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New Life to Plastic: Reducing the Consumption of Plastic Materials and Turning Urban Waste into Opportunity in African Informal Settlements

Carol Maione[1], Eugenio Morello[2]
(1. University of Michigan, United States; 2. Politecnico di Milano, Italy)

Abstract: Uncollected solid waste is one of the riskiest factors strikingly affecting Kenya's slums areas and a poor waste disposal triggers negative attitudes, rising uncontrolled waste accumulation. Mismanagement of such waste typically results in pollution of the local environment and in substantial danger to public health and increased child mortality.

The volume of plastic is increasing at unsustainable rates, raising concerns on its negative externalities locally and globally imposed, such as the non-biodegradability of the material, that can contaminate the environment for centuries; difficulty to reuse or recycle the material in local markets; and greenhouse gas emissions daily contributing to global climate change. Every year, 3,966 tons of plastic are collected in the Nairobi's settlement of Kibera, which hardly cover seven percent of its total amount of material to be disposed of (Mukui, 2015, p. 68).

Sustainability pathways should concern awareness and sensitization of the population, with a focus on low-income and low-educated groups. The management model presented in this paper fosters the construction of a sound material-cycle society through effective use of material and local human resources, in order to avoid an improper disposal and an uncontrolled dumping of waste that can contaminate groundwater and soil and attract disease-carrying animals and insects, besides irreversibly affecting human health. It investigates how improper waste practices impact resource availability and flow of materials within Kibera's slums, providing local-based policies to mitigate the adverse effects of human activities on the environment, and a tangible project.

To achieve these goals, the pilot project "New Life to Plastic", centered around a partnership between the non-profit organization Social Innovation Teams (SIT) based in Milan, the Department of Architecture and Urban Studies of the Politecnico di Milano, and the Soweto East Youth organization in Kibera, addresses this issue by introducing a chain of collection points and re-separation of garbage stations daily managed by a women group. These points are receiving sites, where a target population is spurred to deliver plastic and undifferentiated garbage on payment. Such wastes, along with those collected by informal waste pickers, are brought to the recycling plant and consequently processed.

Early results show the necessity of overcoming existing barriers between local authorities and waste generators, creating a model based on community awareness and participation, and of educating people on the risks posed on human health and climate change. We are currently coping with local challenges, including urban poverty, poor financial resources to implement the project, and carelessness of local communities towards

Carol Maione, MS Urban Planning and Policy Design, University of Michigan; research areas/interests: plastic pollution in

environmentally-friendly and sustainable practices.

Signs of success would encompass social, environmental and economic impacts in the short-run and a proportion of recycled material raised to 20 percent by 2022. Those comprised of: social empowerment of women in the community, through their economic inclusion, technical formation, and environmental education; waste management services enlarged to the slum's areas; reduced consumption of plastic and, therefore, decreased rates of greenhouse gases and toxic emissions; increasing use of second-hand material inputs in place of virgin raw materials; income and job opportunities for waste workers; and safer working conditions, including regular contracts and provision of adequate equipment and vehicles.

Key words: waste management; Nairobi; slums; recycling; gender equity; economic inclusion: circular economy; climate change mitigation

JEL codes: O1, O2

1. Introduction

1.1 Local Context

Yet waste sector remains challenging to Kibera's development, especially in the frame of informality. It visibly weights on the local environment, mostly in form of air, soil, and water contamination, being solid waste from organic material, plastic, and human waste a major polluting source. The preliminary investigation in the early 2016 pointed out how fragile and inadequate systems drive to improper practices, raising serious concerns on environmental degradation and putting human beings at greater risk for ill-health.

While lack of resources has always been considered the central cause of service inefficiency, lack of motivation and deficient governance are likely to vie for the most adverse impacts. As administration is one of the major weaknesses of waste management policy framework in Kenya and limited investments are done, the current government has failed to address the increasing amount of waste, thereby driving to environmental deterioration, to increasing poverty levels and socio-economic inequalities, and to spatial and social exclusion of the urban poor from municipal collection networks.

Moreover, the lack of community awareness on waste-carried diseases and related impacts on human health and lack of sensitivity to and perception of garbage is boosting an incorrect approach to waste management in informal settlements. Local populations mostly spend their waste budget in collection, resulting in low collection rates anyway, inefficient transport systems, absence or scarcity of recovery and disposal processes.

Over the years, few global initiatives coped with informality by advocating the improvement of the livelihoods of urban poor, including Kibera Integrated Water, Sanitation and Waste Management Project (WATSAN), initiated in the Kibera's village of Soweto East in 2007, and Kenya Slum Upgrading Program (KENSUP), launched in the Nairobi's slum areas in 2001 (Nycander et al., 2011, pp. 13-17).

1.2 Pilot Project Frame

Waste management is a principal source of income for people living in slums and informal areas, being community-based organizations (CBOs) and informal workers involved in non-formal collection, picking and scavenging operations. This is likely to be a key factor in reducing the total amount of waste to be disposed of, especially in poorer areas, and in providing local industries with recyclable materials. Therefore, consideration must be given to the current collection system and the role that government and local institutions play in providing

Sub-Saharan Africa. E-mail: cmaione@umich.edu.

those services. They should also be responsible for forming and training workers in the waste sectors, including facilitation of community-based and community-oriented systems, support for and management of informal workers, and skills-based programs. Such programs include: implementation of the current collection system by increasing service provision to reach the Kibera's informal settlements inhabitants — currently excluded from the municipal service; supply of adequate means and safe equipment for all workers, and maintenance and repair of current collecting vehicles; design and provision of collection stations, daily managed by a trained group of local women; and training and sensitization of local communities, including households, informal workers — CBOs members and waste pickers, teachers and local institutions.

Figure 1 Unauthorized Waste Dumpsite in Kibera, Nairobi (Kenya)

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The purpose of this research is to offer an insightful analysis of the intersections between urban planning and environmental impacts, through the proposal of design tips and sustainable actions by fostering local responsibility and turning the issue of garbage collection into an opportunity towards social and environmental sustainability, according to circular economy principles. These strategies focus on promoting environmental sustainability through community involvement; raising awareness on the health and environmental issues that come from improper waste disposal; fostering an effective use of resources and to prevent destruction of the local environment and natural ecosystems; supporting an inclusive policy frame; and creating partnership with local and international stakeholders engaged in the waste sector.

2. Literature Review: Urban Expansion and Sustainable Development in Informal Contexts

2.1 Urban Expansion and Population Growth

More than half of the world's population now lives in cities; therefore, for the first time in history more people live in cities than in the countryside, with rapid growth rates mostly located in the Global South (Mutizwa-Mangiza et al., 2009, pp. 9-15). Thereby, while a good quality of life requires well-functioning infrastructures that zero in on the population's needs; the prodigious urban growth has been exceeding the capacity of cities and urban centers to provide adequate services and infrastructures to their citizens for the last decades. This has raised serious concerns about housing, water supply, municipal waste, sewerage and transport in the informal settlements, where the challenging physical and morphological conditions lead to decayed urban environment and urban facilities remain a monopoly of a privileged minority (Garau et al., 2005, pp. 15-17).

Urbanization and environmental burdens are highly correlated, and as population rapidly increases, so do goods consumption and the amount of waste generated. In developing countries, the lack of adequate waste collection and disposal systems causes social and environmental issues, such as public health problems, outbreak of infections and communicable diseases, which impinge on urban poverty and lead to the deprivation of the poor's capability to live in a safer environment. Poverty is caused for a large extent by heavy pressure on environmental systems, bringing about the loss of essential services and overexploiting locally-available and natural resources (Ferrao & Fernandez, 2013). This situation is dramatically worsened by the dysfunction and inability of the local institutions to satisfy the livelihood of communities and to provide the Nairobi's slums with the resources to attend to their growth, which could eventually lead to alarming poverty rates and environmental disasters.

Within this frame, the metabolism of an urban system represents a more specific indicator of city performance, assessing and monitoring the flows of material and energy throughout the city and the burdens of human activities on the local environments. The study of the metabolism of informal settlements and resource assessment may drive to more responsible planning strategies, integrating environmental policies with a proper management of urban systems. Therefore, reducing the slum's metabolic turnover alleviates contributions to environmental degradation, especially in extreme conditions; relies less on non-renewable and endangered resources depletion; increases urban resilience playing a pivotal role in sustainable development; and reduces alarming levels of urban poverty, with linkages to SDG1, SDG11 and SDG12 (Dodman et al., 2017).

2.2 Contributions to Climate Change

Open dumpsites are the most commonly used methods of waste disposal due to dramatically low rates of collection and poor waste management systems. Unchecked and unplanned waste disposal is posing various risks for the natural environment, including burdens on the existing ecologies; methane leakages produced by the decomposition of waste in landfills; and carbon emissions derived from waste incineration, which are contributing to the creation of extreme microclimatic conditions locally, and to global warming (Palczynski, 2002, pp. 7-22).

Waste prevention is broadly considered the most sustainable approach to waste sector. Not only it avoids waste generation, but also it reduces adverse impacts on the environment. The resulting cut in greenhouse gas emissions favors the spread of environmental and climate benefits, including cleaner production, extended producer responsibility, sustainable consumption and production. Such emissions, both direct, such as releases from process itself, and indirect through energy consumption, are generated at all stages of waste treatment, with

landfills being the largest source of pollution. These emissions depend on waste characteristics, including composition, density, and particle size, and conditions in disposal sites, such as moisture, nutrients, microbes, temperature and ph (UNEP 2010).

2.3 Risks to Human Health

Recent studies by UNEP widely investigated possible associations between proximity of exposure to landfill sites and diseases outbreak. Emissions-related risks can vary significantly from explosion or fire caused by build up of landfill methane in buildings near landfill sites, to respiratory diseases and asphyxiation due to heavy concentration of particles (UNEP 2010).

The costs of air, water and soil pollution result in premature mortality and ill health caused by indoor and outdoor exposure to high levels of pollutants, and the total burden of disease amounts is expected to grow over next decades. Pollution is generated at all stages of waste management and disposal, in that waste is a complex mixture of different substances including those lethal to health. Eventually, uncontrolled dumping usually occurs alongside open burning, leakage of hazardous substances such as leachate and gas, drainage systems, and open sewerages. These situations affect the ecosystem at different levels, thereby causing the outbreak of illnesses such as skin and eye infections, respiratory problems, vector-borne diseases like diarrhea, dysentery, typhoid, hepatitis, cholera, malaria, yellow fever, animals-carried diseases, plague and flea-born fever.

Waste substances are absorbed into the body at different efficiencies through the skin, gastrointestinal tract, and respiratory system. In particular, toxic properties and intrinsic features vary considerably under changing conditions of exposure and individual's characteristics, such as age, gender, and genetic susceptibility, thereby dis-associating the total amount of a toxicant to which a person is exposed from the possible adverse effects (Giusti, 2016, p. 2232).

3. Methodology: Field Survey and Definition of the Project Frame

3.1 Developing the Idea

The idea for the project was developed during the first half of 2016 by a volunteering team that conducted research in the field. Through collaboration with local associations, including Havilla Children's Center — a local center providing aid to the children of Kibera slum — and the UN-Habitat center based in Soweto East and headed by the Secretary of the Kenya Slum Upgrading Programme, they were able to assess the flows of material throughout the slum and estimate the waste-related pollution rates putting human health at greater risk.

The field survey pointed out domestic garbage to be a central cause of waste generation, with alarming amounts of plastic materials illegally disposed of. Mismanagement of these wastes typically results in pollution of the natural environment and the material degradation process may take 10-1000 years to decompose. Such volumes are increasing at unsustainable rates, raising concerns on the material's negative externalities imposed locally and globally, such as underground resources and water contamination; difficulty to reuse or recycle the material in local markets; waste-related co-products; air pollution and minor leakages; and greenhouse gas emissions daily contributing to global climate change.

In response to such issues, the pilot project New Life to Plastic (NLtP) introduces a circular economy model centered around the collection and recycling of plastic by implementing the current waste management system within the slum area and eradicate the problems that stem from improper waste disposal, raising awareness and sensitizing communities towards environmental issues, addressing especially low-income and low-educated

groups. The generation of a circular economy within the slum allows for the creation of income from plastic products consumed, creating a framework for the inclusion of women and minority groups and the promotion of environmentally friendly waste disposal practices by implementing a circular economy model within Kibera slum that targets social and economic inequality. Plastic waste is collected and brought to a receiving point by a group of local women, where it is washed and reworked into a reusable plastic material that can be resold to plastic manufacturing companies in the area, thereby creating financial resources for families that participate, and positive health benefits for all within the community.

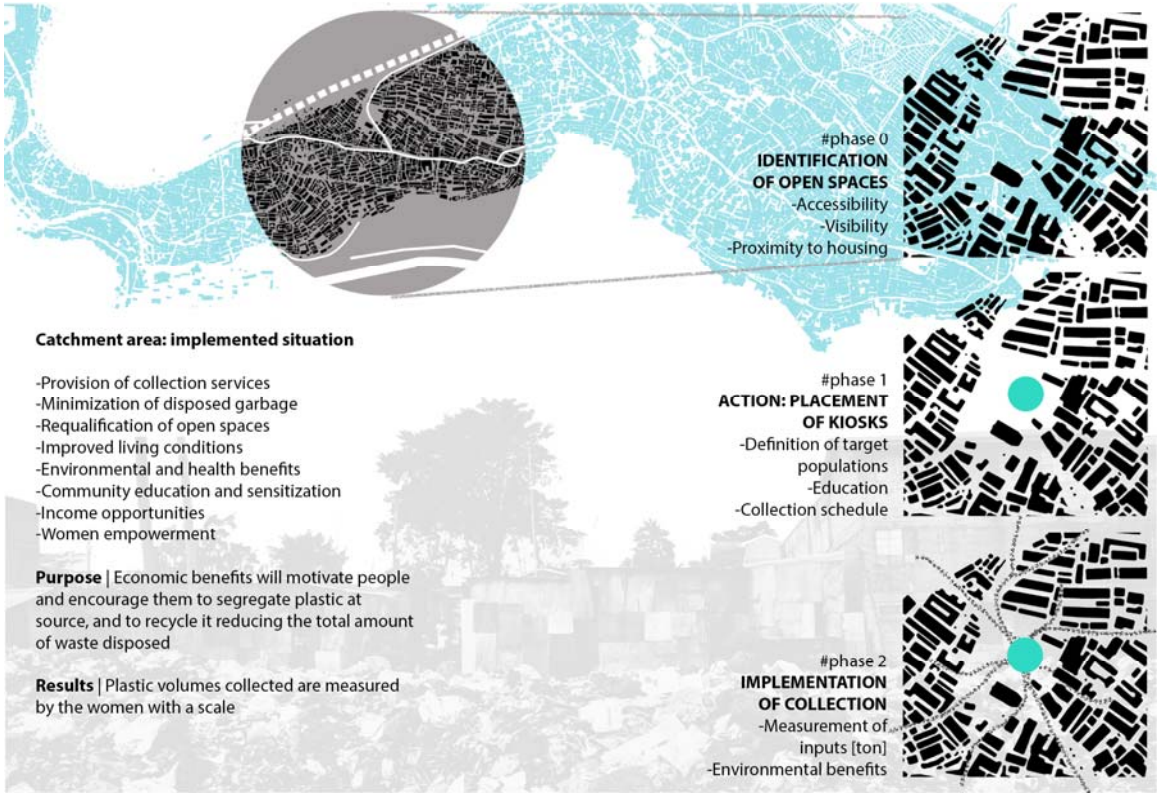

Figure 2 Implemented Situation in a Catchment Area, Kibera's Slum Areas, Nairobi (Kenya)

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3.2 Achieving the Sustainable Development Goals and Major Beneficiaries

The proposal is centered around ideas of engagement and empowerment of local communities in sustainable waste practices and education on sustainable consumption behaviors — referring to SDG12 Responsible Consumption and Production — including reduction of waste generation at production stage, decrease in virgin materials exploitation, and fostering of 3Rs principle approaches within the local and national policy frame. The deep interconnection between the idea and achievement of the Sustainable Development Goals (SDGs) makes it a tool to overcome the major drivers to degradation of the local environment, preventing toxic emissions, unauthorized landfilling, and contamination of land, soil and water sources, thereby reducing the contributions to climate change globally and implementing education, awareness-raising and capacity building on climate change mitigation and impact reduction — SDG3 and SDG13.

In order to enhance inhuman livelihoods and eradicate extreme poverty for Kibera workers — with linkages

to SDG1 and SDG8 — NLtP aims at raising current income rates and implementing local waste-driven businesses by creating job opportunities, and spurring pro-poor local strategies. This results in safer and decent working conditions, including provision of adequate means and equipment, and encourages the formalization and growth of the waste stream, including formalization, training and skill-oriented capacity building. For these reasons, the project incorporates disadvantaged workers in the informal economy, including waste dealers and pickers, youth groups, and community-based organizations, currently unable to access the formal sector of the economy due to the lack of information and education on the recovery and recycling of plastic.

In particular, the major beneficiaries of the pilot project are women, through official recognition of their critical role in the valorization and the safeguard of the environment, by creating a framework in which they are able to participate in economic activities and in the social life of the community they live in. In order for gender-sensitive strategies — SDG5 — to be effective, NLtP aims at ensuring women's full and effective participation and opportunities for leadership in the project, by enhancing the use of enabling technology and machinery to promote the empowerment of the target group.

4. Strategies: Short- and Medium-Term Implementation

4.1 Awareness Raising and Environmental Education

To respond to the needs of Kibera's community, the following set of policies focuses on the implementation of the current educational system, by encouraging local populations to boost capacity building and development and sharing information to enable them to copy with local environmental challenges. Those comprised of: training of the volunteers pre-mission in order to allow knowledge-transfer and constant monitoring and eventual feed backing during their staying on site; coordinated training and teachers preparation in environmental education; collective and participatory learning, promoting child and woman participation; community-based activities and workshops; and child environmental education and yearly programs on environment protection and waste segregation.

To that extent, a holistic environmental education program was launched early in 2016 in the Havilla Children's Center K-12 school, Kibera. In order to create a learner-friendly and innovative environment, the proposed activities aimed at implementing non-formal education systems and awareness-driven development strategies, including after-school workshops on waste reuse and recovery targeting students and families; field trips to interact with the local environment and explore the major waste accumulation stations within the neighborhood and the derived impacts; and creativity-stimulating activities spurring collaboration among waste recovery practices while fostering more responsible behaviors.

Early results showed the necessity to integrate more formal education systems with medium- and long-range environmental programs, in order to contextualize methodologies and approaches in the local environment and tailor effective waste management practices to the needs and the background of each target group. Those comprised of: waste segregation, plastic recovery and assemblage in new products for K-12 children; interview and awareness campaign for waste pickers and the target group of women; formal presentations to master's students at the University of Nairobi; and structured interviews to the waste management stream at UN-Habitat Head Quarter in Nairobi and at the Department of Environment of the City Council of Nairobi (CNN).

4.2 Turning Urban Waste into an Opportunity and Plastic Recycling

Giving a new life to the waste, through a recycling system, aims at building and monitoring of a recycling

plant, paying close attention to those groups currently excluded from either municipal or informal services, and empowering vulnerable individuals and women providing them with active roles in the waste industry. For this model to be effective and reliable, the KPI considered range from income security and job opportunity creation, to investments in locally available materials, human resources and labor force.

The plastic recycling and processing includes six different phases: the process starts with the purchase and collection of the material from local people, mostly informal waste pickers, who collect the garbage and separate it at its source. The second phase involves the storage and stock of plastic in the recycling plants, where the material is classified and segregated according to color and quality. The next phase is the rough cutting, which consists of a manual cut in order to make the plastic pieces manageable in size. The cut pieces are dipped in water tanks in order to remove the impurities, and afterwards they are manually washed in basins. After the washing, the plastic is ready to be processed: this phase assumes the usage of machinery (extruder, grinder, densification machine, etc.) in order to continue on to size reduction and the production of plastic pellets. Finally, the product is packed and sold to local enterprises and artisans or to plastic industries.

Engaging local plastic industries — such as Crown Paints Distributor Brush Manufactures Ltd and premier Industries Ltd in the Nairobi greater area — as final costumers of the semi-finished products, NLtP impinges on local leadership and capacity building by strengthening the waste sector and creating green jobs. In particular, the first phase of implementation offers eleven vacancies, including one local manager — to be chosen among the target group of women — and ten employees, which will be properly trained, served with organizational and technical skills, and officially formalized.

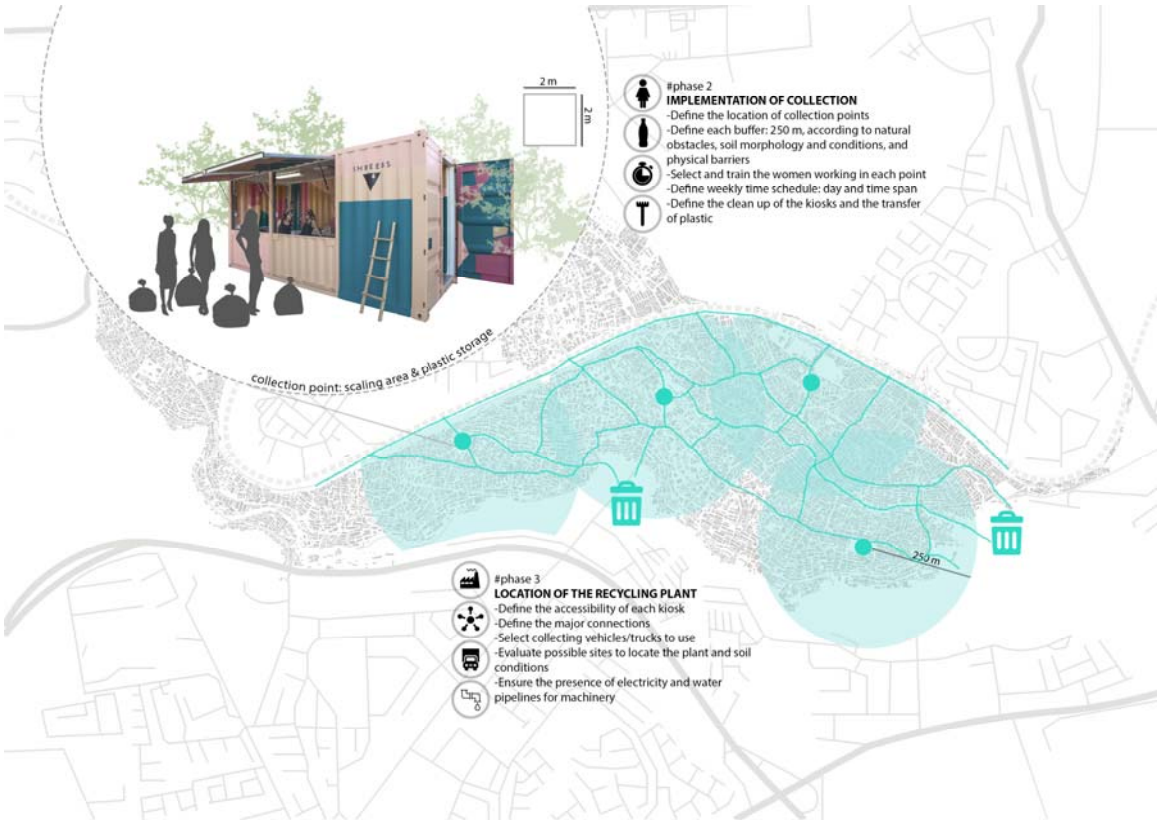

Figure 3 Collection Station Proposed Plan, Kibera's Slum Areas, Nairobi (Kenya)

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5. Social, Environmental and Economic Impacts

5.1 Short- and Medium-Term Expected Results

The early results, published in the Sustainable Development Solutions Network's report, show the necessity of coping with local challenges, including urban poverty, poor financial resources to implement the project, and carelessness of local communities towards environmentally-friendly and sustainable practices (Piselli et al., 2017, p. 78).

NLtP aims at creating a framework for the inclusion of women and minority groups and the promotion of environmentally friendly waste disposal practices by implementing a circular economy model within Kibera slum that targets social and economic inequality. Plastic waste is picked and brought to a collection point by women of the community, where it is washed and reworked into a reusable plastic material that can be resold to plastic manufacturing companies in the area, thereby creating financial resources for families that participate, and positive health benefits for all within the community.

The target social impact NLtP aims to achieve is a social empowerment of women in the Kibera's slum, through their economic inclusion and technical formation. Previously disadvantaged or underutilized social group within the economy, the women will benefit from full and effective participation and opportunities for leadership in the project.

Secondly, in order to reduce the human footprint on the local environment actions should be taken to lower waste accumulation, preventing its generation at source and limiting consumption rates. At household level, it results in reduction of plastic consumption relying on more reusable items, including recovery of domestic waste and plastic food packaging, thereby extending their useful life. Recycling deals with plastic material at the end of its life and turns it into a usable second-hand material to be substituted to virgin raw asset. The recyclables are collected from different sources and transported to materials recovery facilities, in order to be processed and sent to manufacturers. Recycling could be encouraged through the segregation of materials at domestic level, by economically incentivizing, stimulating and motivating communities towards environmental protection and adoption of best practices.

With regard to the economic inclusion of workers in the waste sector, the proposed model will eradicate extreme poverty for Kibera workers by implementing local businesses and providing job opportunities and income possibilities. This will foster development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro- and small-sized enterprises. The project's objective is to enhance and improve the working conditions of 20-30 youth currently collaborating with the Soweto East group in the role of waste pickers, by protecting labor rights, and promoting safe and secure working environments for the workers.

In the long term, the cover ratio of the project will be extended to the whole community living in Kibera, providing for the areas close to the catchment, with the idea of proposing a solution with results that can be replicated in other areas within Nairobi city. Additionally, the project aims to reach an increasing number of people by raising awareness on proper waste management systems and on the interconnections between waste disposal and possible contributions to climate change, through activities, workshops, conference and public events.

5.2 A long-term Perspective towards Zero-Waste Societies

To reduce resource depletion and destruction of the natural environment, local economies need to match

basic sustainability requirements, including system efficiency, conservation of goods and services, and reuse and recycling of materials, while decoupling economic growth from heavy resource consumption. This need for economically, socially, and environmentally sustainable urban development requires a restructuring from linear to circular metabolism, where societies rely more on recovered goods and cut over-exploitation of virgin and raw materials (Connett, 2013).

Zero waste strategies advocate the elimination of the waste treatments and disposal methods producing adverse impacts on the environment, such as incineration and landfilling. While zero waste could seem out of reach for Kibera's informal areas, a substantial reduction in the total amount of waste to dispose of is possible, by building a sound material-cycle society through the effective use of resources and materials should be achieved in short and medium terms, in order to prevent the contamination of the local environment, including air and water pollution, and soil contamination, and the potential contributions to climate change, due to the release of greenhouse gases and toxic emissions associated with uncontrolled dumping. This requires a shift from a linear to a circular metabolism and a comprehensive understanding of present processes and their final aims, to replace them with more sustainable approaches.

Best practices to integrate the industrial recycling process should approach simple and cost-effective actions such as: source separation, in that waste is made by mixing discarded materials and could be prevented by separating such materials at source; door-to-door collection systems through the use of different containers — organic, plastic, paper, glass, metal and non-recyclable materials; composting kitchen and organic waste, and left overs generated by local market and restoration facilities, by segregating wet materials from other waste and thereby preventing materials to be fully recovered and reused — additionally composting is a major cause of methane, carbon dioxide and odor emissions; recycling activities, based upon the quality and efficiency of the service provided; economic incentives, such as extra charge on residuals in order to drastically reduce this fraction, and monetary return for on-site plastic delivery (Connett & Sheehan, 2001).

6. Conclusion

The research focused attention on the gaps in the current waste management systems, making the creation of the proposed material-cycle model its milestones, including effective use of resources to be achieved in short and medium terms. Major findings pointed out lack of awareness on proper waste practices and waste-carried issues being a central cause of mismanagement of environmental assets, resulting in urgent need for education programs for all.

Although waste management and climate change are global issues, we cannot expect large scale solutions to solve local issues. In this perspective, lack of collaboration among municipal actors — such as the Japanese International Cooperation Agency (JICA) and the waste stream of CCN — and local populations — especially low-income and slum inhabitants — fails to outline local-based solutions and effectively engage local communities in waste activities. To that extent, consideration must be given to innovative local-based management models able to fully integrate the final users and consumers.

Additionally, lack of people's responsibility exacerbates their exclusion from the social and economic life of the communities they live in. For this reason, there is the necessity to center development strategies around and successfully empower local populations. Increasing opportunities in the waste sector can therefore foster social control, job availability, gender equality, and enlarged inclusion of vulnerable groups.

Finally, lack of spatial control and spatial hierarchies of waste management and local management of responsibilities makes the whole system less effective, worsening the livelihoods of those residing within the slum areas. To that end, not only does more responsible planning of the waste system provide a safer and cleaner urban environment, but also it is likely to become a tool to reduce social inequalities and urban poverty overall.

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