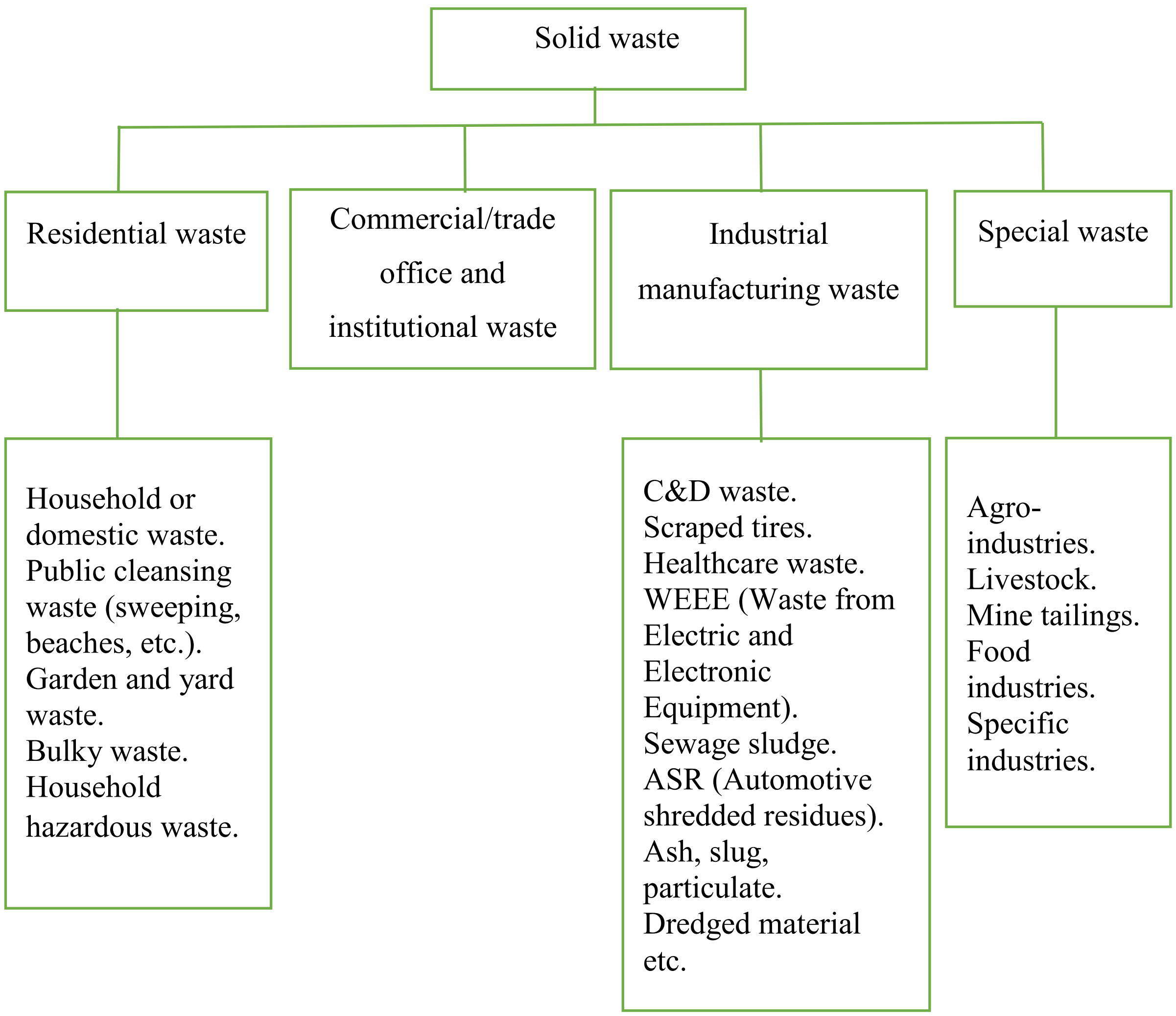

Figure 1: Main categories and types of waste[3]

[3] Maria Christina Lavagnolo, Course on Solid Waste Management and Technology; Module 2b, Solid Waste: Characterisation, ENSTP/ University of Padova 2019.

1.1.2. Municipal solid waste

Municipal solid waste (MSW) is defined to include refuse from households, non-hazardous solid waste from industrial, commercial and institutional establishments (including hospitals), market waste, yard waste and street sweepings. Semisolid wastes such as sludge and night soil are considered the responsibility of liquid waste management systems. While hazardous industrial and medical wastes are, by definition, not components of municipal solid waste, they are normally quite difficult to separate from municipal solid waste, particularly when their sources are small and scattered. (Schübeler et al., 1996)

According to Kaza (2018), the world generates 0.74 kilogram of waste per capita per day, yet national waste generation rates fluctuate widely from 0.11 to 4.54 kilograms per capita per day[4]. Waste generation volumes are generally correlated with income levels and urbanization rates.

The Sub-Saharan Africa region generated 174 million tonnes of waste in 2016, at a rate of 0.46 kilogram per capita per day. Less than half of the waste produced here is collected formally. (Kaza, 2018).

1.1.3. Municipal solid waste management

Municipal solid waste management (MSWM) refers to the collection, transfer, treatment, recycling, resource recovery and disposal of solid waste in urban areas (Schübeler et al., 1996). Solid waste management systems should be designed to respond to the specific needs of the people they serve.

Waste collection refers to the picking up (at the house, at the curb, at central location points, etc.), and transport of waste to the place of treatment, valorisation or discharge by municipal services or similar institutions, or by public or private corporations, specialized enterprises or general government. This activity involves routing of the vehicle to different pick-up locations, any weighing and control of the waste, until the vehicle is full or has completed its task.

Municipal waste collection may be selective, that is to say, carried out for a specific type of

[4]https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html#:~:text=The%20world%20generates%202.01%20billion,from%200.11%20to%204.54%20kilograms.

product, or undifferentiated, in other words, covering all kinds of waste at the same time.

Transfer in the waste jargon refers to the transport of waste from the point where the collection was completed and until unloading of the waste at a treatment or disposal facility. Transfer may also involve putting waste collected using small trucks (in narrow streets, old cities) into larger trucks.

Waste treatment are processes carried out to ensure that waste has the least possible impact on the environment. Treatment can be mechanical, thermal, biological or a combination of these. Generally, the processes give rise to a valuable material. The most popular waste treatment processes are incineration, composting and biogas production. Gasification and pyrolysis are mostly used in industrial processes in developed countries.

Composting is a biological treatment method that uses aerobic microorganisms to decompose organic matter. The product of the process is a humus like material, water, carbon dioxide and energy as illustrated with the equation that follows.

$$C_6H_{12}O_6(fresh\ putrescible\ waste) + 6O_2 + microorganism \rightarrow 6CO_2 + 6H_2O + biomass(stable\ humus) + energy\left(2870\frac{KJ}{mole}\right)$$

Under specific quality control of the substrate and of the process, the final product may be classified as Compost: a stabilized and sanitised product, which is beneficial to plant growth. To produce a stable and safe compost, parameters such as the C/N (Carbon/Nitrogen) ratio of the waste, temperature variations during the process, oxygen, substrate structure and moisture.

Incineration is the complete oxidation of organic substances into carbon dioxide and water in the presence of air (oxygen) at temperatures ranging from 850° (MSW) to 1200°C (hazardous waste). Thermal degradation of waste at temperatures ranging from 400 – 600°C in the absence of oxygen is called Pyrolysis; the products are syngas ($CO, H_2, CH_4, C_2 - C_6$), liquids (hydrocarbons, tar), solids (char, ashes, metals). In the presence of limited amount of oxygen (partial oxidation) between 700 and 900°C the process is called gasification and the products are syngas, solids (ash, metals)

Biogas production is the stepwise anaerobic degradation of organic substances by microorganisms. The product is a biogas that is mainly composed of carbon dioxide and methane.

As for aerobic degradation, substrate composition, oxygen, water content, temperature and pH are important parameters that need to be controlled to ensure a proper output.

Resource recovery also called material recovery is using waste as an input material to make new products. Recycling and composting are examples of material recovery processes. Incineration and biogas production are energy recovery processes as they convert waste to energy.

Disposal refers to the final elimination of waste. The ultimate disposal method is landfilling. Open dumping has been and continues to be the disposal method for many countries in the developing world.

A **sanitary landfill** is a facility constructed and destined to waste disposal. The main characteristics of this facility are the barrier or lining systems, rainfall drainage, leachate and biogas collection schemes and treatment. These systems have as aim to protect the environment and human health from the outputs of landfilling.

An **open dump** is a site where solid waste is discharged and deposited without any environmental protection, most often illegally. The site is not prepared to receive waste and is neither controlled. Open dumps – example in Figure 2 – can cause heavy pollution and health hazards as:

- ground and surface water contamination;
- release of greenhouse gases;
- open fires and explosion;
- slope instability, generally causes “waste slides”;
- soil contamination ;
- odours;
- spread of diseases.

Figure 2: Some open dumps in the world[5]

The problem of SWM systems in Africa is that, most of the time, technologies are imported from other continents and implemented without an appropriate strategy for the local needs. Generally, SWM systems in less developed economies are characterized by (Lavagnolo & Grossule, 2018):

- Disposal facilities represented substantially by open dumps or poorly engineered and managed landfills;
- Uncontrolled waste burning;
- Widespread littering, very low waste collection coverage and precarious waste transport vehicles;
- Recovery of valuable waste resources by the informal sector (informal recycling and scavenging).

A SWM system should respond to the following requirements (Cossu, 2009):

- decrease in waste production,

[5] https://cominsud.wordpress.com/

- guaranteeing an efficient service of collection and disposal,
- optimization of material resource recovery,
- emphasis on climate change and minimization of GHG,
- reduction of waste volumes destined to landfills,
- optimization of energy balance with use of energy from waste,
- reduction of emissions, monitoring of toxicological effects and minimization of health risks,
- environmental sustainability.

It is mandatory that these requirements should be integrated and evaluated in the various geographic contexts in which a series of economic, social and geomorphologic situations may influence choices.

1.1.4. Waste management hierarchy

This is a concept that accords priority action options to solid waste management based on sustainability (Achankeng, 2004). The concept is often described by the "3Rs"–Reduce, Reuse, Recycle, and valorisation followed by unavoidable disposal (Eko, 2017). Figure 3 illustrates the waste management hierarchy and gives a brief description of the related concepts.

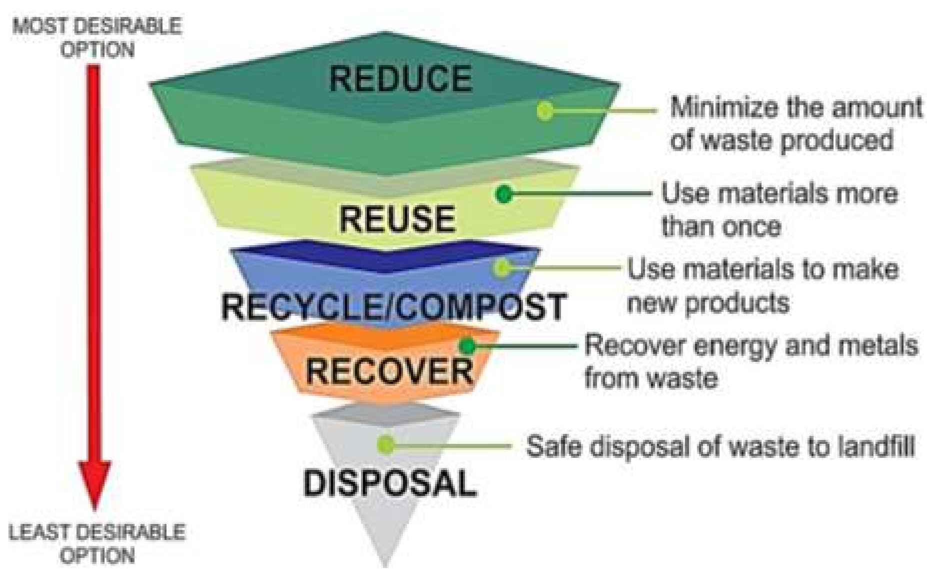

Figure 3: Waste management hierarchy (Sharif et al., 2017)

Despite their great success in the developed world, the 3Rs have been very difficult to implement in developing economies. This can be accounted for by the fact that most technologies that accompany the 3Rs are absent or cannot be acquired by the developing countries due to high energy demand and economic investments. In such cases, when the circumstances are premature for the application of the 3R concept as part of a Circular Economy strategy, a 3S strategy (Sanitisation, Subsistence economy and Sustainable landfilling) should be implemented (Lavagnolo and Grossule, 2018).

1.1.5. The 3S - Sanitisation, Subsistence economy and Sustainable landfilling

The 3S approach, at variance with the 3R concept, is not perceived as a hierarchical structure, but rather is based equally on all three pillars as shown in figure 4.

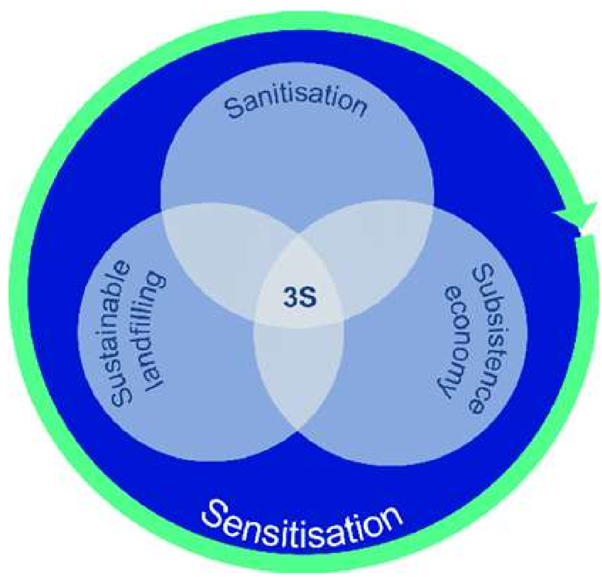

Figure 4: Graphical scheme of the 3S model proposed as a strategic tool to address the actual requirements of waste management in areas with economic constraints (Lavagnolo & Grossule, 2018)

Sanitisation aims to improve the standards of living in the country, achieving basic rules of hygiene in waste management.

Subsistence Economy is aimed at returning waste to the economy as a resource with appropriate technologies, providing economic profits and new business opportunities and involving the informal sector activity in a remunerated and formalized way.

Sustainable Landfilling is needed to safely dispose of residues devoid of any economical or technical value.

For the 3S to be successful, **sensitisation** of local populations -not only technicians and administrators - is an essential tool that should not be neglected. As an example, in Yaoundé, a literary café has been put in place to raise awareness in environmental topics, particularly solid waste management, involving local people of different cultural levels (Lavagnolo & Failli, 2018). The venue welcomes common people and is a room for discussion, conviviality and sharing through the hosting of awareness, sensitization, education and training campaigns with the objective to enlarge and spread knowledge on SWM basic principles.

1.2.Circular economy concepts

The traditional take, make, dispose linear economy is gradually living space to a new concept known as the circular economy. In the linear economy, resources are extracted, transformed into products, consumed and discarded at their end of life. This system, characterized by overexploitation of natural resources (especially the non-renewable ones) leading to resource depletion, pollution, accumulation and destruction of valuable waste fractions presents many drawbacks.

Increasing concerns about the environment and sustainability in the previous century lead to development of notions such as “people-planet-profit”, “cradle-to-cradle”, “multi-value creation” and “responsible entrepreneurship”, alternative technologies, such as the concept of cradle-to-cradle and closing the loop, took hold when economic analysis showed the enormous benefits of circular resource management (Kormut’ák et al., 2013) . The main aim of the circular economy is to close the linear loop by giving value to end of life products.

Figure 5 shows an illustration of the transition from the linear to the perfect circular economy.

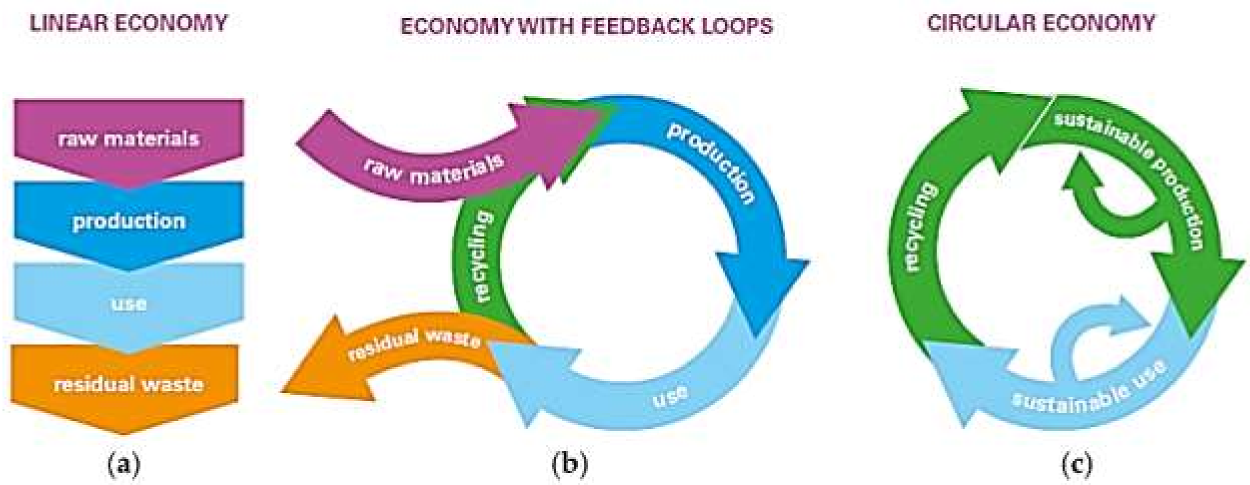

Figure 5: Linear economy (a), circular economy with some feedback loops (b), and circular economy (c) (Rli - Council for the Environment and Infrastructure, 2015)

1.2.1. Definition

The term circular economy takes a wide range of definitions depending on the author. A circular economy (CE) can be defined as " an economic model aimed at the efficient use of resources through waste minimisation, long-term value retention, reduction of primary resources, and closed loops of products, product parts, and materials within the boundaries of environmental protection and socioeconomic benefits" (Morseletto, 2020).

Circular economy refers to an industrial economy that is restorative by intention; aims to rely on renewable energy; minimizes, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design. Here, the circular economy is based on a few principles: design out waste, build resilience through diversity, rely on energy from renewable sources, think in 'systems,' and waste is food (Ellen MacArthur Foundation, 2013).

In 2017, Kirchherr, Reike and Hekkert studied one hundred and fourteen (114) definitions of the circular economy. The aim of this work was to come up with a generalized definition that entails the understanding of the concept by different people. The authors define circular economy as:

"an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes.

It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers" (Kirchherr et al., 2017).

1.2.2. Targets of a circular economy

The Circular Economy is based on business models, which reject the linear "take-make-waste" approach. It aims to: (i) maintain products in use for a longer time by reusing and repairing them, reducing waste generation, and (ii) use more secondary raw materials in production cycles, creating new growth and job opportunities (Cossu& Williams, 2015).

In other words, circular economy aims for the creation of economic value (the economic value of materials or products increases), the creation of social value (minimization of social value destruction throughout the entire system, such as the prevention of unhealthy working conditions in the extraction of raw materials and reuse) as well as value creation in terms of the environment (resilience of natural resources*)* (van Buren et al., 2016).

Circular economy targets are grouped into five main areas of application: efficiency, recycle, recovery, reduction and design. Though studied separately in literature, these targets generally overlap as illustrated in figure 6 (Morseletto, 2020).

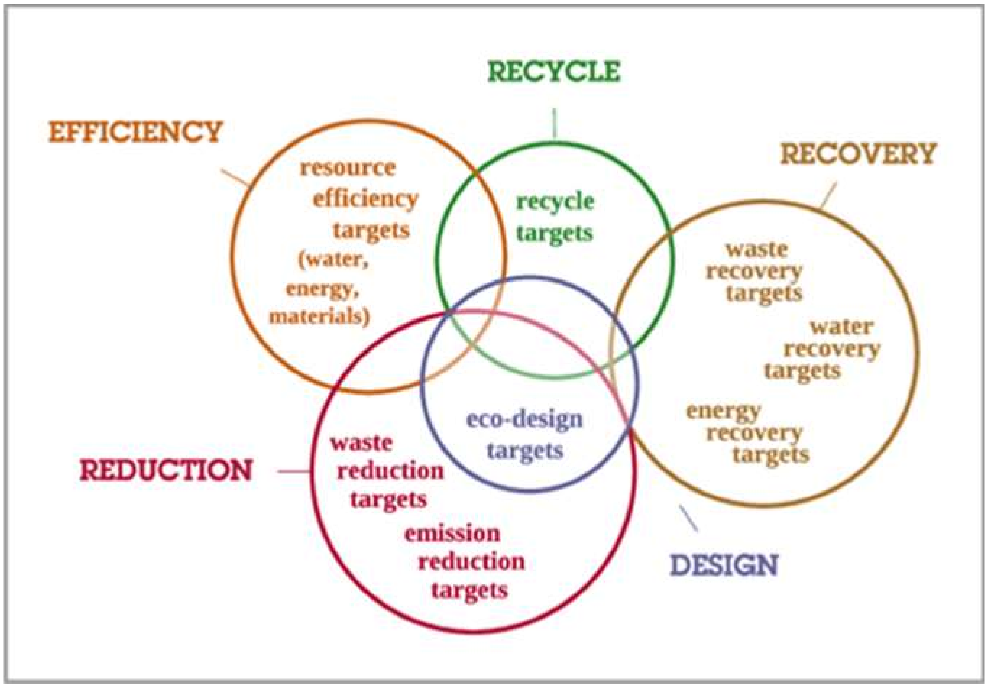

Figure 6: Main existing circular economy targets by area of application (Morseletto, 2020)

"Circular economy targets are classified into three groups according to where they act in the production chain; useful application of materials, extend lifespan of products and their parts, and smarter product manufacturing and use" (Morseletto, 2020; van Buren et al., 2016). Some strategies have been put in place to analyse these targets, the most common ones being the 3Rs (Reduce, Reuse, Recycle). Reuse and recirculation of products and materials are the basis of the concept of circular economy (Nascimento & Xavier, 2018). However, ten other CE strategies (labelled R0-R9) employed in increasing order of circularity fall into the three target groups.

A higher level of circularity of materials in a product chain means that those materials remain in the chain for a longer period, and can be applied again after a product is discarded, preferably retaining their original quality. As a result, in principle, fewer natural resources are needed to produce new materials required for manufacturing products and for their subsequent use. Avoided resource extraction and production of materials benefit the environment (Potting et al., 2017). Figure 7 shows the three groups of targets and their corresponding strategies.

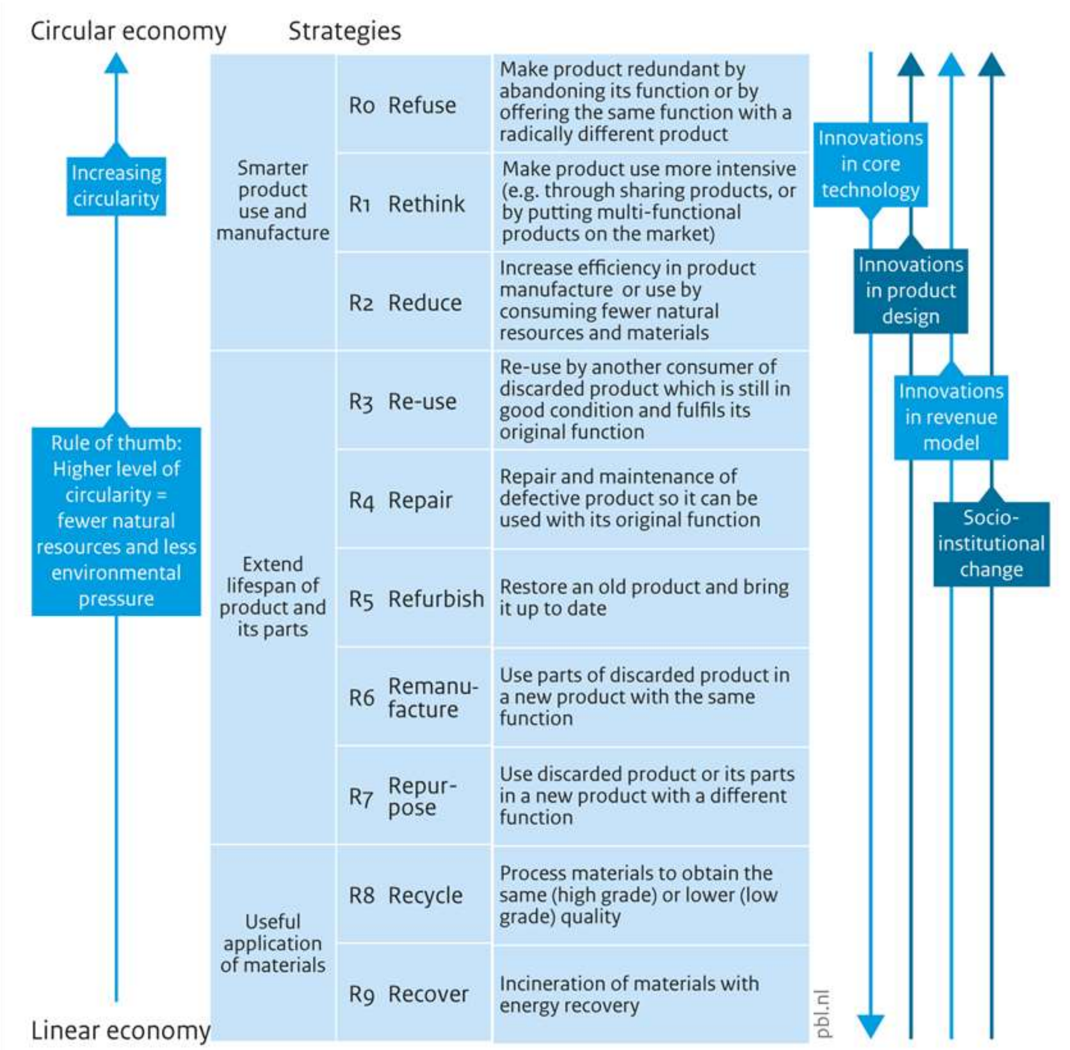

Figure 7: Circularity strategies within the production chain in order of priority (Potting et al., 2017)

1.3.Urban mining

Concern about increasing global consumption of non-renewable resources, progressive shortages of primary raw materials, reduction of space available for final disposal of wastes, the need for quantity and volume reduction of wastes generated, the need for control of environmental contamination caused by emissions from waste treatment, changing social attitudes towards waste management, are several reasons why processes such as recycling, resource recovery, urban and landfill mining, waste minimisation and material recovery have been put to place (Cossu &

Williams, 2015).

The urban mining approach promotes the reduction of the need for mining in the virgin mines, its consequent negative impacts, and the exploration of natural resources. The scientific community also knows this approach as Waste to Resources (WtR) (Ottoni et al., 2019).

Urban mining refers to the process of reclaiming compounds and elements from products, buildings, and waste. It concentrates on recovering metals embodied in waste, especially e-waste. The practice of sending our waste elsewhere for processing has enabled urban mining to become a salient urban informal economic activity in e-waste processing sites across the developing world (Grant, 2018).

A new knowledge base is necessary to advance from the present state of recycling to a next "urban mining" state, where materials are recovered in a more focused and effective way that takes valuable as well as hazardous substances into account along their path from origin to use phase and final sink. The concept of urban mining to date has not taken into account the question of where recycling takes place. Locating urban mining processes close to the sources of secondary materials and thus within service- oriented urban areas has significant advantages (Brunner, 2011).

Urban mining originally focused on electrical and electronic wastes (WEEE) which contain relatively high concentrations of expensive metals and rare earth elements (Cossu & Williams, 2015).

Continuous extraction of raw materials from the earth and their accumulation in end of life products has turned the cities into living mines. Urban mining is very different from traditional mining and its "holes in the ground," extraction sites generally located in the interiors of countries away from urban centres (Labban, 2014).

Positive aspects of urban mining include the conservation of global resources (saving the environment, reincorporating materials already enmeshed in the global material system, and turning residuals into resources) and providing local livelihood opportunities (although in its present form, scavenging and informal processing are far from decent work) (Grant, 2018).

Urban mining is far cheaper than conventional mining. Oxford learner's dictionary defines conventional mining as the process of getting coal and other minerals from under the ground. Table 1 shows the amount of metals that can be obtained through conventional mining from ores and urban mining from the city.

Table 1: Amount of metal available from primary and urban mining. Based on statistics in Umicore (2011) (Grant, 2018)

Metal	Primary Mining	Urban Mining
Gold (AU)	5 grams/ton in ore	200–250 grams/ton in PC circuit boards
		300–350 grams/ton in cell phones
Platinum (PGMs)	2-6 grams/ton in ore	2000 grams/ton in automotive catalysts
Copper	4500- 9000 grams/ton in ore	112,5600–131,250 grams/ton in cell phones

Landfill mining is described as a process of extracting minerals or other solid natural resources from waste materials that previously have been disposed of by burying them in the ground (Krook et al., 2012).

Urban mining is an important tool to reduce environmental pollution and health issues related to waste management. In addition, urban mining reduces the amount of natural materials stripped from earth as their recuperation from various waste streams tend to be increasingly cost efficient. One can find an up to 50 times higher concentration of valuable metals and minerals in WEEE than in the ores extracted from mines. Millions of these electrical and electronic appliances are still waiting to be recovered in cities all over the world. Up to forty elements can be recovered from an old mobile phone. For some very rare metals such as europium and terbium, urban mining is gradually becoming the only source. Recovering all these elements from waste reduces the demand for conflict minerals thereby reducing conflicts. Urban mining also reduces the demand for landfill area.

1.4. Community-based solid waste management (CBSWM)

When the government fails to provide adequate solid waste management for its citizens, they have to take the responsibility to do so. Community incentives are tools that serve this purpose.

A community here refers to "a group living in a specific geographical or administrative area, for example, a neighbourhood, which has access to and uses the same service" (Anschütz, 1996). For community incentives to be successful, the need for community participation is indispensable.

Community participation is an active process by which the community influences the direction and execution of a development project to enhance their well-being in terms of income, personal growth, self-reliance, or other values they cherish (Paul, 1987). Community participation, for example, is far more than the contribution of resources (labour, money, and supplies); it involves participating in the decision- making process to identify community problems, and designing and implementing strategies to address these problems. This results in the community taking responsibility for, and ownership of, its own development (Asomani-boateng, 2007).

CBSWM is a waste management system that recognises the community as the active role player in cleaning up their neighbourhoods and/or to earning an income from solid waste. The CBSWM approach is deep-seated on the principle of Kurt Lewin that states that people are likely to modify their own behaviour when they participate in problem solving. Thus, CBSWM gives people control over their environment to participate, maintain and improve its aesthetic value (Ndidzulafhi & Sinqobile, 2019).

As a response to the inefficiency of their SWM system (due to lack of community participation and financial burdens), Nkulumane a suburb in Bulawo city, Zimbabwe put up a community based waste management system with main objective to decrease reliability on the city council and increase community awareness on waste management problems through participation. This CBSWM did not receive funding and relied on partnership between the community and the private sector. The CBSWM was managed by a Community Based Organisation (CBO), which recruited workers from the local population. Local population was expected to source separate waste into organics (which will then be composted in their backyards) and inorganics (which will then be placed at the roadsides for collection by the CBO's trucks). Unlike in Kaduna, Nigeria (Rigasa et al., 2016); Putrajaya, Malaysia (Khaliesah et al., 2015) and Johannesburg, South Africa

(Schoeman, 2018) where there are recycling companies and informal waste collection, Bulawo city did not practice any recycling activity, hence no income was recovered from the waste (Ndidzulafhi & Sinqobile, 2019).

A similar project though funded by DANIDA (Danish International Agency) in Lusaka, Zambia failed, because in their quest to decentralise control, it instead left the local authorities disempowered (Nchito & Myers, 2004).

Christian village in Accra, Ghana conducted a community based composting system with the aim to reduce the amount of waste going into the landfill and give value to their waste. The project consisted of source separating the waste into two waste streams: organics (for composting) and inorganics (to be disposed into the landfill). Still, the project failed due to lack of incentives, little community participation: the population where reluctant to source separate their waste and the distance to the collection point was not favourable for them to transport the waste thereof. Despite all the difficulties in implementing the project, the compost produced was of very high quality. (Asomani-boateng, 2007).

In some cities, CBSWM systems are set-up, run and financed by the residents themselves. Such project carried out in two South Indian cities enabled them to improve cleanliness in their cities, recover cost through composting and recycling of waste, and create jobs for the community. However, the project failed to sustain due to low wages leading to lack of motivation from the workers, low recycling fractions as only about 25% of the residents successfully segregated their wastes, poor technical management and lack of space for composting (Colon & Fawcett, 2006).

Neighbourhood Based Waste Management (NBWM) have proven to be an adequate solution in areas where setting up a CBSWM plan was not possible. Neighbourhood Based Organisations (NBO) manages NBWMs. The main difference between NBO's and CBO's lies in their status and function. In Jakarta, NBOs are formal organizations within local government, while CBO's are not part of the local government structure. Regarding (Pasang et al., 2007).

In Yaoundé, Cameroon there exist various CBO's such as Tam-tam mobile, GIC VOCAPE, GIC JEVOLEC that have been set up by the population as a response to the inefficient waste management system in place. These CBO's have as main goal sanitisation of the different neighbourhoods. Some of the organisations collect particular waste streams (plastics, metals and glass) for reuse and recycling while others collect the mixed waste and then separate the organics, which are later composted (Ngambi, 2016).

1.5.Eco-centers

1.5.1. Definition

Eco-center is a term primarily used in Canada to designate a waste collection and sorting centre. This is a type of waste disposal facility where waste is recovered, recycled and then incinerated or stored. Communities most often manage eco-centers[6]. Eco-Centers are integrated waste management ecological centres that can be established by local governments to comply with legislation.

An Eco-Center is envisioned to be the central facility that houses appropriate technologies to recover and process materials out of the collected pre-segregated waste in order to reduce the capacity requirements for disposal. An eco-center is a practical option for local governments to improve planning and implementation of their Solid Waste Management program by promoting circular economy.

Resources are collected, re-processed and brought back to the mainstream economic loop. Pre-segregated waste is refined and sent to the various treatment facilities while non-segregated waste is segregated prior to treatment. The eco-centres contain different facilities depending to its targets. Some only deal with collecting and segregating waste whereas others possess on site recycling facilities and even sustainable landfills.

1.5.2. Goals and objectives

A successfully running eco-centre is integrated within a comprehensive Solid Waste Management system, which includes activities such as segregation at source, scheduled segregated collection, social marketing campaigns, etc. (Paul, 2015). Eco-centres provide several benefits to the community:

Eco-centers enhance resource recovery. By bringing together more waste and involving the informal sector, a more important volume of material can be recovered from waste. Organics can

[6] https://www.linternaute.fr/dictionnaire/fr/definition/ecocentre/

be composted and the inorganics like paper and plastics may be reused or recycled.

Mitigates the environmental and health hazards related to waste management. Providing the population with a suitable area to get rid of their waste saves them from the nasty open dumps and their numerous hazards. Higher recovery and recycling rates means less waste required for disposal reducing the demand for landfill space and the amount of landfill gases produced.

Create jobs and promotes inclusive growth. An eco-centre provides a safer and healthier environment for the informal waste collectors. Formalising their activity increases their living standards due to higher and more standard wages.

On site learning facilities, inspire and unite communities. Some eco-centre possess an education centre, which is a place where various groups, especially educational institutions; can gain access to sustainable environmental practices. It secures a permanent knowledge source for sustainability. By involving and educating the community, more people will gain knowledge and interest concerning waste and work towards the proper functioning of the SWMS be it locally or globally.

Are cost effective. Eco-centres are designed to work with what is locally available and the design is adapted to the priorities of local governments. Income can be generated from the sale of recyclables and compost. The money can be used to pay wages to workers and ensure proper running of the centre.

1.5.3. Some case studies

In January 2001, the government of the Philippines came out with a government act known as Ecological Solid Waste Management Act of 2000 in which various stakeholders especially Local Government Units (LGUs) in the Philippines were tasked to upgrade their solid waste management systems. The law promotes waste minimization, material recovery, reuse and recycling and especially requests to establish a composting component and to close dumpsites prior to 2007. As a response to this law, several local governments in the Philippines designed and set up eco-centres as the major tool for their solid waste management system.

In August 2004, Bayawan City finalized its solid waste management plan, which proposed the establishment of a Waste Management and Ecology Centre (Boorsma et al., 2009). The centre has the following components.

- Material recovery facility (MRF) that improves segregation and avoids the mixing of organic materials, recyclables and residuals. As seen in figure 8, Bayawan's MRF uses slides and gravity force. In addition to its low construction cost and independence over electricity, this system ensures a more efficient operation and reduces maintenance. Composting plant for the organic fraction. This is the most important waste fraction in the Philippines. Produced compost is the sold as a cost recovery mechanism.

Figure 8: Perspective of the Bayawan City material recovery facility.(Boorsma et al., 2009)

- Sanitary landfill. The residues from the MRF and compost are landfilled in this facility.
- Wastewater and septage treatment. Liquid waste and greenhouse gases produced because of landfilling are treated prior to discharge into the environment.

Similar projects were carried out in Bais (Libradilla et al., 2009), Ormoc (Fumar et al., 2011) and San Carlos cities. San Carlos city was able to attain a waste diversion rate of 64% in 2015 (Paul, 2015) due to its eco-centre.

A study carried out in Sweden to know the user's perspective regarding eco-centres reveals the citizens are very receptive and most of them enjoy using it. Most users to recycling centres live in houses. Location of recycling centres close to housing areas, workplaces and shopping centres would minimise travel distances. Users request for longer opening hours and more education.

Users are generally positive towards the service offered at recycling centres. For them, important improvements are longer opening hours and better information available at home and at the recycling centre. The major difficulty for users is to understand which fraction their waste belongs to, and thus which container they should throw it into (Kihlstedt & Engkvist, 2010).

Conclusion

This chapter enabled us to get knowledge about what is waste, solid waste, municipal waste and some processes involved in municipal solid waste management. The circular economy and urban mining have been defined and explained and some community-based incentives have been presented. The concept of eco-centres has been defined and its benefits outlined.

CHAPTER TWO : PRESENTATION OF THE RESEARCH AREA

Introduction

In this chapter, the study area will be analysed, as well as the steps taken in order to achieve the objectives described in the introduction of the thesis.

Materials consider the tools (equipments) that have been used in order to collect data, design and represent the different systems in order to improve some drop off points in Yaoundé. The main instruments used were questionnaire, camera, metre, GPS, information and communication technology tools.

The research methodology employed in this work follows a mixed approach: quantitative and qualitative. Information about the current practices and the history of chosen sites was obtained through the qualitative approach whereas the quantitative approach was employed to collect statistical data.

2.1. Presentation of the research area

2.1.1. Geographical location

Yaoundé, the “city of seven hills”, is located within latitudes 3°50′ and 3°55′ N, and 11°27′ and 11°35′ E on the southern plateau of Cameroon, in the middle of the equatorial forest at about 250 km east of the Atlantic Ocean. It is the political capital of Cameroon and the head quarter of both the Mfoundi division and the centre region. The town is bordered in the north by the municipality of Soa, in the east by Nkolafamba municipality, in the south east by the Mfou municipality, in the south west by the Mbankomo municipality and finally in the north west by Okola municipality.

Yaoundé spreads over a hilly area on a plateau, which varies between 700-800m of altitude, crowned by great mountains with curved forms at about 1000-1300m.

Figure 9 illustrates the study area.

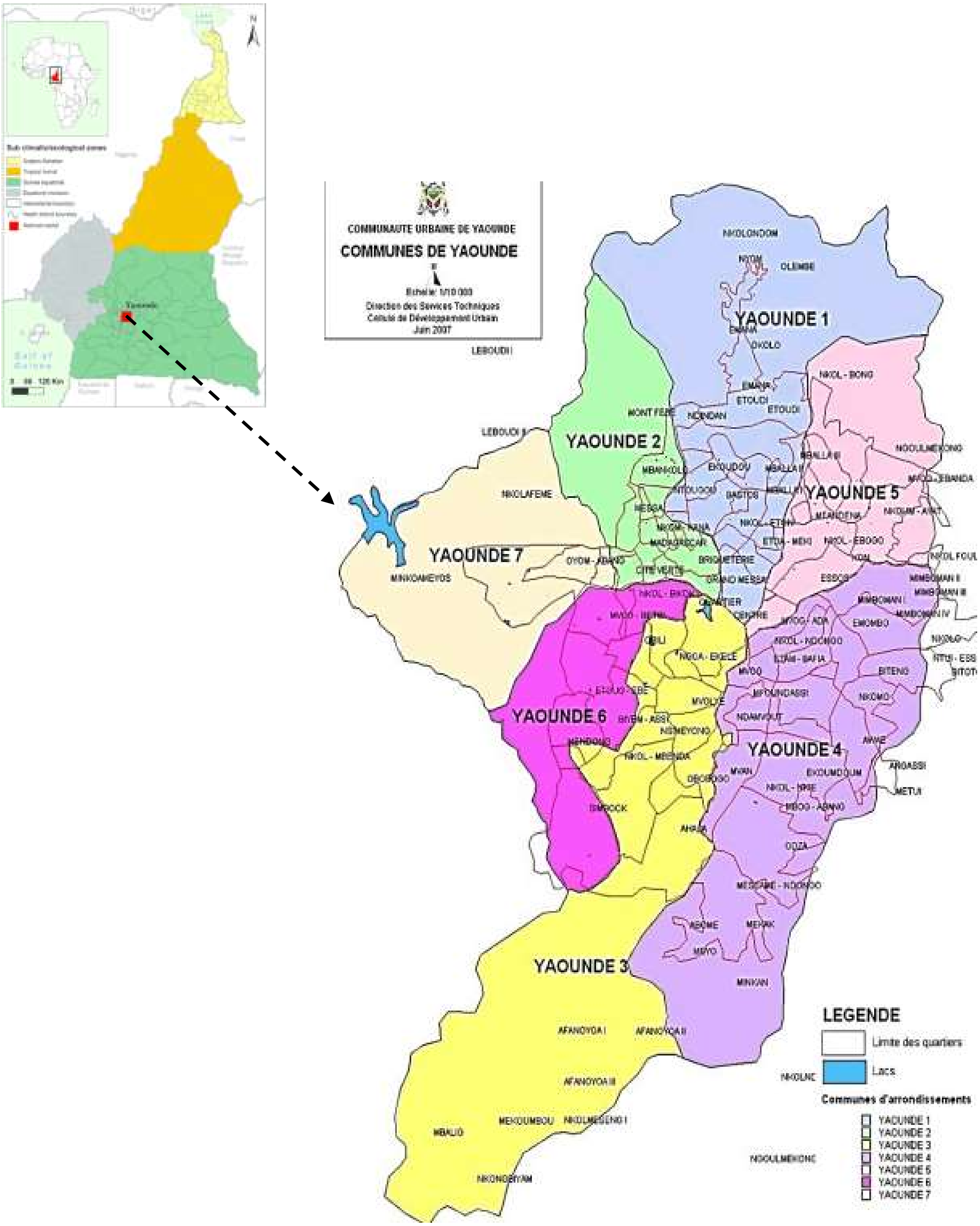

Figure 9: Location of the study area. (PDU Yaoundé, 2020)

2.1.2. Climate

The climate of Yaoundé is tropical wet and dry (Aw), with constant temperatures throughout the year. Yaoundé has an average annual temperature of 23.7 °C[7] that varies from 18°C to 28°C during the humid season (lowest temperature occurs in October) and from 16°C to 31°C during the dry season, (highest temperature occurs in February). Yaoundé experiences four climatic regimes:

- a long dry season (from mid-November to mid-March);
- a short rainy season (from mid-March to mid-June);
- a short dry season (from mid-June to mid-September);
- a long raining season (from mid-September to mid-November).

Qualified as bimodal, Yaoundé has a mean annual rainfall of 1291mm with January being the driest month and October the wettest.

The winds are rarely violent, apart from some rare cases where we have squall tornados. The annual thermal amplitudes are relatively low (about 9°C). The mean annual hygrometry is of 80% in the whole town, with variations between day and night from 35 to 98% respectively.

Maximum sunstroke duration, of 6 to 9 hours per day, is too scarce and that between 3 and 7 hours counts about 40 to 60% of days per year. The sunstroke duration below 2 hours accounts only 10-24% of days per year.

2.1.3. Demographics

Yaoundé covers a surface area of 304 km² and had a population of 3 992 411 inhabitants[8] in 2020 this gives a population density of 13 133 inh/km². In 1950, the population was 31 644. Yaoundé has grown by 169 986 inh since 2015, which represents a 4.45% annual change. In 1987, law n° 87-15 of 15th July 1987 transformed Yaoundé into Yaoundé Urban Council composed of seven (07) sub-divisions (Yaoundé I – VII) ruled by mayors elected by the population. The city mayor governs the urban council and has as goal to attain economic, social and cultural

[7] https://fr.climate-data.org/afrique/cameroun/centre/Yaoundé-3987/#:~:text=Yaoundé%20Climat%20(Cameroun)&text=Une%20moyenne%20de%20298%20mm,plus%20haut%20taux%20de%20pr%C3%A9cipitations.

[8] https://worldpopulationreview.com/world-cities/Yaoundé-population

development of the town. Figure 10 illustrates population growth in Yaoundé over the years and the respective annual changes (population growth rate in percentage). The graph also shows projections for the next 15 years.

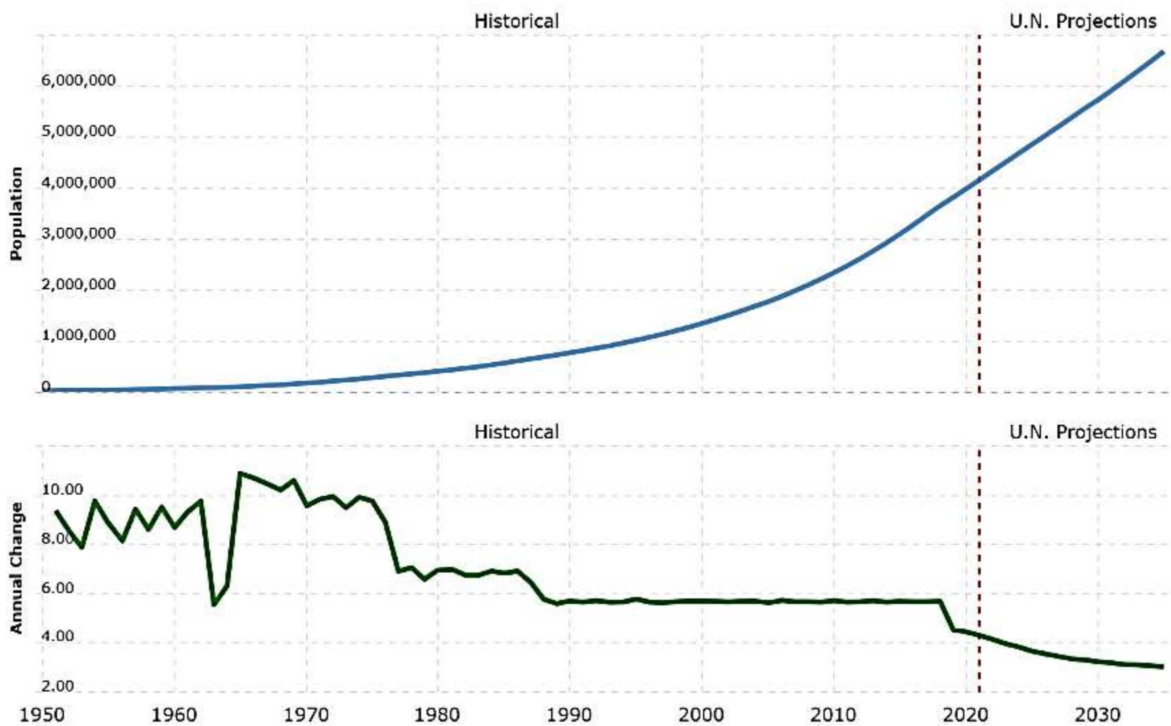

Figure 10: Trends in Yaoundé population growth.
(https://www.macrotrends.net/cities/20365/Yaoundé/population)

The main ethnic groups found in Yaoundé are the Beti (Ewondos, Etons and Bulus), Bamilekes, Bassas, Douala, Haoussa, Mbamois, and Anglophones.

Yaoundé has an outstanding number of primary and secondary schools and 42 universities of which two (02) are state universities.

2.1.4. Economic activities

Most of the activities are centred on the administrative structure of the civil and diplomatic services. Yaoundé is a tertiary city and major industries in the city include tobacco, dairy products, and breweries, sawmills, paper mills, mechanics, clay, glass goods, timber and building materials. It is also a regional distribution centre for coffee, cocoa, copra, sugar cane and rubber.

Local residents engage in urban agriculture, trade and small informal businesses. There is diversification of its productive economic activities, with the service sector contributing about half of the total domestic production

CHAPTER THREE: MATERIALS AND METHOD

3.1. Materials

3.1.1. Questionnaire

The questionnaire we used is a mixed data collection tool, which has the objective to evaluate quantitatively the amount of waste disposed of in unauthorized dumps and the amount diverted away by informal recyclers in the city of Yaoundé. This data will help us make a state of the art of waste disposal and recycling in Yaoundé. For the purpose of this work, two different questionnaires were used. The first one (Appendice I) helped to study the open dumps and understand how the locals perceive it and the second questionnaire (Appendice II) focused on the informal sector involved in waste recycling in the Mokolo market.

3.1.2. Information and communication technology tools

Varieties of software were used to analyse the collected data, particularly AutoCAD, ArcGIS, REVIT, LUMION 10, MS Excel, and MS Word. Google map and mobile topographer are apps that were of great use as well.

i. **AUTOCAD**

This is a computer-aided design (CAD) software that architects, engineers, and construction professionals rely on to create precise 2D and 3D drawings. Introducing the geographical position of our different sites into the software enabled us to redraw the contours of the site. Knowing the shape of the dump from observation and the height/depth of waste in it from measurement, the approximated area and volume of the dumps were calculated. The site was also located on the Yaoundé map downloaded from google map. The 2D and 3D plans of our eco-centres were later designed.

ii. **MS EXCEL**

Excel permits us to proceed methodically in terms of calculations thanks to its many sheets that enable us to perform different calculation operations at the same time. Collected data was analysed and represented graphically using this tool.

iii. **MS WORD**

This is the didactic software for the writing up of our thesis, used to edit and compile data to present in a general and orderly manner to the understanding of everyone. Editing of our work and correction of grammar and vocabulary was done using this software known worldwide for its multiple assets in documentary editing.

3.1.3. Global Positioning System (GPS)

The GPS is a satellite positioning system, which determines the geographical coordinates of any point on the surface of the globe. Coordinates of chosen sites were collected using the GPS app called *Mobile Topographer*. These coordinates, converted into linear coordinates in the app enabled us to delimitate the perimeters of the dumpsites.

3.2. Desk study

This involved the scooping of relevant documents (Articles, reports, textbooks, and thesis) to ensure that the objectives were issues that needed to be addressed in the study area, and has local and international significance for the environment and society. It also involved the establishment of:

- a plan to carry out the field work;
- design of a recycling centre and its eco-centers;
- profitability analysis of the possible solutions.

A study of how to use software important to portray the results obtained from the method was done. For example, a training on how to use ArcGis which was used to come out with the map showing the location of our different sites.

3.3. Field work

In order to meet the objectives of this work, fieldwork was carried out in two steps:

- identification of the different sites ;
- survey to define the different waste fractions in quantities and qualities and explore the actual informal recycling activity.

Table 2: List of the selected sites

i. Identification of the different sites

A preliminary visit was carried out in the town to identify various dumpsites. The list was then refined and only the most important ones were studied. The sites were chosen based on the volume of waste disposed, the age and size of the dump. Eight (08) sites were selected across the city and are mentioned in table 2.

ii. Survey

The survey was done in two steps: a first survey was done to study the localisation and the characteristics of the open dumps and a second one to understand how actual recycling is carried out in the Mokolo market.

Quarter	Sub-division
Centre des handicapés (Akok-ndoué)	Yaoundé VI
Briquetterie mokolo	Yaoundé II
Marché Mvog-Mbi	Yaoundé IV
Mokolo Elobi	Yaoundé II
Hippodrome	Yaoundé I
Obobogo	Yaoundé III
Kondengui	Yaoundé IV
Etoug-Ebe	Yaoundé VI

- Study of the open dumps

Localisation has been carried out with the help of the students of Master's in Architecture (March 2; 2019/2020) under the supervision of prof. Maria Cristina Lavagnolo and prof. Dunia Mittner and the collaboration of Eng. Patrick Fonkou, a young researcher in environmental engineering. I have done the data on volume of waste and the elaborations. The objectives of this survey were:

- to collect information on sites history;
- to measure the size and volume of waste dump;
- to characterise (in type and quantity) the waste discarded at the dump.

The open dumps studied during this survey are located as in figure 11.

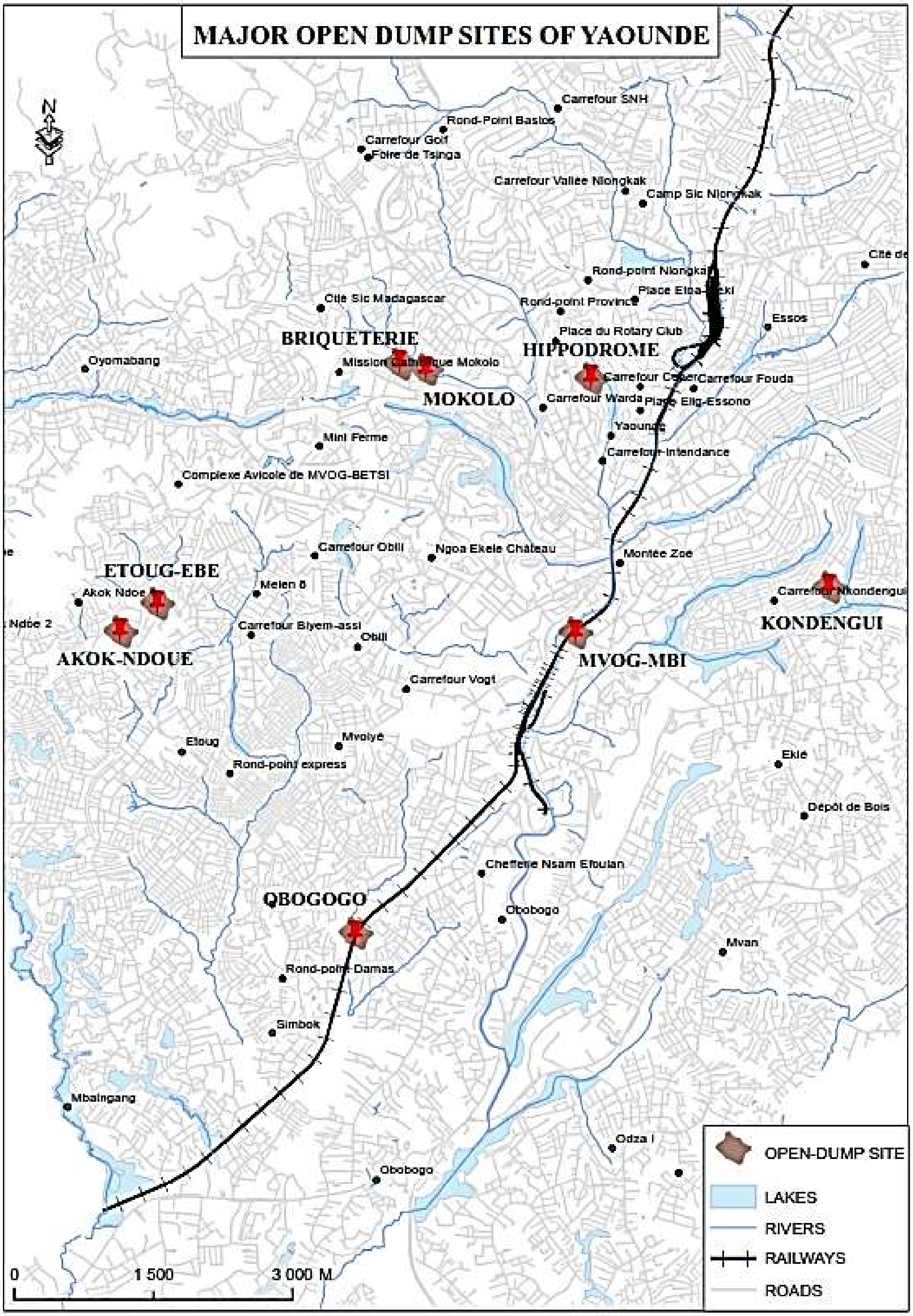

Figure 11: Location of the selected open dumps

– History of the sites:

Locals were interviewed in order to know the history of the site. Some were very open for discussion and others very reluctant. The activity was very difficult in some neighbourhoods where the population was not collaborative.

– Shape and size of the dump:

The shape and size of the dumps were calculated using Google Earth and AutoCad. The height of the different dumps was measured using a metre. This information (shape, size and height) gave us the possibility to calculate the volume of the dump, considered then – with a certain approximation - as the volume of waste dumped.

– Waste characterisation;

A questionnaire (Appendice I) was used to characterise the waste. The main aim was to know the history of the site, the type and quantity of waste produced in the neighbourhood and discharged in the dump, the presence or absence of HYSACAM in the neighbourhood and the implication of the informal sector. A simplified analysis has been considered to define the characteristics of the different fractions of waste: waste samples (4 samples of 50 kg each) were taken from different parts of the dump then properly mixed and analysed. The final sample (about 200 kg) was analysed into the different valuable fractions (e.g.: plastic bottles, papers, organics, etc.). As for the quantity of each fraction, the proportion in the sample was linked to the volume of the dump through simple calculation and also compared to the situation observed on site. Some residents found around the dump were interviewed to better understand the type of waste produced and the discharge point.

- The recycling centre in Mokolo market

The second survey was aimed at understanding the recycling activity-taking place in the Mokolo market and the working conditions of the informal recyclers. To achieve this, a second questionnaire (Appendice II) was used. The questionnaire has 38 questions concerning the recycling activity, collection and transportation of recyclables, economic benefit of the activity, working conditions and the effect of the activity on the health of the recyclers and the environment. As for the previous survey, many of these recyclers were reluctant to take part as some confused us with agents from the council.

3.4. Data analysis

Data collected were analysed with the use of Microsoft Excel Spreadsheets and thereafter, the results were represented using graphs, tables and charts. Similarly, data collected from interviews were analysed and related to works already done in order to pull out conclusions concerning them.

Volumes of the dumps calculated during field campaign, were used to evaluate the amount of waste accumulated in the dump for a period of one month, the amount of each waste fraction, the amount diverted by the informal sector and the potential economic value derived from selling the waste recovered from the dump. The following hypothesis were taken:

- the volume of waste in the dump can be assumed as the volume of the dump: volume accumulated in one month is calculated starting from the daily waste volume;
- all waste found in the dump is considered fresh with a density of 600 kg/m^3;
- a plastic bottle weighs 32.6 g (Islam, 2018): approximately 31x1.5L bottles = 1kg of plastic;
- 1L glass bottle weighs 1kg;
- the price of waste used to evaluate the potential economic value is the average price obtained from the survey that took place in Mokolo.

The amount of waste accumulated in one month is given by:

$$M_m = \rho V * 30\ days \qquad (1)$$

Where:

- $M_m (\frac{kg}{month})$ is the amount of waste accumulated in one month
- $\rho\ (kg/m^3)$ is the density of fresh mixed waste
- V (m^3/day) is the volume of waste disposed daily

From characterisation of the waste stream, the amount of each fraction is:

$$M_f = \%_f * M_d \qquad (2)$$

Where:

- M_f (kg/month) is the amount of each fraction

- $\%_f$ is the percentage of each fraction

The amount removed informally, M_{if} (kg/month) is given by:

$$M_{if} = \%_{if} * M_f \qquad (3)$$

The economic value, EC (FCFA/month) that can be derived from waste is:

$$EC_f = M_f * P_a \qquad (4)$$

$$EC = \sum EC_f \qquad (5)$$

Where:

- M_{if} (kg) is the amount removed informally
- EC_f (FCFA/month) is the amount of money derived from each fraction
- P_a $(FCFA)$ is the average price per unit of each fraction

3.5.Design approach of the eco-centre

Eco-centres will be designed following three main configurations as shown in figure 12.

1. Configuration A, the eco-centre contains all the activities, recycling too;
2. Configuration B contains repair, reuse and resale activities;
3. Configuration C, just separation and storage

In any configuration, waste is sorted immediately after arrival at the eco-center. Then the segregated fractions are sent for repair, resale and/or recycling and/or transported towards the recycling point. Residues are collected and transported by HYSACAM to the municipal landfill.

The center opened every day from Monday to Sunday and will follow a system of rotation that permitted each worker to have one free day per week.

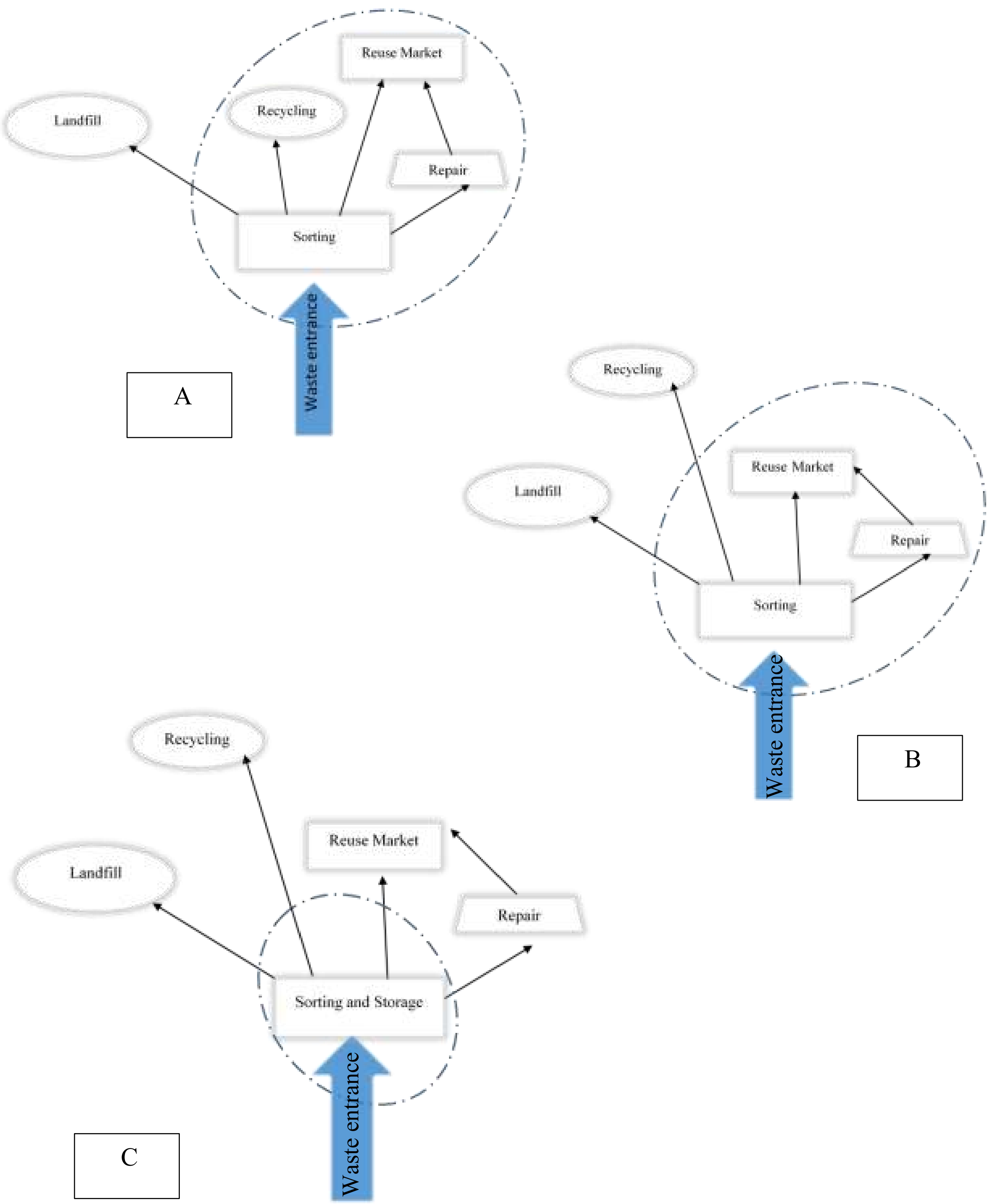

Figure 12: Conceptual scheme of the eco-centers. (A) Center having sorting, repair reuse market and recycling; (B) Center with reuse market; (C) Center having only sorting.

3.5.1. Collection of the mixed waste fraction

$$M_d = \frac{M_m}{30\ days} \qquad (6)$$

$$V_d = \frac{M_d}{\rho} \qquad (7)$$

$$V_c = V_d * f * E_C \qquad (8)$$

$$f = \frac{7\ days/week}{number\ of\ opening\ days/week} \qquad (9)$$

Where,

- M_m $(kg/month)$ is the amount of waste accumulated monthly
- M_d (kg/day) is the amount of waste produced daily
- ρ (kg/m^3) is the density of fresh mixed waste taken as 600 kg/m^3
- V_d (m^3/day) is the volume of waste disposed daily
- V_c (m^3) is the actual volume of waste that reaches the eco-centre
- E_C is the collection efficiency
- f (days) is the collection frequency, which is the number of days in between the opening days

The area of the collection area is given by;

$$A_c = A_b * N_b \qquad (10)$$

Where,

- N_b is the number of bins
- A_c (m^2) is the area required for storing the collected waste
- A_b (m^2) is the space occupied by one bin

3.5.2. Sorting

The amount of each waste fraction obtained from segregation of the mixed waste is given by equation.

$$S_f = S_E * \rho V_f \qquad (11)$$

Where:

- $S_f(kg)$ is the weight of the segregated fraction
- S_E is the segregation efficiency
- $\rho V_f\ (kg)$ is the mass of the waste fraction

The amount of residues after segregation of chosen fractions is obtained from equation 12.

$$R = \rho V_c - \sum S_f \qquad (12)$$

Where:

- $R\ (kg)$ is the amount of residues

3.5.3. Storage of residues

$$V_R = \frac{R}{\rho} f \qquad (13)$$

f, N_b and A_R are calculated from equations (4), (5) and (6) respectively.

Where:

- $V_R\ (m^3)$ is the volume of waste residues
- f (days) is the frequency of collection of the residues
- $A_R\ (m^2)$ is the area required for storing the residues

At centers where transport is needed, the amount of recoverable waste transported to the reuse/recycling unit each week is given by equation 14.

$$T = f \sum S_f \qquad (14)$$

Where:

- $T\ (kg)$ is the amount to be transported
- $f\ (days)$ is the number of days in between transport

Conclusion

Materials and methods used to meet the objectives stated in this work have been presented above. Methodological design approach used for the eco-centres were described and explained in details.

CHAPTER FOUR : RESULTS AND DISCUSSION

Introduction

Results obtained from fieldwork are presented and analysed in this chapter: open dumps in some neighbourhoods of the city are described and informal recycling in Mokolo market is presented.

4.1.The Open dumps

The dump is briefly described regarding its history, waste categories and implication of the informal sector. The economic value of the dump regarding recovering of some inorganic fractions is calculated for a period of one month. This value is calculated by considering that all the valuable fractions are removed from the mixed waste stream.

4.1.1. Mvog-Mbi

The dump is found behind the Mvog-Mbi market. Created in 1964, the Mvog-Mbi market is situated in Yaoundé 4. Initially, the site was a drop off point for the market, which was displaced due to some construction projects. However, citizens continued to dispose of their waste at the spot, gradually turning it into a dumpsite. According to some citizens found around the site, HYSACAM collects waste at the dump once every two months. Some pictures of the site can be seen on Figure 13.

Figure 13: The open dump in Mvog-Mbi

4.1.1.1. Waste categories and quantities

Based on the calculations described in the materials and methodology (Chapter 2), the volume of waste accumulated in this dump in two months is about $410m^3$. The main categories of waste found in this dump are plastics (mainly PET), metals, glass, textiles, paper, cardboard, food waste and WEEE. These fractions are illustrated on figure 14.

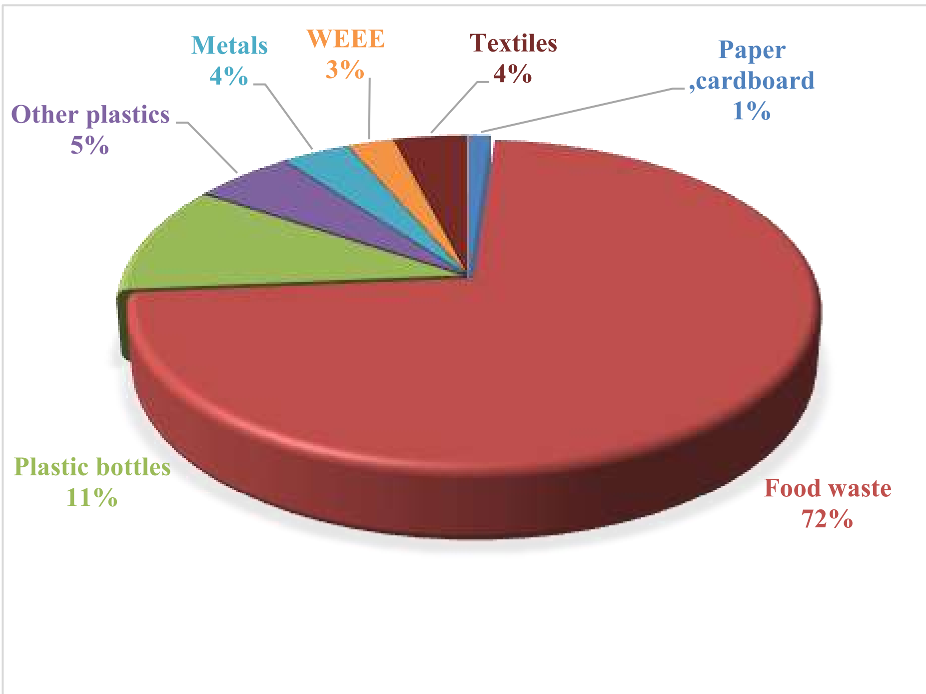

Figure 14: Waste categories in Mvog-Mbi

4.1.1.2. The informal sector

Some scavengers refurbish themselves with waste from this site. They collect the fractions they are interested in and later repair/transform for sale or use either on site or off site. The amount of waste diverted from the dump by these scavengers is given in table 3. Table 3 gives an estimate of the economic value that can be derived from diverting some inorganic waste fractions in the dump.

Table 3: Evaluation of the economic value that can be derived from waste in Mvog-Mbi

Waste fraction	Percentage (%)	Mass of fraction (kg)	Mass removed informally (kg)	Amount left (kg)	Average price per unit kg of waste (FCFA)	Economic value of the waste (FCFA/month)
Paper ,cardboard	1.1	1 353.0	852.4	500.6	5	6 765
Food waste	68.2	83 873.7	25 162.1	58712	-	-
Plastic bottles	10.1	12 423.0	7 453.8	4 969.2	279	3 466 017
Other plastics	5.1	6 297.6	-	6 297.6	50	314 880
Metals	3.5	4 268.1	640.2	3 627.9	288	1 231 183
WEEE	2.4	2 952.0	885.6	2 066.4	112	330 255
Textiles	3.8	4 649.4	1 859.8	2 789.6	-	-
Total (FCFA)					**5 349 100**	

From this table, we note that the informal sector diverts part of the waste from the dumps for their activities. The very low amount diverted can be explained by inaccessibility of the remaining parts and contamination from the mixed waste stream. By diverting all the recoverable fractions from the dump, the fractions with the highest potential in Mvog-Mbi are plastic bottles and metals. WEEE is also an interesting fraction, despite the fact that the price is very low compared to its potential. The waste fractions other plastics and paper, cardboard are not very cost effective as the price per unit is very low compared to the time required to collect one unit of the waste.

4.1.2. Kondengui

Found behind the Yaoundé central prison of Kondengui in Yaoundé IV, the site covers a surface area of about 630 m² and belongs to the prison's administrator. This site has been serving as a waste disposal site for the prison and the population for the past 20 years. Initially, HYSACAM installed a 20 m^3 bin on the site, which is no longer present as seen on figure 15. Today, the site serves as transfer station where HYSACAM dumps waste thrice per week and collects it twice for final disposal at the Nkolfoulou landfill. Apart from the prison and HYSACAM, inhabitants of neighbouring quarters such as Ekounou, Emombo and Carrosel also dump their waste here.

Figure 15: Side view of the dump in Kondengui

4.1.2.1. Waste categories and quantities

The categories of waste found in this dump are textiles, organics, plastics, glass, paper and cardboard. Figure 16 illustrates the contribution of these fractions to the main waste stream. Based on the calculations described in the materials and methodology (chapter 2), the volume of waste accumulated in this dump in 3.5 days is $329m^3$. The very large volume is accounted for by the fact that the site serves as a transfer station for HYSACAM.

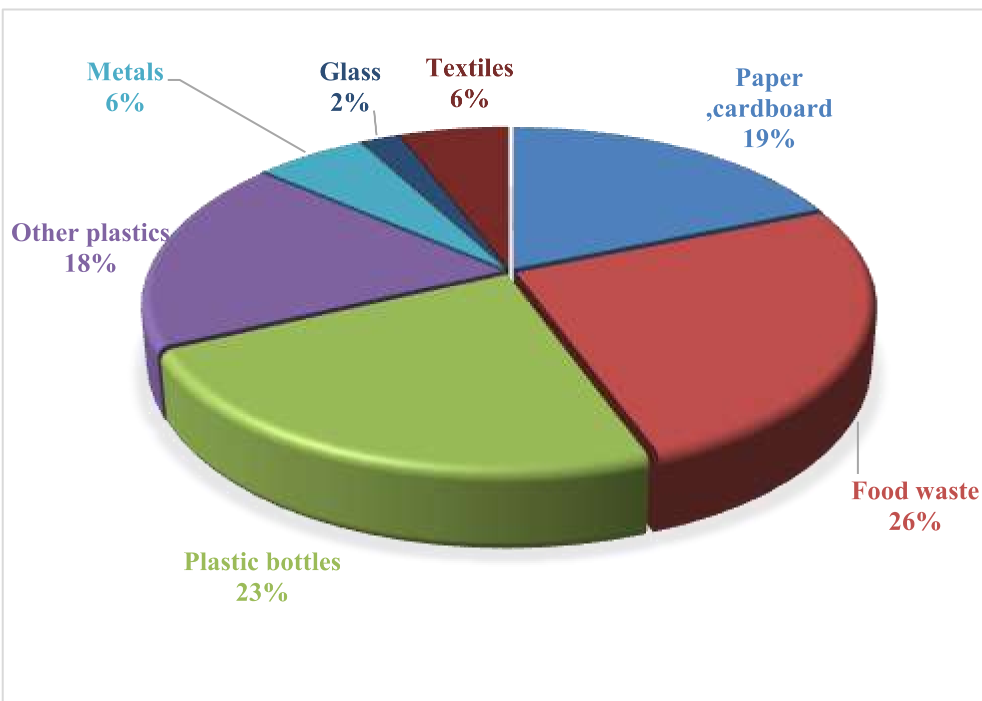

Figure 16: Waste categories in Kondengui

4.1.2.2. The informal sector

A 20 years-old boy from the neighbourhood supervises waste picking on this site. He sorts the waste once they arrive at the dump and takes away the fractions of interest (mainly metals and plastics) that he later sells, to the informal actors. He earns about 50 – 75 CFA francs/kg of metal and 100 CFA francs/ 20 small bottles. These collectors then sell back the waste bought at a higher price.

The amount of waste diverted from the dump by the informal sector is given in table 4. The table gives an estimate of the economic value that can be derived from the inorganic waste in the dump.

Table 4: Evaluation of the economic value that can be derived from waste in Kondengui

Waste fraction	Percentage (%)	Mass of fraction (kg)	Mass removed informally (kg)	Amount left (kg)	Average price per unit kg of waste (FCFA)	Economic value of the waste (FCFA/month)
Paper, cardboard	15.2	257 860.8	77 358.2	180 502.6	5	1 289 304
Food waste	20.9	353 628.0	155 596.3	198 031.7	-	-
Plastic bottles	19.1	322 664.4	161 332.2	161 332.2	279	90 023 368
Other plastics	15.0	253 800.0	25 380.0	228 420.0	50	12 690 000
Metals	4.7	79 524.0	67 595.4	11 928.6	288	22 939 615
Glass	1.7	28 764.0	14 669.6	14 094.4	15	431 460
Textiles	4.7	79 185.6	50 678.8	28 506.8	-	-
Total (FCFA)					**127 373 747**	

From table 4, the informal sector diverts part of the waste from the dumps for their activities; the amount diverted is very low compared to the amount present. This is due to inaccessibility of the remaining parts and contamination from the mixed waste stream. The fractions with the highest potential in Kondengui are plastic bottles and metals. The fractions other plastics and paper are not very cost effective as the price per unit is very low compared to the time required to collect 1 unit of the waste. As these fractions are contaminated by organics from the mixed waste stream, it is difficult to obtain good quality reusable material from the dump.

4.1.3. Briqueterie

Located in Yaoundé II, to the right of the canal that links Mokolo to Briqueterie, the dump was initially a HYSACAM bin that overflowed. The natives call this part of the neighbourhood "quartier haoussa". Near the Mokolo market, the absence of a standard bin gives rise to a spread of small dumps created by the population to get rid of their waste. The dump is 16 years old, is close to the road and to the market and mainly used by the market. The volume and area of the site vary with the collection frequency from HYSACAM. On visiting the site, it covered a surface area of about 118m² and HYSACAM had been there two days before. Figure 17 shows some pictures of the site.

Figure 17: Open dump in Briqueterie

4.1.3.1. Waste categories and quantities

Based on the calculations described in the materials and methodology (chapter 2), the volume of waste accumulated in this dump in three days is about 70 m^3. The categories of waste found in this dump are textiles, organics, plastics, glass, paper and cardboard, WEEE, metals and inert waste. Figure 18 illustrates the main categories of waste found in this dump.

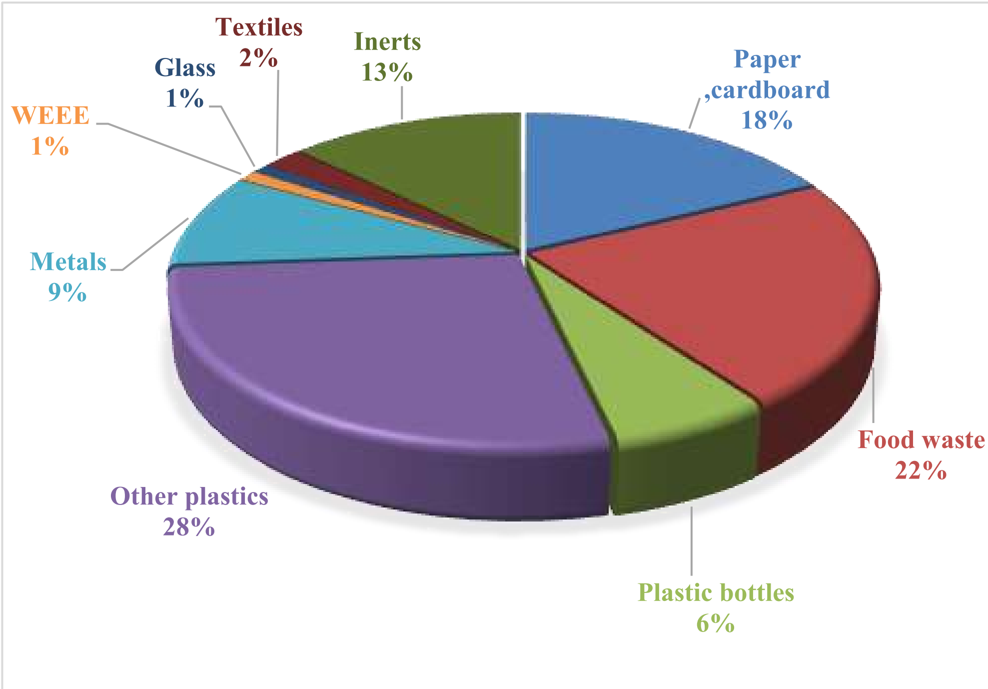

Figure 18: Waste categories in Briqueterie

4.1.3.2. The informal sector

The amount of waste diverted from the dump by the informal sector is given in table 5. The table gives an estimate of the economic value that can be derived from the inorganic waste in the dump.

Table 5: Evaluation of the economic value that can be derived from waste in Briquetterie

Waste fraction	Percentage (%)	Mass of fraction (kg)	Mass removed informally (kg)	Amount left (kg)	Average price per unit kg of waste (FCFA)	Economic value of the waste (FCFA/month)
Paper ,cardboard	17.7	74 466.0	2 978.6	71 487.4	5	372 330
Food waste	22.2	93 156.0	-	93 156.0		-
Plastic bottles	6.4	26 964.0	8 089.2	18 874.8	279	7 522 956
Other plastics	27.5	115 290.0	23 058.0	92 232.0	50	5 764 500
Metals	9.2	38 682.0	27 077.4	11 604.6	288	11 158 269
WEEE	1.0	4 284.0	-	4 284.0	112	479 272
Glass	1.0	4 200.0	-	4 200.0	15	
Textiles	2.1	8 946.0	447.3	8 498.7		-
Inerts	12.8	53 760.0	0.0	53 760.0		-
Total (FCFA)					**25 360 328**	

From table 5, the informal sector diverts a very low amount (less than 30%) of waste from the dumps for their activities; the low amount can be explained by inaccessibility of the remaining parts and contamination from the mixed waste stream. By diverting all the recoverable fractions from the dump, the fractions with the highest potential in Briquetterie are plastic bottles and metals. The fractions other plastics and paper are not very cost effective as the price per unit is very low compared to the time required to collect 1 unit of the waste.

4.1.4. Mokolo-elobi

Mokolo market is one of the biggest markets in Central Africa. The market has grown very fast from 2010 and waste collection is now very difficult due to the market structure. This has led to the birth of an open dump. This dump has been here for about 10years. Some pictures of the site are shown in figure 19.

Figure 19: Open dump in Mokolo Elobi

4.1.4.1. Waste categories and quantities

From the calculations described in the materials and methodology (chapter 2), the volume of waste accumulated in this dump is about $25m^3$ per day. The main categories of waste found in Mokolo are organics, plastics, glass, textiles, metals, paper and cardboard. Figure 20 illustrates these fractions.

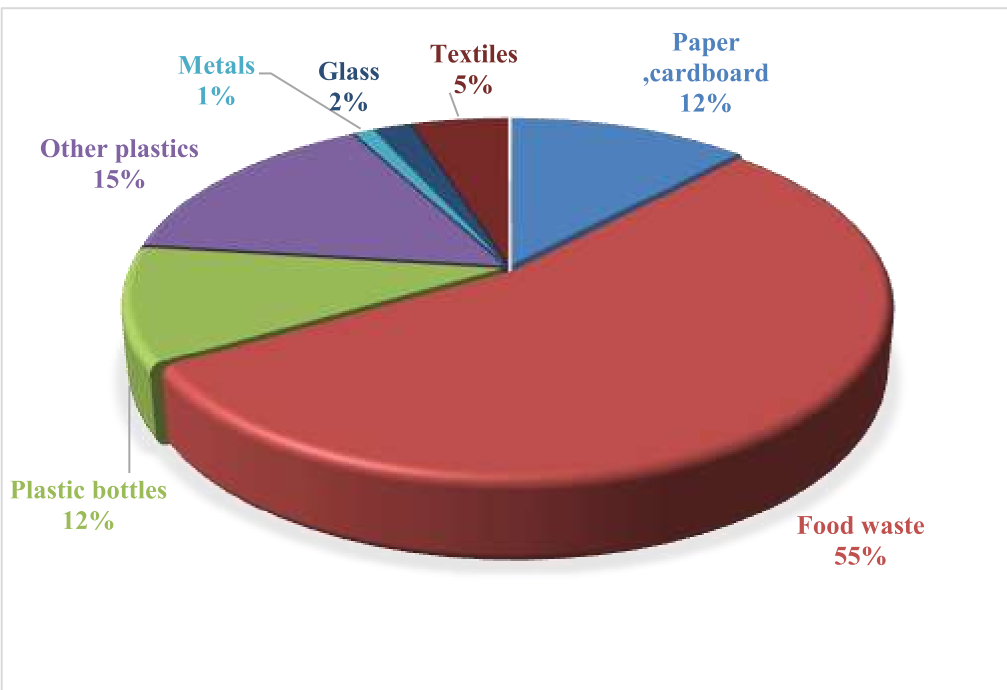

Figure 20: Waste categories in Mokolo Elobi

4.1.4.2. The informal sector

Although a lot of recycling takes place in this market, the amount of recyclable waste collected in this dump is very low, simply because waste recyclers obtain their waste from different sources. The amount of waste diverted from the dump by the informal sector is given in table 6. The table gives an estimate of the economic value that can be derived from the inorganic waste in the dump.

Table 6: Evaluation of the economic value that can be derived from waste in Mokolo-elobi

Waste fraction	Percentage (%)	Mass of fraction (kg)	Mass removed informally (kg)	Amount left (kg)	Average price per unit kg of waste (FCFA)	Economic value of the waste (FCFA/month)
Paper ,cardboard	12.0	54 000.0	-	54 000.0	5	270 000
Food waste	54.5	245 250.0	-	245 250.0		-
Plastic bottles	10.5	47 250.0	-	47 250.0	279	13 182 750
Other plastics	15.2	68 400.0	61 560.0	6 840.0	50	3 420 000
Metals	1.0	4 500.0	4 050.0	450.0	288	1 298 077
Glass	1.9	8 550.0	-	8 550.0	15	128 250
Textiles	4.9	22 050.0	-	22 050.0		-
Total					**18 299 077**	

From table 6, we note that the informal sector diverts very little waste from Mokolo. As the dump lies in the market, waste pickers generally do not refurbish themselves from this dump, they mobilize their activities around dumps that are found in residential area. The fraction that presents an interesting potential here is metals.

4.1.5. **Obobogo**

Situated in Yaoundé 3, the quarter grew very fast from 2013 when the road was built. Since no drop off point had been designed for the population; they started disposing of their waste along the roadside. Today, the dump covers a surface area of about 780 m². Figure 21 shows some pictures of the site.

Figure 21: The open dump in Obobogo

4.1.5.1. Waste categories and quantities

From the calculations described in the materials and methodology, we observe that the volume of waste accumulated in this dump is about 165.1m^3 per week. The main categories of waste found in this dump are textiles, inerts, metals, plastics, organics, paper and cardboard. These waste fractions are illustrated in figure 22.

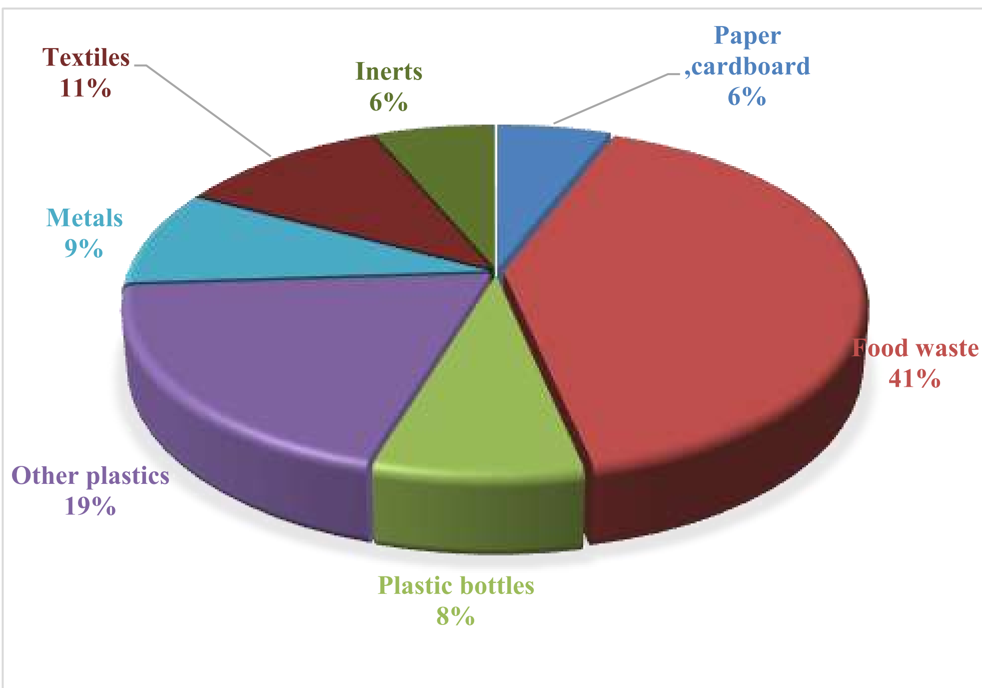

Figure 22: Waste categories in Obobogo

4.1.5.2. The informal sector

The amount of waste diverted from the dump by the informal sector is given in table 7. The table gives an estimate of the economic value that can be derived from the inorganic waste in the dump.

Table 7: Evaluation of the economic value that can be derived from waste in Obobogo

Waste fraction	Percentage (%)	Mass of fraction (kg)	Mass removed informally (kg)	Amount left (kg)	Average price per unit kg of waste (FCFA)	Economic value of the waste (FCFA/month)
Paper ,cardboard	5.8	26 842.2	-	26 842.2	5	134 211
Food waste	40.8	188 496.0	37 699.2	150 796.8		-
Plastic bottles	8.0	36 960.0	24 024.0	12 936.0	279	10 311 840
Other plastics	19.2	88 704.0	-	88 704.0	50	4 435 200
Metals	8.9	41 118.0	-	41 118.0	288	11 860 962
Textiles	10.8	50 080.8	5 008.1	45 072.7		-
Inerts	6.3	29 106.0	-	29 106.0		-
Total (FCFA)					**26 742 213**	

Very little waste is diverted from this dump. By diverting all the recoverable fractions from the dump, the fractions with the highest potential are plastic bottles and metals. The fractions other plastics and paper are not very cost effective as the price per unit is very low compared to the time required to collect 1 unit of the waste. As these fractions are contaminated by organics from the mixed waste stream, it is difficult to obtain good quality reusable material from the dump.

4.1.6. Etoug-Ebe

This dump exists since the installation of the first inhabitants in the neighbourhood. Two years after their arrival, a bin was placed, but its volume coupled with the collection frequency is insufficient for the ever-growing population. Figure 23 shows some pictures of the site.

Figure 23: Open dump in Etoug-Ebe

4.1.6.1. Waste categories and quantities

As seen on figure 23, the $20m^3$ bin present on the site is always full at the end of the day. This implies the volume accumulated in this dump in one day is about $20m^3$. The waste stream is composed of plastics, glass, textiles, metals, food waste, paper and cardboard. Figure 24 illustrates the main categories of waste found in this dump.

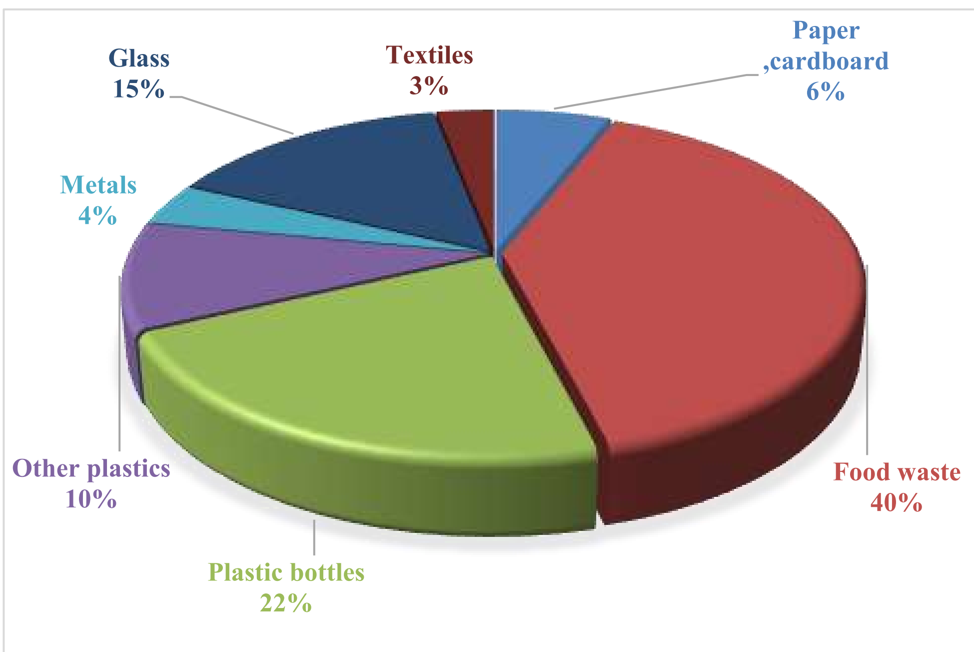

Figure 24: Waste categories in Etoug-Ebe

4.1.6.2. The informal sector

The amount of waste diverted from the dump by the informal sector could not be obtained; according to inhabitants of the neighbourhood, very little scavengers refurbish themselves at the dump. Table 8 gives an estimate of the economic value that can be derived from the inorganic waste in the dump.

Table 8: Evaluation of the economic value that can be derived from waste in Etoug-Ebe

Waste fraction	Percentage (%)	Mass of fraction (kg)	Mass removed informally (kg)	Amount left (kg)	Average price per unit kg of waste (FCFA)	Economic value of the waste (FCFA/month)
Paper ,cardboard	6	21 600	-	21 600	5	108 000
Food waste	40	144 000	-	144 000		-
Plastic bottles	22	79 200	-	79 200	279	22 096 800
Other plastics	10	36 000	-	36 000	50	1 800 000
Metals	4	14 400	-	14 400	288	4 153 846
Glass	15	54 000	-	54 000	15	810 000
Textiles	3	10 800	-	10 800		-
Total (FCFA)					**28 968 646**	

The presence of the informal sector was not identified here. Reuse/recycling of plastic bottles, metals and glass can be very cost effective if the fractions are diverted from this dump. Other plastics, paper and cardboard are not very cost effective as the price per unit is very low compared to the time required to collect one unit of the waste. These fractions are contaminated by organics from the mixed waste stream making it difficult to obtain good quality reusable material from the dump.

4.1.7. Akok-Ndoue

Akok Ndoue is a locality found in Yaoundé VI. The dump was created in the early 90s and has a trapezoidal shape with a surface area of about 542.4m². The dump is surrounded by a thick vegetation used for gardening and divided into two halves by a stream that runs across the quarter. The dump was created in the past due to the absence of roads for the collection company to reach the neighbourhood. Today, despite the presence of the road, the dump illustrated with figure 25 still exists because the company rarely collects here. Apart from dumping, the site serves for some other activities such as gardening, cattle rearing, and farming.

Figure 25: Open dump in Akok-Ndoue

4.1.7.1. Waste categories and quantities

Based on the calculations described in the materials and methodology (chapter 2), the volume of waste accumulated in this dump for a period of three months is about $1598m^3$. The waste stream in Akok-Ndoue is composed of metals, WEEE, inerts, food waste, plastics, paper and cardboard. Figure 26 illustrates the main categories of waste found in this dump.

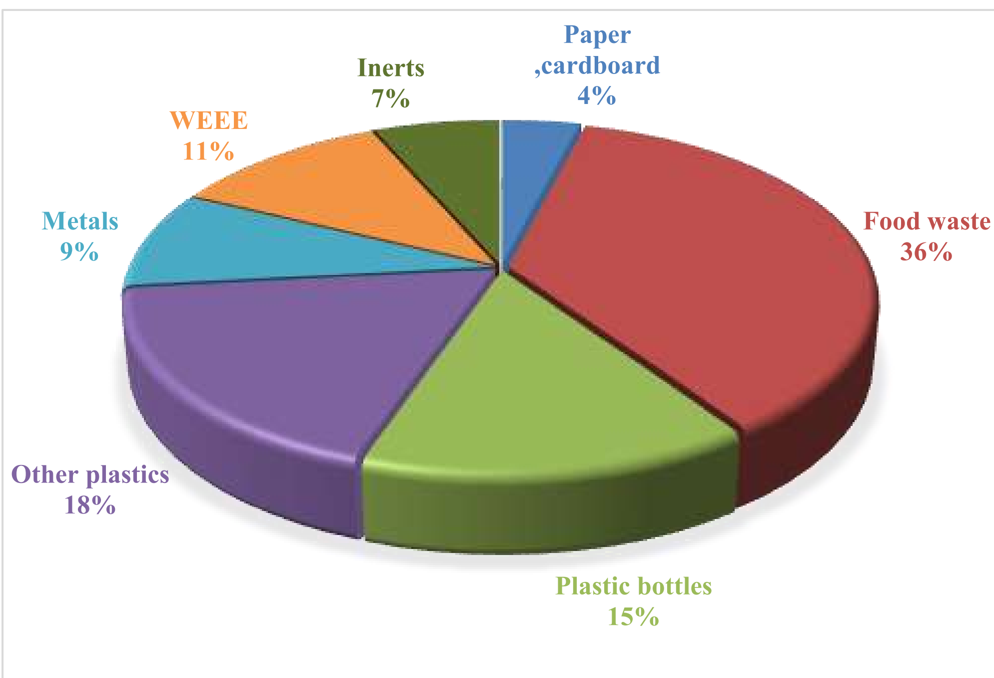

Figure 26: Waste categories in Akok-Ndoue

4.1.7.2. The informal sector

The amount of waste diverted from the dump by the informal sector could not be obtained; according to inhabitants of the neighbourhood, the most important fraction collected here are the organics, which serve as feed for the cattle. Table 9 gives an estimate of the economic value that can be derived from the inorganic waste in the dump.

Table 9: Evaluation of the economic value that can be derived from waste in Akok-Ndoue

Waste fraction	Percentage (%)	Mass of fraction (kg)	Mass removed informally (kg)	Amount left (kg)	Average price per unit kg of waste (FCFA)	Economic value of the waste (FCFA/month)
Paper ,cardboard	4.00	12 792.00	-	12 792.00	5	63 960
Food waste	36.50	116 727.00	-	116 727.00	-	-
Plastic bottles	14.75	47 170.50	-	47 170.50	279	13 160 570
Other plastics	18.00	57 564.00	-	57 564.00	50	2 878 200
Metals	9.00	28 782.00	-	28 782.00	288	8 302 500
WEEE	11.25	35 977.50	-	35 977.50	112	4 024 983
Inerts	6.50	20 787.00	-	20 787.00	-	-
Total					**28 430 212**	

The presence of the informal sector was not identified here. This can be explained by the position of the dump that makes access difficult. Reuse/recycling of plastic bottles, metals and WEEE can be very cost effective if the fractions are diverted from this dump. Other plastics, paper and cardboard are not very cost effective as the price per unit is very low compared to the time required to collect one unit of the waste. These fractions are contaminated by organics from the mixed waste stream making it difficult to obtain good quality reusable material from the dump.

4.1.8. **Hippodrome**

Located in Yaoundé I at the place named "derrière rue hippodrome", the dump was created for three main reasons:

- On the demand of a glass company named SOCAVER, to anonymous persons in 2014. These persons collected glass bottles from nightclubs, offices and individuals to resell them to the company. SOCAVER collected the bottles only during the period going from 2014 to 2015. Since then, about 200 glass bottles are deposited here each week. The manager of the site still succeed to sell some of the bottles to locals who reuse them for their activities.

- The second reason is the huge amount of construction waste found on the site, which comes from the neighbouring building site and according to some inhabitants.
- Finally, the accumulation of residential waste on the site.

Two years ago, the minister of housing and urban development ordered to clean the dumpsite and organized it as a small eco centre as seen on figure 27.


Figure 27: Eco-centre in hippodrome

4.1.8.1. Waste categories and quantities

Figure 28 illustrates the main categories of waste found here. The volume of waste was not calculated, because the site now serves as eco-centre and receives particular waste fractions. The portion of other waste fractions remaining is cleaned by HYSACAM and the population no longer dispose of their waste on the site.

The types of waste collected here are mainly construction and demolition wastes (gravel, bricks, plaster), metals and glass bottles. An inhabitant of the neighbourhood recognized by the council supervises the activity.

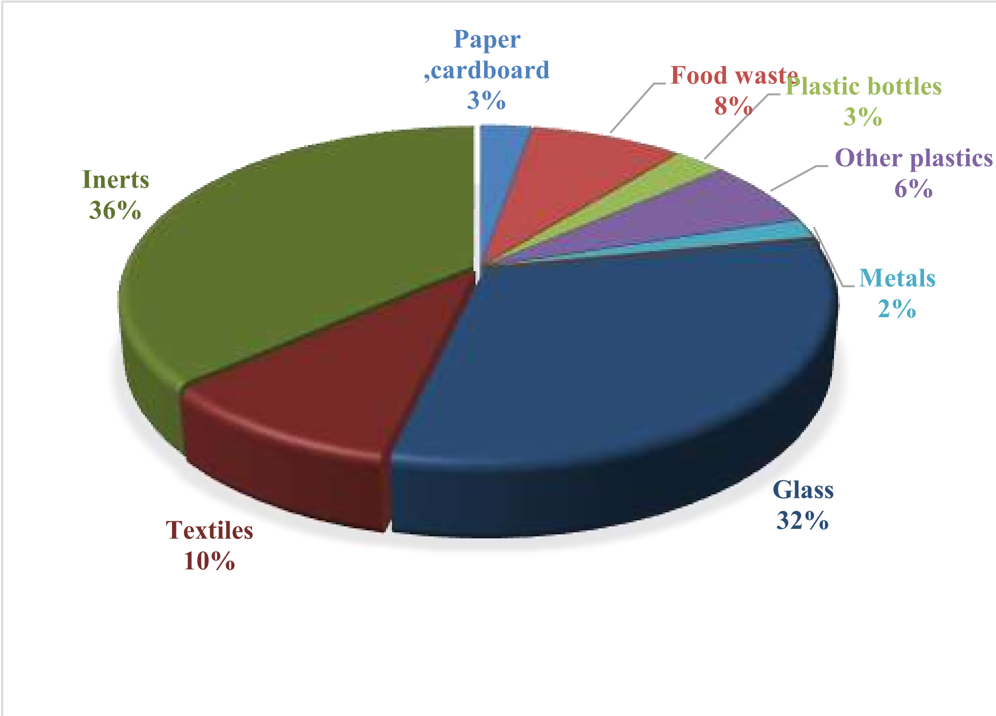

Figure 28: Waste categories in hippodrome

Tables 3 to 9 give an estimate of the economic value that can be derived from collecting and selling (informally) all the recoverable inorganic waste fractions from the different dumps. Overall, it is observed that the fractions presenting the highest potential are plastic bottles, glass, metals and WEEE. The fractions other plastics and paper are not very cost effective as the price per unit is very low compared to the time required to collect 1 unit of the waste.

In addition, in Yaoundé in particular and in Cameroon in general, papers and plastics (except bottles) generally reach the waste stream very contaminated and as there is no recycling industry for these fractions, the informal sector rarely engages in this. Recycling firms that use plastic waste use only bottles, as there is no need to segregate the plastic into the different types before processing. Concerning paper and cardboards, paper destined for reuse and recycling are collected directly at press prints and cardboards are reused in households and stores and only reach the dumpsites when they are damaged. This explains the very low cost applied to the sale of paper and cardboards in the recycling market in Mokolo. Textiles are also reused at household levels (by giving to family members or even to the needy); once it reaches a dump, a textile can no longer be reused.

4.2.Informal waste reuse and recycling in the Mokolo market

Informal waste reuse and recycling in the market takes place in the place called "Mokolo Elobi". The government does not recognise this activity: workers lack of a proper working space and do not benefit from any type of support. The revenue gained from this is just enough for them to live in a way that satisfies their needs, they have almost nothing left to ameliorate their working conditions. Lack of proper working space exposes the recyclers to adverse external conditions (sun, rain, theft), hardening their working conditions. In order to carry out their activity where they are settled, the recyclers pay 200 FCFA/day to the council.

Cleaning and sale of recovered waste fractions is the main activity carried out here. The following fractions were identified during our visit:

- plastic bottles of all kinds, volumes and dimensions (water bottles, soap, cosmetics);
- glass bottles (whisky, oil, cosmetics);
- metals (mostly aluminium) and
- WEEE.

Figure 29 illustrates the most important waste fractions recovered in Mokolo.

Figure 29: Waste fractions recycled by the informal sector in Mokolo market

Thirty-nine informal waste recyclers and repairers were interviewed in Mokolo and around. The interview aimed at knowing the types of waste collected, the quantity collected and sold as well as the price of the waste and of the recovered material. Figure 30 illustrates the count of informal actors that are involved in reuse/recycling of the different waste fractions

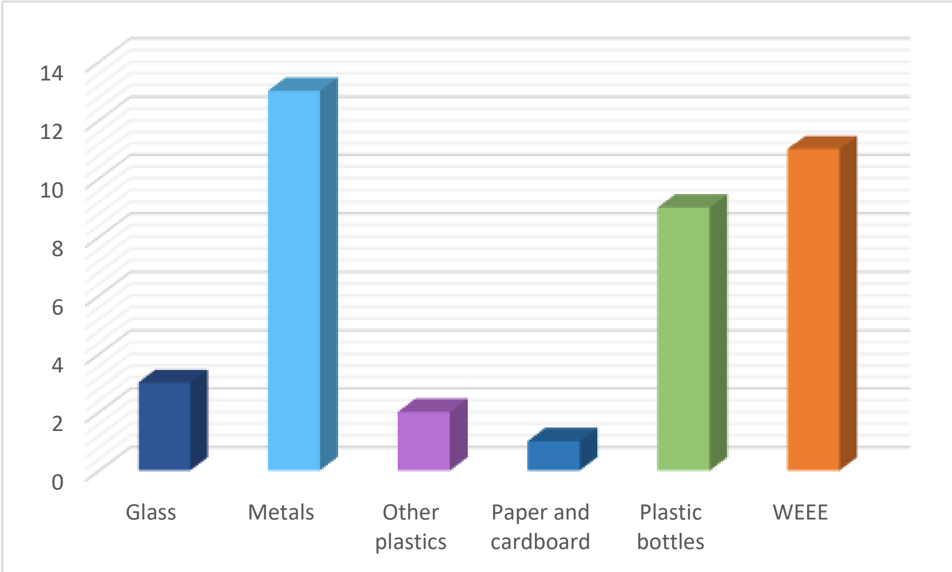

Figure 30: Count of informal actors involved in each waste stream

Plastic and glass bottles are cleaned and sold on site; aluminium is recycled and used to produce aluminium pots locally called “macocotte”.

All the reusers and recyclers buy the waste on site from informal collectors who move into the different neighbourhoods of the city, collecting the waste scraps from open dumps and buying from individuals that practice source segregation of their waste. The price of the waste is universal (all the recyclers buy the same waste type at the same price) and varies according to the volume.

Table 10 presents the origin of waste, the processes it undergoes, the recovered products as well as the waste that arises from the process.

Table 11 gives the average prices of the waste and recovered products.

Table 12 gives the lowest and highest of the waste and recovered products respectively.

Table 13 gives the average quantities collected and sold daily.

Figure 31 shows the monthly revenue obtained from the sale of recyclables.

Table 10: Informal recycling of waste in Mokolo market

Waste fraction	**Plastic bottles**	**Aluminium**	**Glass**	**WEEE**
Type	All types of plastics bottles irrespective of their volume and initial use	Old aluminium roofs Old car batteries	All types of glass bottles irrespective of their initial use	All sorts of WEEE Phones, chargers, kettles, irons, Cables
Origin	Bins, households, offices, neighbourhoods	Deposits	Bins, households, offices, neighbourhoods	Bins, households, offices, neighbourhoods
Process	Sorted, washed and sold	Sorted, melted, reprocessed	Sorted, washed and sold	Repair of damaged components
Products	Plastic bottles	Cooking pots	Glass bottles	New WEEE, Cu
Waste produced from the process (residues)	Water Damaged bottles	Earth Aluminium scraps Wood ash Smoke	Water Damaged bottles	Undesired electric components
Waste (residues) management	– Water: discharged on the spot or in the neighbouring bush – Unused bottles (very old, too dirty, damaged): thrown in the open dump present in the market	– Earth: comes from Mbalmayo. Washed, dried, reused and thrown away once it is too spoiled. – Aluminium scraps: reintroduced in the process. – Wood ash: used in the moulding process. – Smoke: goes to the atmosphere.	– Water: discharged on the spot or in the neighbouring bush – Unused bottles (very old, too dirty, and damaged): thrown in the open dump present in the market.	– Undesired electric components: thrown in the nearest dump. Some informal collectors take away these components and use/resell to others.

Table 11: Lowest and Highest prices of the waste and recovered products

Waste fraction	Lowest Price per unit (FCFA)	Highest Price per unit (FCFA)	Lowest Price per unit of the final product (FCFA)	Highest Price of the final product (FCFA)
Glass	10	20	25	50
Metals	0	500	300	1000
Other plastics	50	50	75	75
Paper and cardboard	5	5	25	25
Plastic bottles	5	10	10	20
WEEE	20	350	25	3000

Table 12: Average prices of waste and recovered products

Waste fraction	Average of Price per unit (FCFA)	Average of Price of the final product (FCFA)
Glass	15.0	33.3
Metals	288.5	630.8
Other plastics	50.0	75.0
Paper and cardboard	5.0	25.0
Plastic bottles	9.4	17.5
WEEE	111.9	900.5

Table 13: Average quantities of waste collected and of recovered product sold daily

Waste fraction	Average of Quantity of waste collected daily	Average quantity of final product sold daily
Glass (bottles)	117	83
Metals (kg)	398	438
Other plastics (kg)	40	30
Paper and cardboard (kg)	150	150
Plastic bottles	486	442
WEEE (unit of object	651	430

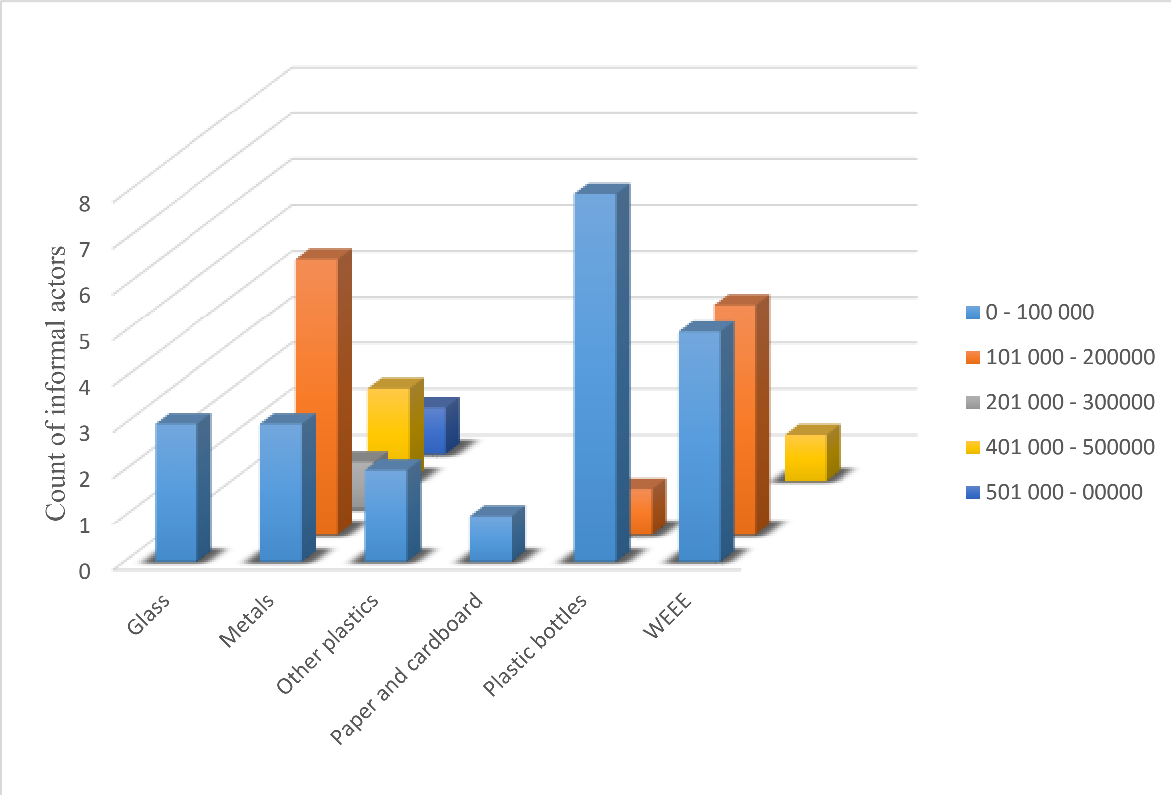

Figure 31: Monthly revenue in FCFA obtained from the sale of recovered products

Conclusion

This chapter presented some open dumps around the city of Yaoundé. The parameters that were used to describe the dumps are waste quantity and quality, collection frequency from the collection agent (HYSACAM), amount of waste diverted by the informal sector and economic value that can be derived from selling inorganic waste from the dumps. A study of the informal sector showed us that plastic bottles, glass bottles, metals (aluminium) and WEEE are the most recovered fractions with metals generating the highest revenue.

In the next chapter, five eco-centres will be designed based on the results presented in this chapter, each one of these will serve Mvog-Mbi, Obobogo, Kondengui, Mokolo & Briquetterie and Etoug-Ebe & Akok-Ndoue.

CHAPTER FIVE : DESIGN OF AN ECO-CENTER

Introduction

The aim of this chapter is to design a facility, as an approach to solve the problem earlier mentioned, due to the accumulation of large waste volumes in the cities. An eco-center was designed for each of the sites presented in chapter 3 (except for Hippodrome that is already an eco-center). The strategy adopted for the eco-center is the **3Ss** (sanitisation, subsistence economy and sustainable landfilling) with a particular focus on waste reduction. The eco-centres have different configurations depending on their functions.

5.1.The eco-center

An eco-center can be designed with four different functions: waste storage, waste valorisation, sale of recovered products and environmental sensitisation. The eco-center can have different configurations, from a simple storage place to a complex site for waste storage, reuse, repair and sale.

The eco-centers designed in this work were mainly for plastic bottles, metals, glass and WEEE. Workers also diverted other waste fractions according to quality and quantity whenever demanded or for personal use. Separated fractions were repaired, reused and/or recycled. The residues remaining after sorting are supposed to be collected by HYSACAM at least once per week.

Each open dump (described in chapter 3) will be replaced by an eco-center. Due to proximity of the dumps at Mokolo and Briquetterie, only one eco-center has been designed to serve the two neighbourhoods. The same principle has been applied for the dumps at Akok-Ndoue and Etoug-Ebe.

Recoverable fractions for reuse and repair from Obobogo and Kodengui were taken to Mvog-Mbi for repair and resale; those from Etoug-Ebe & Akok-Ndoue were taken to Mokolo. Transportation is done using tricycles. Table 14 summarises the configuration of the different eco-centres.

Table 14: Configuration of the different eco-centres

Eco-centre	**Configuration**
Kondengui	Storage and separation
Obobogo	Storage and separation
Mvog-Mbi	Storage and separation, repair and reuse market
Etoug-Ebe + Akok-Ndoue	Storage and separation
Briquetterie + Mokolo	Storage and separation, repair, reuse market, recycling

Figure 32 illustrates the eco-centre and their different configurations.

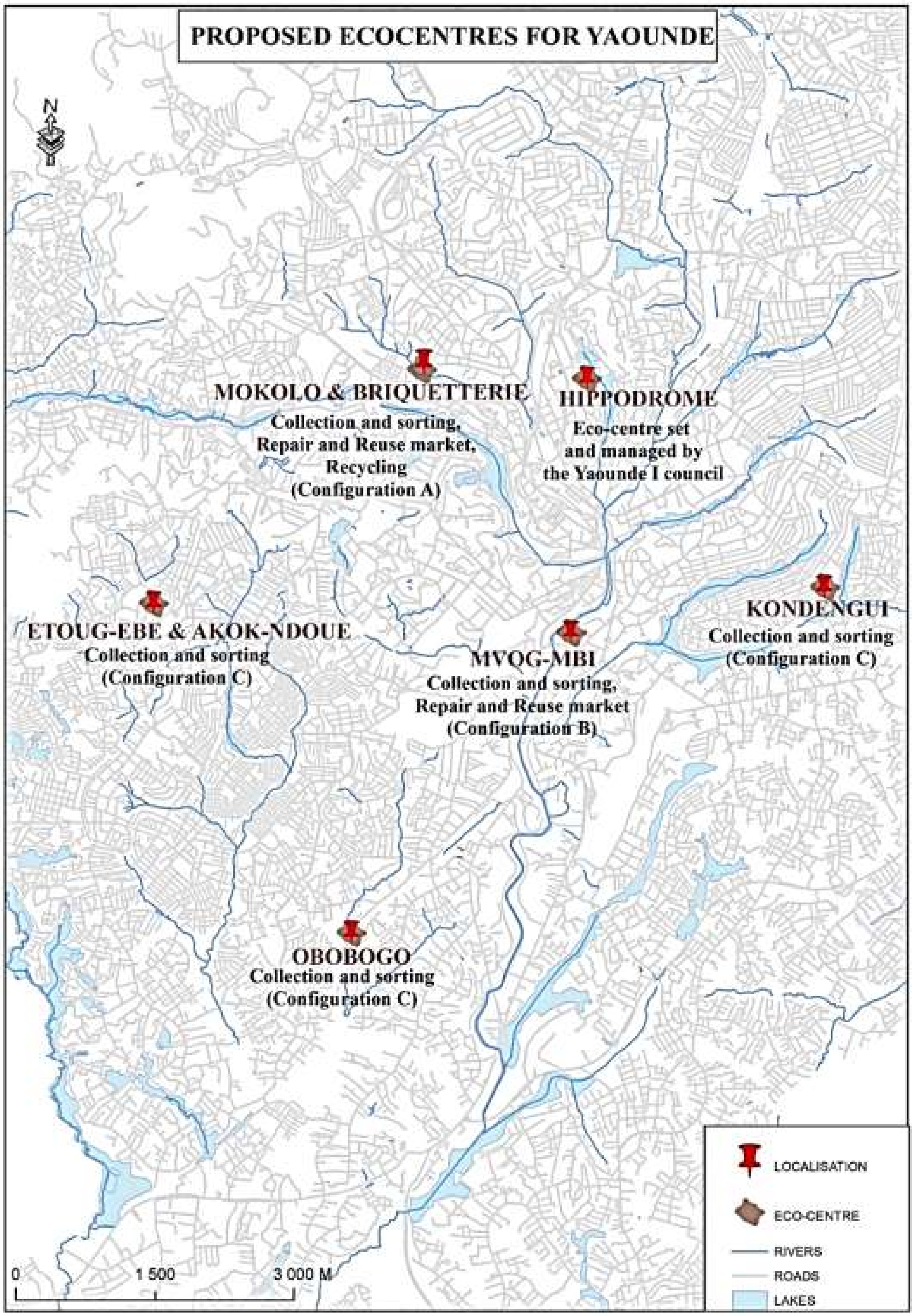

Figure 32: Location of the proposed eco-centres

Figures 33 and 34 are the 2D plans of the two main configurations (configuration B and C). Configuration A has the same 2D plan as configuration B. The only difference between configurations A and B is the fact that configuration A is associated to recycling units out of the centre. The 2D plans were drawn from the dimensions of Mokolo and Obobogo respectively.

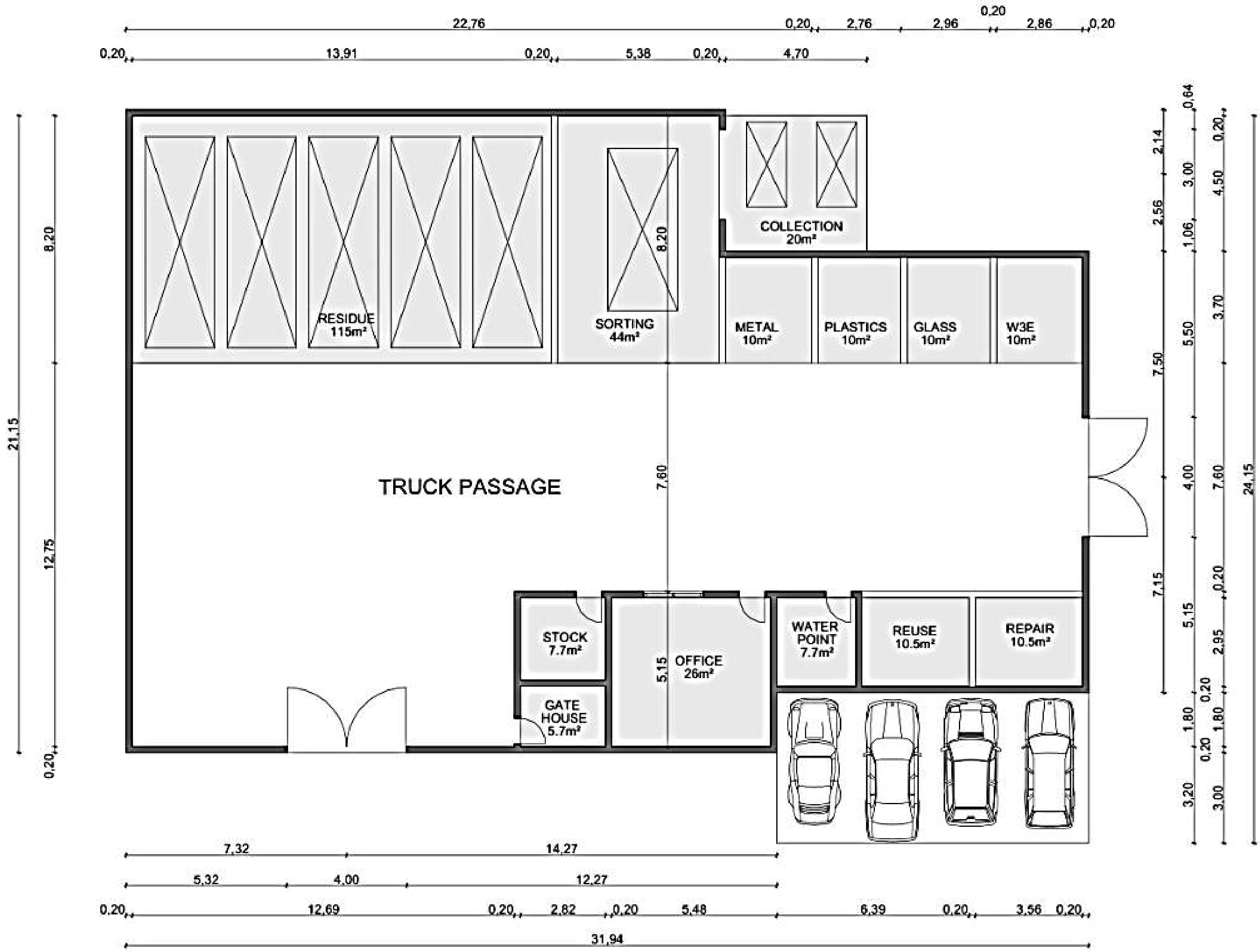

Figure 33: 2D plan of eco-centre with configurations A and B

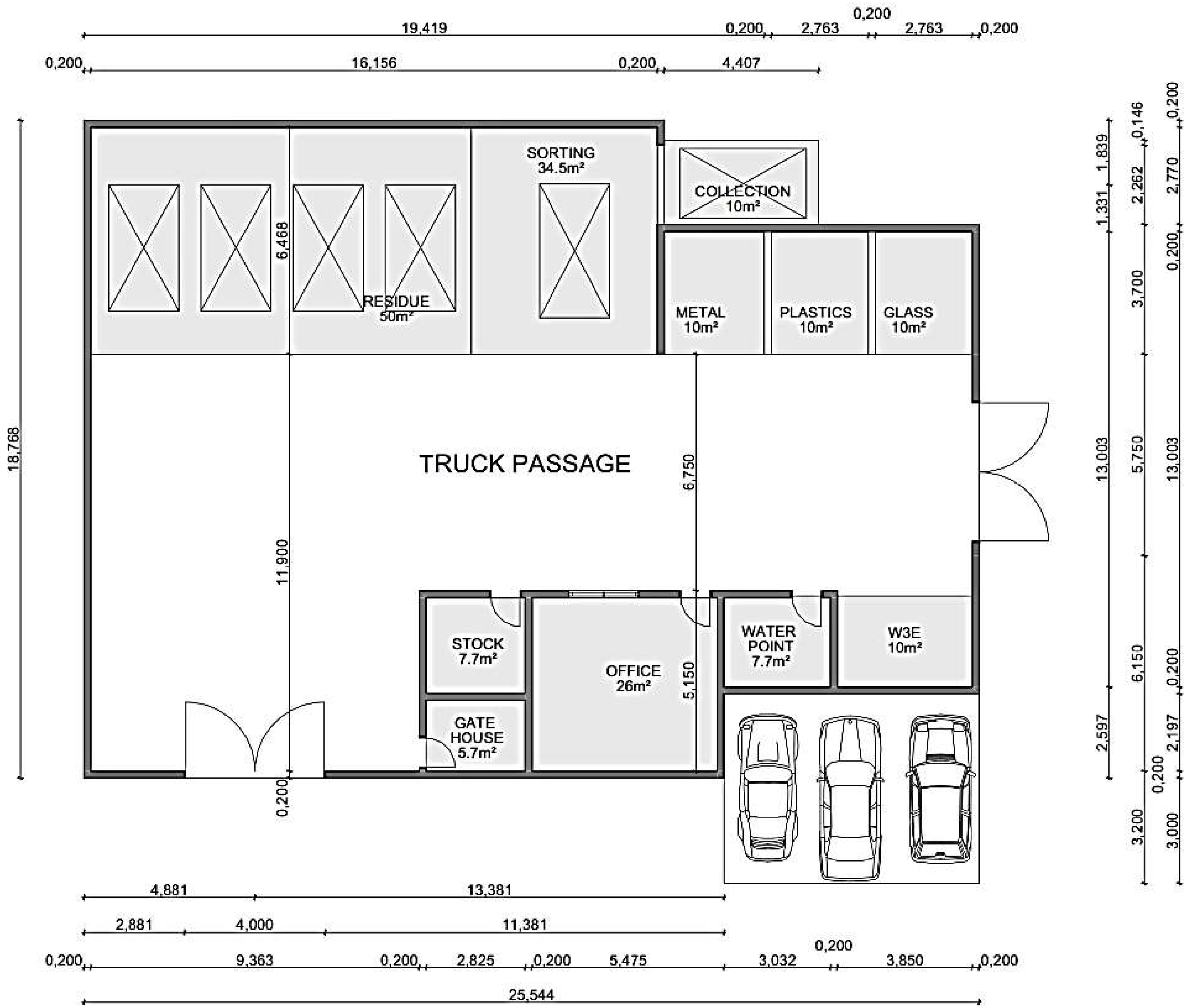

Figure 34: 2D plan of eco-centre with configuration C

5.1.1. The collection and sorting unit

This corresponds to waste entrance and sorting of the conceptual scheme shown in figure 31.The collection and sorting unit is made of three main areas (units), a space for collection (of the mixed waste fraction and residues), a space for sorting, and a storage room for the recoverable fractions.

Collection of the mixed waste fractions

The mixed waste stream was stored temporarily in a $6m^3$ container prior to sorting.

The amount of waste that reaches the site daily was gotten from the volume of waste accumulated in the dump in one month using equation 6.

The space needed for collection of mixed waste was calculated using equations 7 to 10 described in the methodology and the results obtained are presented in table 15.

Table 15: Estimation of the space needed for the collection unit

	Mvog-Mbi	Mokolo & Briquetterie	Etoug-Ebe & Akok-Ndoue	Kondengui	Obobogo
Number of opening days	7	7	7	7	7
Collection frequency (days)	1	1	1	1	1
Collection efficiency	85%	85%	85%	85%	85%
Volume of bins V_b (m^3)	6	6	6	6	6
Surface area occupied by a bin A_b(m^2)	6.84	6.84	6.84	6.84	6.84
Mass disposed daily M_d ($kg/$	4 100	30 000	22 660	56 400	15 400

$day)$					
Daily volume V_d (m^3/day)	6.83	50	37.77	94	25.67
Actual volume collected V_c (m^3)	5.80	42.5	32.10	79.9	21.82
Number of bins N_b	1	2	2	2	1
Surface area for collection of mixed waste A_c (m^2)	**10**	**20**	**20**	**20**	**10**

Figure 35 illustrates the dimensions of the skip used for collection of the mixed waste fraction.

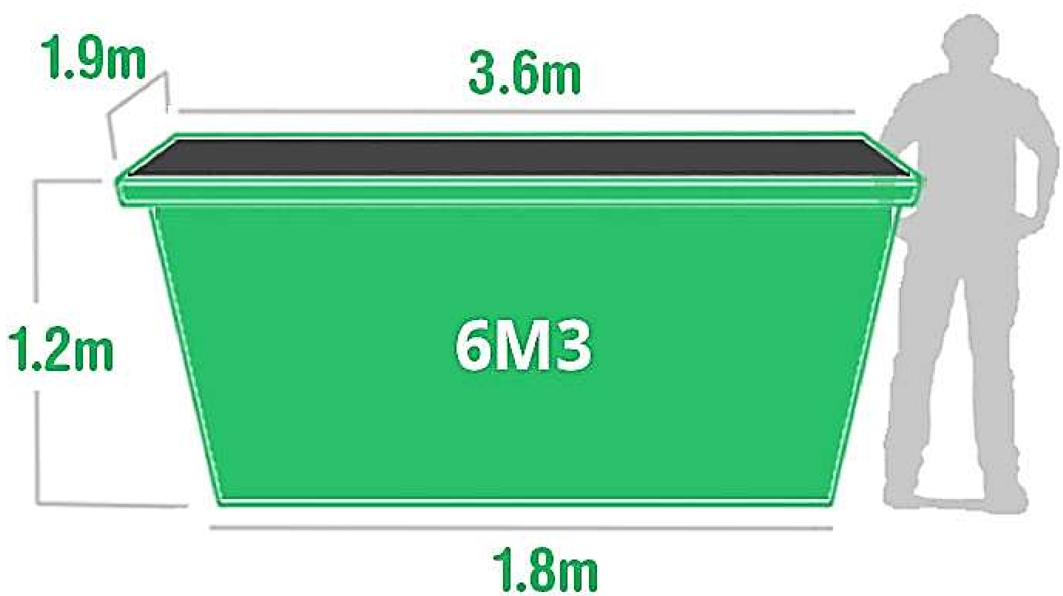

Figure 35: Dimensions of skip used for collection of the mixed waste stream. (Evergreen waste[9])

Sorting

[9] https://evergreenwaste.co.za/services/

Sorting was done manually on a platform. The mixed waste was spread on the table and different fractions separated by positive sorting. Sorting operations comprised of:

- unloading the waste;
- manually (with protective measures) spreading the waste;
- hand picking (with protective measures) visually identifiable waste ;
- collecting and stockpiling the remaining waste.

Figure 36 shows the dimensions of sorting platform.

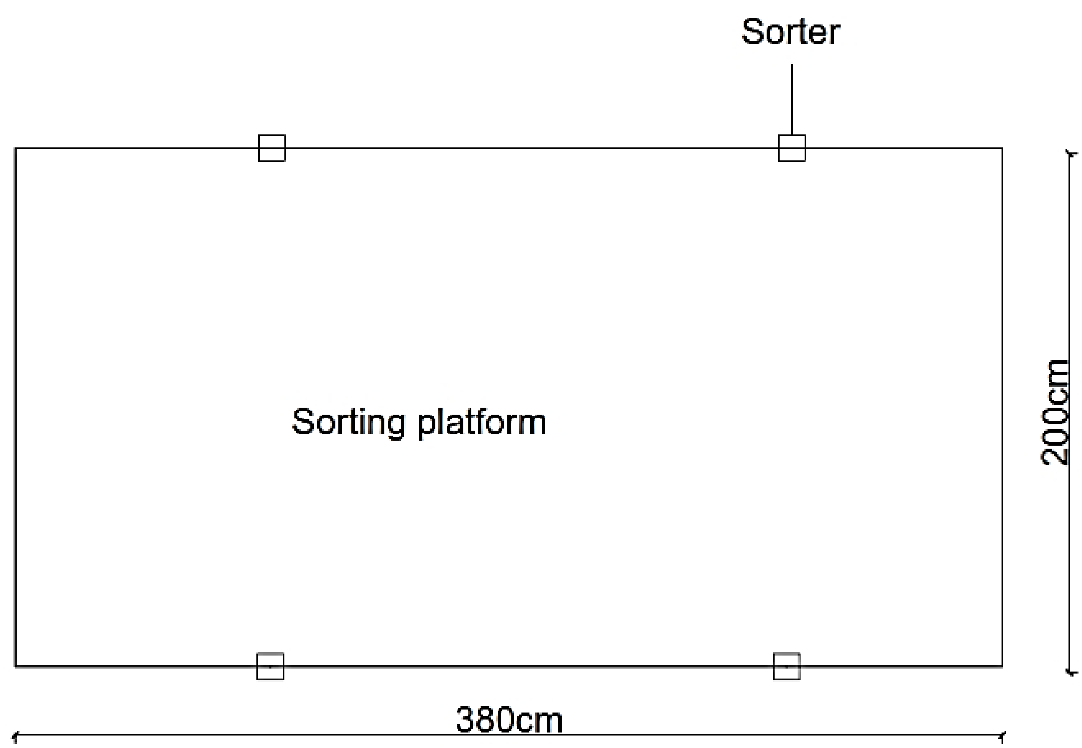

Figure 36: Dimensions of the sorting platform (left). Example of a sorting conveyor (right). (Steep Hill Equipment Solutions[10])

Taking the segregation efficiency at 90%, the actual mass of the different fractions that were recovered by manual sorting are given by equation 11 and presented in table 16. The space required for storage of the residues prior to final disposal was designed using equations 12 and 13 and

[10] https://www.steephillequipment.com/equipment-listings/conveyors/belt-conveyor/9-modular-belt-conveyor/

presented in table 17.

Table 16: Segregated amount of the different fractions

Neighbourhood	Waste fraction	Plastic bottles	Glass	Metals	WEEE
Mvog-Mbi	Mass of fraction (kg)	414.1	-	142.27	98.40
	Amount segregated (kg)	372.69	-	128.04	88.56
	Residues left (kg)	3510.70			
Mokolo & Briquetterie	Mass of fraction(kg)	2 538	435	1 531.5	153
	Amount segregated (kg)	2 284.2	391.6	1 378.35	137.7
	Residues (kg)	25 808.25			
Etoug-Ebe & Akok-Ndoue	Mass of fraction (kg)	2 132.35	1 800	1 439	1 199.25
	Amount segregated (kg)	1 295.46	1 620	3 791.12	1 079.33
	Residues(kg)	14874.1			
Kondengui	Mass of fraction (kg)	10 755.48	958,8	2 650.8	-
	Amount segregated (kg)	9 679.93	862.92	2 385.72	-
	Residues	43 471.428			
Obobogo	Mass of	1 232	-	1 370,6	-

	fraction (kg)				
	Amount segregated (kg)	1 108.8	-	1 233.54	-
	Residues (kg)	13057.66			

In cases where the fractions were very dirty (contaminated), segregation was followed by pre-cleaning.

Table 17: Estimation of the space needed for storage of the residues

	Mvog-Mbi	**Mokolo & Briquetterie**	**Etoug-Ebe & Akok-Ndoue**	**Kondengui**	**Obobogo**
Days between collection	3.5	2.3	3.5	7	7
Residual volume (m^3)	20.48	100.35	253.58	169.05	76.17
Volume of bins V_b (m^3)	20	20	20	20	20
Surface area of a bin $A_b (m^2)$	12	12	12	12	12
Number of bins N_b	1	5	5	13	4
Surface area for collection of residues A_c (m^2)	**15**	**70**	**70**	**180**	**50**

Storage of recoverable fractions

Segregated fractions obtained after sorting were kept in separate boxes prior to repair, sale and recycle. These boxes have a generic area of 8m² and 10m² depending on the configuration and the amount of waste received at the centre. Recoverable material from eco-centres C will be taken to eco-centres A and B. Table 18 gives the amount of recoverable waste that has to be transported from the collection unit to the recycling and repair unit. This amount was calculated with equation 14.

Table 18: Amount of recoverable waste transported to the reuse/recycling unit

	Mvog-Mbi	**Mokolo & Briquetterie**	**Etoug-Ebe & Akok-Ndoue**	**Kondengui**	**Obobogo**
Amount to transport **T** (kg)	142.27	-	7 785	12 928.57	2 342.34

5.1.2. The reuse/repair/recycling unit

The main activity of this unit is cleaning and sale of recovered fractions for plastic and glass, repair and sale of WEEE. Metals are taken to a recycler who turns them into pots. Some parts of the WEEE are also recycled to recover copper. The unit consists of a space reserved for cleaning of the incoming waste, repair of some parts and sale of the final products.

The cleaning space was covered and equipped, had a water supply and is intended for washing plastic and glass bottles or any other fraction that requires cleaning.

Table 19 gives an estimation of the spaces needed for cleaning and repair.

Table 20 presents the space requirement for construction of the different eco-centres. The table also gives a summary of the different areas required for each unit.

Table 19: Estimation of spaces needed for cleaning and repair

	Mvog-Mbi	**Mokolo & Briquetterie**
Surface area for cleaning(m^2)	10	10
Surface area for repair(m^2)	10	10

Table 20: Different sections of the eco-centre and their areas

	Mvog-Mbi	**Mokolo & Briquetterie**	**Etoug-Ebe & Akok-Ndoue**	**Kondengui**	**Obobogo**
Surface area for collection of waste(m^2)	10	20	20	20	10
Surface area for collection of residues (m^2)	15	70	70	180	50
Surface area for segregation (m^2)	34	37.2	37.2	37.2	34
Surface area for offices (m^2)	30	30	30	30	30
Surface area for reuse and repair (m^2)	20	20	-	-	-
Surface area left for circulation(m^2)	300	300	300	300	300
Net area (m^2)	441	517.2	457.2	607.2	456
Space requirement($\boldsymbol{m^2}$)	**450**	**550**	**500**	**650**	**500**

5.2. Sustainability analysis of the proposed solution

Today, every project should be a step to meet at list one sustainable development goal. To ensure a project's sustainability, the three pillars of sustainable development: environmental friendly, economic prosperity and social equity should be met. The proposed solution is a step to meet SDGs 1, 3, 6, 8, 11 and 12. Figure 34 illustrates the interaction between the three pillars of sustainable development.

Figure 37: The three pillars of sustainability[11]

5.2.1. Environmental protection

Environment in this context refers not only to nature but also to man's immediate environment. With the rise of climate change, increase in global warming, and depletion of resources, many tools have been put in place to foster environmental protection. Some of these are waste reduction methods such as the circular economy defined by the 3Rs in the developed world and the 3S for developing economies. These tools have as main aim to ensure a safer environment by reducing the amount of landfilled waste hence reducing greenhouse gas emissions. The following lines explains how the eco-centre ensures environmental protection.

❖ **The 3S (Sanitisation, Subsistence economy, Sustainable landfilling)**

Sanitisation: aims at improving living conditions by ensuring a cleaner and safer environment to the community and workers. The eco-centre ensures sanitisation of the environment by providing a cleaner facility for waste disposal, a proper workspace for scavengers employed to run

[11] https://www.futurelearn.com/info/courses/sustainability-society-and-you/0/steps/4618

the facility and reduction of landfilled waste volumes by reuse and recycling of waste.

Subsistence economy: is ensured by returning waste as a resource to the economy and including the informal sector in a remunerated and formalised way. Reuse and recycling of inorganic waste fractions is the main aim of setting the eco-centre. These recovered waste are later sold. Collection, reuse/recycling and sale of the waste and recovered products is ensured by the informal actors.

Sustainable landfilling: HYSACAM collects unused waste from the eco-centres as well as residues from the different processes for disposal at the landfill. By reducing the amount of waste going to the landfill, the area needed for landfilling also decreases giving space for more non-recoverable waste to be landfilled. Diverting metals from the landfill prevents leachate contamination by these.

- **Raw material preservation**

Resource recovery enhances virgin raw material preservation. By using old damaged products to make new ones, repairing and reusing, the need for new raw material decreases. This has an impact on the emission of Green Houses Gases (GHG) that are highly emitted during the extraction of virgin raw material.

5.2.2. Social equity

The aspects of our work that favoured social equity are:

- **Education**

The eco-centre is also facility that aims at educating people on waste and sustainable waste management actions. Sensitisation campaigns will be organised at the centre to initiate the population to waste reduction at home, source separation and the importance of waste management for their health and environment.

- **Equity in Social Economy**

Equity in the social economy is the consideration of the social status of each inhabitant for him to profit from the centre. The centre is open and receives waste from everybody irrespective of their social status.

- **Job creation**

Implementation of our project will provide a stable job to some scavengers.

5.2.3. Economic prosperity

Economic prosperity being one of the factors affecting sustainability of a project, its analysis on a good length of time has to be done thoroughly. This analysis has as aim to get the economic profit out of this project and the time of return of investment of the project. The objective being to determine the cost of implementing an eco-centre and comparing with the economic value that can be derived from the waste. The cost analysis presented here is for the construction of the eco-centre at Mokolo & Briquetterie.

I. Initial investment

The initial investment takes into account the material purchase cost, its installation fee and manpower of the project. Tables 21, 22, 23 and 24 show the quantitative estimates for construction, collection, transport, sorting, reuse, repair and furnishing office tools.

Table 21: Estimation of the cost of construction of the eco-centre

Designation	Unit price (FCFA)
Preparatory works	553 824
Structural works	15 289 160
Finished work	3 920 000
Plumbing and sanitation	1 210 000
Electricity	750 000
Total	**21 722 884**

Table 22: Estimation of the cost of collection and transport

Designation	Quantity	Unit price (FCFA)	Total price (FCFA)
Collection bin (6m^3)	2	700 000	1 400 000
Collection bin (20m^3)	5	1 000 000	5 000 000
Storage bags (100kg)	100	150	15 000
Tricycle	1	1 500 000	1 500 000
Total		**7 915 000**	

Table 23: Evaluation of the cost of sorting, repair and reuse

Designation	Quantity	Unit price (FCFA)	Total price (FCFA)
Sorting platform	1	100 000	100 000
IPE	10	28 750	287 500
Weight balance	1	100 000	100 000
Cleaning materials	1	250 000	250 000
Repair tools	1	100 000	100 000
Total		**837 500**	

Table 24: Evaluation of the cost of setting the office

Designation	Quantity	Unit price (FCFA)	Total price (FCFA)
Computer	1	100 000	100 000
Office tools	1	50 000	50 000
Furniture	1	50 000	50 000
Total		**200 000**	

II. Project total cost

The total cost of the project is simply the initial investment. This gives a value of **30 675 384 FCFA** as total cost of the project.

III. Exploitation and maintenance cost

Pay roll

This refer to the human force necessary to run the eco-centre. Twelve people will be employed here, distributed as shown in table 25.

Table 25: Estimation of the cost of human resources

Role	Number	Annual wage (FCFA)	Total (FCFA)
Sorters	4	1 200 000	4 800 000
Repairer	4	1 800 000	7 200 000
Driver	1	600 000	600 000
Manager	1	1 200 000	1 200 000
Gateman	2	600 000	1 200 000
Total		**15 000 000**	

The centre has to kept cleaned and devices taken care off. The sorting platform is immobile so needs less maintenance. For the mobile equipment, we have the tricycle, bins, basins, buckets. Detergents, bags and sponges have to be replaced once they are used out. From Ondo (2019) the maintenance cost of a system is usually 1% of the initial investment. This is valued at **306 754 FCFA** annually.

In order to obtain the economic benefits of the project and to see whether it is attractive, we will proceed in the calculation of the cash flow and the Net Present Value.

IV. Cash-flow

From the amount of waste received from the dump, and the average prices of the sale of recoverable material, the monthly revenue generated by the eco-centre is calculated and presented in table 26.

Table 26: Economic value generated by the eco-centre

Waste fraction	Quantity (kg)	Average Price (FCFA)	Total cost (FCFA)
Plastic bottles	2 284.20	542.5	1 239 179
Glass	391.6	33.33	13 052
Metals	1378.35	288	396 965
WEEE	137.7	900.5	123 999
Total (FCFA)		**1 773 194.178**	

This gives an annual revenue of **21 278 330.14 FCFA.**

The cash flow is defined as the difference between the revenue generated and the expenses (exploitation and maintenance cost). As such the annual cash flow of the eco-centre is **5 971 576 FCFA.**

V. Net present value (NPV)

This permits us to determine whether an investment is profitable or not. A positive value mean the project is profitable.

NPV= -Io +$\sum_{i=1}^{n} CFi/(1+t)^\wedge i$

With;

Io: initial investment

CFi: Cash Flow for the year i

t: updating rate (3%)

n: project's lifespan

Table 27 was obtained by calculating an NPV for 10 years.

Table 27: NPV of the project for 10 years

Year	Cash flow	NPV (FCFA)
1	5 971 576	-24 877 737
2	5 971 576	-19 080 090.80
3	5 971 576	-13 282 444.19
4	5 971 576	-7 484 797.59
5	5 971 576	-1 687 150.99
6	5 971 576	4 110 495.61
7	5 971 576	10 082 071.61
8	5 971 576	16 053 647.61
9	5 971 576	22 025 223.61
10	5 971 576	27 996 799.61

VI. Profitability index

It helps calculate the value created by the investment. It is given by:

Ip = 1 + NPV/Io

We then get Ip = 1 + 27 996 799.61/30 675 384

= **1.91**

VII. Return on investment time

This represents the time difference between the investment and the cumulated return of the same amount due to the project. It can be gotten graphically as shown in figure 38.

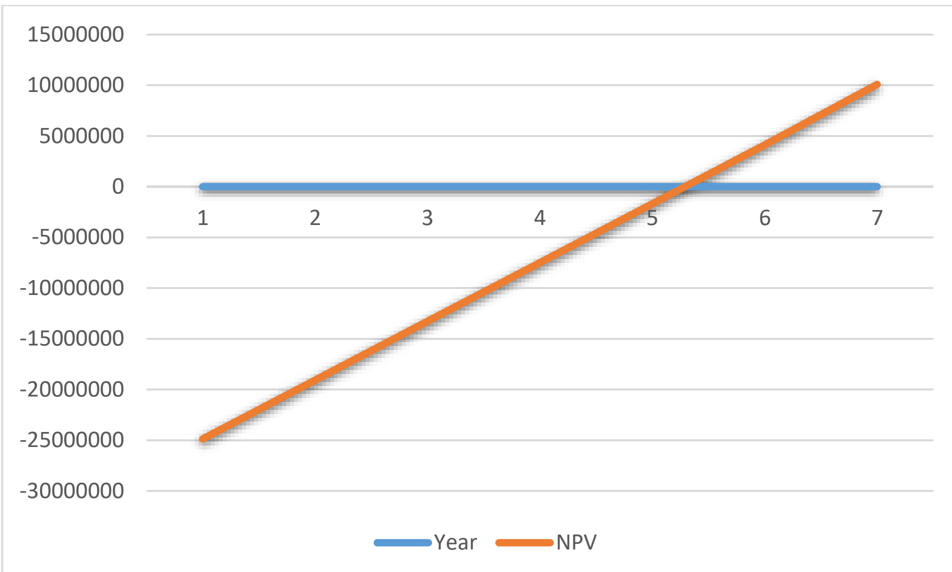

Figure 38: Return on investment graph (Time and NPV curves represented)

Conclusion

In this chapter, we were called on to design eco-centres for waste collection and recovery in some neighbourhoods of Yaoundé. An eco-centre that deals with waste collection, reuse, recycle and repair can be designed and ran with an initial investment of **30 675 384 FCFA**. The sustainability values of the project were later on evaluated. The eco-centre contributed to sanitisation of the environment, upgrading the working conditions of the informal sector actors and has a profitability index of 1.91. The return on investment period of the project was 6 years.

GENERAL CONCLUSION AND PERSPECTIVES

This research work suggested a new approach for solving part of the problem of waste management with a specific focus on improving the working conditions of scavengers in the city of Yaoundé, Cameroon. The main objective was to propose a model of eco-center Yaoundé as a solution to open dumping in some parts of the city and provide a more organised and healthier working environment for the scavengers. To meet this objective, the following specific objectives were identified: evaluation of the open dumps in Yaoundé, assessment of the participation of scavengers in waste recovery, design a model of eco-centers for Yaoundé.

The research went through documentary research and visual observation to identify some important open dumps in the city of Yaoundé. Two surveys were carried out to study the open dumps and evaluate informal waste recovery in Yaoundé. The first survey focused on waste quantity and quality, collection frequency and scavenger's activities at the open dumps. The second survey that took place at the Mokolo market informed us on the amount of waste collected and sold daily, the price of the waste and recovered products, recovery process and its impacts on the environment and health and finally the monthly revenue obtained from the sale of recoverables.

Open dumping in Yaoundé is mainly due to the lack of proper collection methods; low collection frequency from the waste collection company and uncontrolled urbanization. Inorganic waste fractions from these dumps can be diverted and recovered in a more formal way. In general, a waste recycler earns an average monthly revenue of 50 000 FCFA from plastic and glass bottles, 150 000 FCFA from WEEE and 300 000 FCFA from recycling of aluminium.

Creating eco-centres in replacement of open dumps will sanitise the environment ensuring better health conditions for the community. The center is ran by scavengers from the community, improving their living and working conditions as it provides a proper work environment and more important wages. The eco-centre creates a direct link between the scavengers, the waste recyclers and the clients. The eco-center proposed in the course of this work is sustainable and contributes to SDGs 1, 3, 6, 8, 11 and 12.

The way forward

In order to complete the present work and improve the quality of the results obtained, the following should be done:

- design of a community compost plant at Akok-Ndoue to transform organics from the different eco-centers;

- design of source segregation of waste from the different neighbourhoods to improve the efficiency of the eco-centers;
- promote the use of eco-centres as a solid waste management tool by the city council,
- recycling unit for aluminium and copper should be designed and included in the full configuration of the eco-centre.

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APPENDICE

(I)

QUESTIONNAIRE CONCERNING SOME OPEN DUMPS IN THE CITY OF YAOUNDÉ

(Please give me 5 minutes of your time and help me answer to these questions// *S'il vous plait accordez moi 5 minutes de votre temps et aidez-moi à répondre à ces questions*)

In which Neighbourhood do you live? ________________________________
Dans quel quartier résidez-vous?

Gender? MALE ☐ FEMALE ☐
Sexe? MASCULIN FEMININ

Your status: Resident ☐ Trader ☐ Both ☐
Votre statut: Résident Commerçant Les deux

Do you live with a family? YES ☐ NO ☐
Habitez-vous en famille? OUI NON

If yes, how many people make up your family? ________________________________
Si oui, combien êtes-vous dans votre famille ?

HISTORY OF THE SITE/HISTORIQUE DU SITE

How long have you here (on the site)? ________________________________
Depuis combien êtes-vous ici (près du site)?

Where do you dispose of your waste? Here ☐ Elsewhere ☐
Où jetez-vous vos ordures ? Ici Ailleurs

____

Why do you drop your waste here?
Pourquoi videz-vous vos ordures ici?

No nearby bin ☐ Community decision ☐
Pas de poubelle proche Décision communautaire

The dump was there when I arrived ☐ Other ☐
La décharge existait à mon arrivé Autres

____

Did the dump exist on your arrival? YES ☐ NO ☐
La décharge existait-elle déjà avant votre arrivée ? OUI NON

If yes, How was it? ________________________________
Si oui, Comment était-elle ?

Was the shape and size different from what it is now? YES ☐ NO ☐
Avait-elle une forme différente de l'actuelle décharge? OUI NON

What was the site used for before becoming a dump? ________________________________
Que représentait le site avant d'être une décharge

Does HYSACAM collect waste in this quarter? YES NO
HYSACAM collecte les déchets dans ce quartier ? OUI NON

If yes, how? ____________________
Si oui, comment ?

When was the last time HYSACAM cleaned? ____________________
À quand remonte la dernière fois que HYSACAM a nettoyé ?

ABOUT THE WASTE/A PROPOS DES DECHETS

Which type of bin do you use?
Quel type de poubelles utilisez-vous ?

Old bag / Vieux sac — Old bucket / Vieux seau — Waste bag / Sac poubelle — Other / Autre

____

How many bins do you have in your home? ____________________
Combien de poubelles utilisez-vous?

What is its volume? 5L 30L
Quel est son volume?

How long do you take to fill it? 1 day 3 days 1week
En combien de temps la remplissez-vous ? 1jour 3jours 1semaine

Generally, what makes up your waste?
En général, de quoi est constitué vos déchets ?

TYPE	**TICK /** ***COCHEZ***	**Qty (high, medium, low)** ***Qte (haute, moyenne, basse)***
Paper ,cardboard/ *papier* ,carton		
Food waste/ déchets alimentaires		
Plastic bottles/Bouteilles plastiques		
Metals/métaux		
DEEE/WEEE		
Glass/Verre		
Textiles/Textiles		
Others/ Autres		

____

Do you separate your waste? YES NO
Triez-vous vos déchets? OUI NON

INFORMAL SECTOR/SECTEUR INFORMEL

Is there anyone that collects waste here? YES NO NO IDEA

Quelqu'un collecte-t-il les ordures ici ? *OUI* *NON* *AUCUNE IDEE*

What does he collect?
Que collecte-t-il ?

Waste *Déchet*	YES *OUI*	NO *NON*
Paper and Cardboard *Papier et carton*	☐	☐
Plastic bottles *Bouteilles plastiques*	☐	☐
Any plastic material *Tout type de plastiques confondus*	☐	☐
Metals *Métaux*	☐	☐
Glass *Verre*	☐	☐
WEEE *DEEE*	☐	☐
Textiles *Textiles*	☐	☐
Food waste *Déchet alimentaire*	☐	☐
Other Autre	☐	☐

____

For which purpose does he collect? ______________________
Pourquoi les collecte-t-il ?

What is his final product? ______________________
Quel est son produit fini ?

Do you know him personally? YES ☐ NO ☐
Le connaissez-vous personnellement ? *OUI* *NON*

Thanks for your participation// Merci pour votre participation

(II)

QUESTIONNAIRE TO UNDERSTAND THE COLLECTION AND RECYCLING ACTIVITY OF THE INFORMAL SECTOR IN THE MOKOLO MARKET

(Please give me 5 minutes of your time and help me answer to these questions// S'il vous plait accordez moi 5 minutes de votre temps et aidez-moi à répondre à ces questions)

In which Neighbourhood do you live? ____________________
Dans quel quartier résidez-vous?

Gender? MALE ☐ FEMALE ☐
Sexe? MASCULIN FEMININ

Do you live with a family? YES ☐ NO ☐
Vivez-vous en famille? OUI NON

If yes, how many people make up your family? ____________________
Si oui, combien êtes-vous dans votre famille ?

Does the income generated from your activity allow you to live in a way that you consider suitable for your needs?
Le revenu généré vous permet-il de vivre d'une façon appropriée à vos besoins?
YES ☐ NO ☐
OUI NON

COLLECTION AND TRANSPORT/COLLECTE ET TRANSPORT

From which part of the city do you collect waste? ____________________
De quelle partie de la ville collectez-vous vos déchets ?

Do you buy the waste? YES ☐ NO ☐
Achetez-vous les déchets ? OUI NON

How much do you buy it? ____________________
A combien l'achetez-vous ?

At which frequency? Daily ☐ Weekly ☐ Monthly ☐
A quelle fréquence ? Journalière Hebdomadaire Mensuelle

Is the waste segregated prior to collection? YES ☐ NO ☐
Le déchet est-il trié au préalable ? OUI NON

If no, how do you segregate the waste? ____________________
Si non, comment triez-vous les déchets ?

Where do you carry out segregation?
Où effectuez-vous le tri ?
Collection point ☐ Recycling point ☐ Other ☐
Point de collecte Point de recyclage Autre

____

On which criteria do you segregate? ____________________
Sur quel critère effectuez-vous le tri ?

What happens of the remaining waste?
Qu'advient-il du reste des ordures ?

Abandoned *Abandonné* ☐ Dustbin *Poubelle* ☐ Open dump *Décharge sauvage* ☐

How do you transport the collected waste to you working place? ______________________
Comment transportez-vous les déchets collecté à votre atelier de travail ?

Where do you store them? ______________________
Où les stockez-vous ?

How much can you pay to receive the waste you need for your business without moving?
Combien seriez-vous prêt à payer pour recevoir les déchets dont vous avez besoin pour votre activité sans vous déplacer ?

____

At what frequency will you like to receive such service?
A quelle fréquence aimerez-vous bénéficier d'un tel service ?

Daily *Journalière* ☐ Weekly Hebdomadaire ☐ Monthly Mensuelle ☐

RECYCLING/RECYCLAGE

Which material (waste stream) do you reuse/resell/recycle?
Quel matériau (Déchet) réutilisez/vendez/recyclez-vous ?

Material (Waste) *Matériau (Déchet)*	YES *OUI*	NO *NON*
Paper and Cardboard *Papier et carton*	☐	☐
Plastic bottles *Bouteilles plastiques*	☐	☐
Any plastic material *Tout type de plastiques confondus*	☐	☐
Metals *Métaux*	☐	☐
Glass *Verre*	☐	☐
WEEE *DEEE*	☐	☐
Textiles *Textiles*	☐	☐
Food waste *Déchet alimentaire*	☐	☐
Other Autre	☐	☐

Which quantity do you collect? Daily/weekly/monthly ____________________
Quelle quantité collectez-vous ? journalier/hebdomadaire/mensuel

What do you do of the incoming waste? (The process) ____________________
Que faites-vous des déchets entrant ? (Le processus)

____

Which are the products after cleaning for reuse/recycling? ____________________
Quels sont les produits après nettoyage pour réutiliser/recycler ?

Where do you store the final product? ____________________
Où stockez-vous le produit fini ?

Which waste does your activity generate? ____________________
Quels sont les déchets que génèrent votre activité ?

What do you do of this waste? ____________________
Que faites-vous de ces déchets ?

ECONOMIC VALUE/VALEUR ECONOMIQUE

Where do you sell the final product? ____________________
Où vendez-vous le produit fini ?

Which quantity do you sell? Daily/weekly/monthly ____________________
Quelle quantité vendez-vous ? journalier/hebdomadaire/mensuel

How much do you sell it? ____________________
A combien le vendez-vous ?

What is the monthly revenue gained from the sale of recyclables?
Quel est le revenu mensuel obtenu de la vente des matières recyclables ?

0 – 100k ☐ 101k– 200k ☐ 201k– 300k ☐ 301k– 400k ☐

401k – 500k ☐ > 500k ☐

Do you think you may earn more if some conditions are changed? Which are these conditions?
Pensez-vous pouvoir gagner plus dans d'autres conditions ? Quelles sont ces conditions ?

YES / *OUI* ☐ NO / *NON* ☐

WORKING CONDITIONS/CONDITIONS DE TRAVAIL

Which are your working conditions? ____________________
Quelles sont vos conditions de travail ?

What would you need to upgrade your working conditions? ____________________
De quoi auriez-vous besoin pour améliorer vos conditions de travail ?

Which are the risks linked to your activity? ____________________
Quels sont les risques liés à votre activité ?

What do you do to limit these? ____________________
Que faites-vous afin de les limiter ?

EFFECT ON HEALTH, ENVIRONMENT & WELLBEING/EFFET SUR LA SANTE, L'ENVIRONNEMENT & LE BIEN-ÊTRE

Why did you get into this activity? ____
Pourquoi vous êtes-vous lancez dans cette activité ?

Which are the impacts of your activity on your health? ________________________________
Selon vous, quels sont les impacts de votre travail sur votre santé ?

____

Which are the impacts of your activity on the environment?
Selon vous, quels sont les impacts de votre travail sur l'environnement?

____

Do you know that your activity can be organised to reduce the health and environmental hazards it causes? For instance by putting gloves, wearing masks, air exchangers, safe final waste collection.
Savez-vous que votre activité peut être organisée pour réduire les risques sanitaires et environnementaux qu'elle entraîne ? Par exemple, en mettant des gants, en portant des masques, en utilisant des échangeurs d'air, en collectant les déchets finaux en toute sécurité.

YES *OUI* ☐ NO *NON* ☐

____

Thanks for your participation// Merci pour votre participation

(III)

ECOCENTER DESIGN PICTURES

FRONT VIEW

AERIAL VIEW

STORAGE OF RESIDUE AND SORTING AREAS

REUSE AND REPAIR UNIT