



Community-based energy **Briquette** **production** from urban organic waste at Kahawa Soweto Informal Settlement, **Nairobi**

Mary Njenga, Nancy Karanja, Gordon Prain, John Malii,
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ABSTRACT

Solid waste management presents a major challenge for many municipal authorities in Sub-Saharan African cities, where rapid growth, social and cultural change, widespread poverty, inadequate and weak local enforcement capacity and limited financial resources all contribute to environmental degradation and waste disposal challenges. Nairobi, the capital city of Kenya, generates over 2000 tonnes of solid waste daily and only 40% is collected and disposed. The city experiences a high level of poverty and unemployment among the poor who constitute over 60% of the population. Many youths living in the informal settlements are highly affected by lack of jobs in the formal sector and to address their plight, they have come up with initiatives to address poverty and unemployment as well as environmental burdens and insecurity in their neighborhoods through recycling waste resources. One major problem that the urban poor in cities of Sub-Saharan Africa have to contend with is inaccessibility of affordable cooking fuel, and it has been shown from numerous studies that the majority of people depend on charcoal for cooking. The residents of Kahawa Soweto village are no exception to this challenge and so Soweto Youth in Action (SOYIA) youth group, in collaboration with Urban Harvest and Kenya Green Towns Partnership Association (Green Towns), developed an action research initiative on making fuel briquettes from urban solid waste generated from the neighborhood and environs with the objective of generating income and providing employment while contributing to environmental management. In the course of the project TERRA NUOVA, the private sector and the University of Nairobi joined the partnership to provide specified technical expertise. This action research project was the follow-up to a larger study on solid waste management carried out in 2003-2004 by Urban Harvest and partners where SOYIA youth group was one of the CBOs that played a key role to the success of that project.

The fuel briquette-making project was implemented from February 2007 to February 2008 at Kahawa Soweto village when a pilot briquette production pilot plant was established and had the following items needed for the process: three briquette presses, paper shredder, drying rack and storage/sales facility. Gender responsive diagnostic studies on sources of raw materials and market opportunities were carried out in the village and its environs. Training courses on governance including issues of leadership, conflict resolution and gender, project management with networking, advocacy and resource mobilization components including the technical side of fuel briquette production and marketing were conducted. During the training, gender responsive sub-committees on resource mobilization, production and sale and marketing were formed and developed the rules and regulations for governing their enterprise and a business plan using participatory methods. The fuel briquettes were made from common waste materials and their quality evaluated in a participatory manner. In terms of calorific value, ash content, moisture content, volatile matter, time taken to ignite, time needed to cook a mixture of maize and beans (*githeri*) and time taken to burn completely to ash; charcoal dust and waste paper type of briquette was received the highest rating followed by charcoal dust + sawdust and waste paper and the lowest rating was given to the ones made from charcoal dust + maize cobs and waste paper. Based on these observations, the

SOYIA youth group is concentrating on producing briquettes from charcoal dust and waste paper and 600 units had been produced in January and February out of which 300 were sold. The briquettes were sold to residents of Kahawa Soweto and environs at Ksh 3-5 (US\$ 0.04-0.06) per piece. Further studies on quality enhancement, possible impact of fuel briquette technology in climate change especially through emission of greenhouse gases and health risks from indoor pollution particularly on women and children need to be given attention.

1.0 INTRODUCTION

Rapid urbanization estimated at 6.9% a year in Nairobi has resulted in the massive expansion of unplanned settlements in and around the city. It is estimated that 60% of the population is comprised of very poor people with limited assets who live in slum areas characterized by lack of sufficient services and infrastructure such as water, sanitation and electricity (UN-Habitat, 2003). A study carried out by Lee-Smith *et al.*, (1987), revealed that although 65% of households had access to electricity, only 14% of these used it for cooking. To be able to use electricity for cooking, a household needs to acquire an electric cooker which means considerable expenditure. The same survey found that 25% of households use cooking gas, but almost none of them lived in the informal settlements. Kerosene and charcoal are by far the most commonly used sources of cooking fuel in Nairobi especially in slum areas where it is estimated that between 72 and 83% of households are affected (Lee-Smith *et al.*, 1987). Annual consumption of charcoal has been estimated at 2.4 million tonnes (Republic of Kenya, 2002) and 700 tonnes are consumed in Nairobi per day, producing 70 tonnes of charcoal dust which clogs waterways and exacerbates air pollution especially when burned (World Bank, Development Market Place, 2006). Shortage of low cost sources of energy has resulted in families' abandoning traditional foods that require long cooking time, such as *githeri* (maize and beans) to prepare faster cooking foods such as *ugali* (maize meal paste) or have resulted to using unhealthy materials as sources of energy such as plastics which have potential negative health impacts. There is a need among households in slum settlements for safe and affordable alternative sources of cooking fuel.

Along with the crisis of availability of low-cost domestic fuel, developing countries also face another challenge: waste management. Seventy percent of the more than 2000 tonnes of solid waste generated daily by Nairobi is organic in nature (JICA, 1997). However, only about 40% of the waste generated is formally collected and disposed of (ITDG, 2003). This means that approximately 560 tonnes of organic waste are available for recycling in various forms. Earlier studies (Karanja *et al.*, forthcoming) estimate that less than one percent of this enormous resource is currently utilized by community-based composting activities. There is a real opportunity here to confront both the waste problem and the domestic fuel challenge at the same time. Fuel briquettes, which can be made from different types of waste material, offer a low-cost alternative domestic fuel and help low-income urban families prepare safe and nutritious meals. Accessing organic materials and converting them into fuel briquettes would also provide employment and income to the youth and women among whom unemployment – and under-employment – is high in all urban centers in Kenya.

Production of fuel briquettes involves the collection and compaction of a combination of combustible waste materials that are not directly usable because of their low density and processing them into a solid fuel product of any convenient shape that can be burned like wood or charcoal. Although the term waste refers to something that is useless or worthless, it must be borne in mind that “*waste, like beauty is in the eye of the beholder.*” Therefore, conversion of organic wastes into fuel briquettes is being undertaken by NGOs and CBOs in various countries who have seen the positive side of *waste*. In Namatala slum in the

small town of Mbale in eastern Uganda doughnut-shaped briquettes four inches in diameter are made of discarded coffee hulls, rice husks, charcoal particles, sawdust, wood chips, and waste paper. The paper serves as a binder for the other materials. At first, these briquettes produced a lot of smoke, but a solution was obtained from briquette makers in Kenya who soaked the paper, allowing it to ferment, converting into a slurry. This is added to the other ingredients as the binder, which, when dry, burns without producing smoke. The group sells some of the briquettes they produce, while the rest are used in their homes (UNEMA, 2007).

In Kisumu, Kenya, a study led by Lagrotech Consultants and supported by the Livestock Production Programme of DfID, established that 4,162 cattle produced about 12 thousand tonnes of manure annually, which, if turned into fuel dung cake, they would produce about 2500 tonnes of dung cake as good as commercial charcoal worth Ksh12.6 million (Lagrotech, 2005).

The majority of fuel briquette-making activities in Kenya are located in urban and peri-urban areas, over 50% of which are in Nairobi. This could be due to the high cost of wood fuel in urban areas, employment and poverty-reduction opportunities offered by briquette making, and the local availability of low- or no-cost waste ingredients for briquettes (Terra Nuova *et al.*, 2007). For example, the Kayole Environmental Management Association (KEMA) employs street boys to collect garbage from the residents of Kayole Estate and from the streets and dumping sites in Nairobi city. KEMA has developed an innovative screw-operated device that presses organic wastes into cooking briquettes. Large-scale briquette making initiatives have also been established in the Karen area of Nairobi. Chardust Ltd, which won the World Bank Development Marketplace prize in 2005 for “Carbon Collectors in Kibera Slum”, purchases 4 tonnes of dust per day from Kibera slums and involves over 250 people along the supply chain (Chardust, 2008). This company sells 220 tonnes of fuel briquettes per month to domestic users, restaurants and poultry farmers for brooder heaters (Chardust, 2008).

1.1 Location of Pilot Site

An opportunity to pilot briquette making as an income generating enterprise was identified in Kahawa Soweto village, an area classified as an urban slum and located 21 km west of Nairobi city centre in Kasarani division. As of 1999, there were 1,000 households within the village, 700 dwelling units and a population of about 8000 people (UN-Habitat, 1999). A majority of the residents are former sisal farm workers or their descendents who settled in Kahawa Soweto after sisal farming was no longer viable. There is a high level of unemployment, which is exacerbated by an estimated 15% HIV/AIDS prevalence.

The Soweto Youth in Action (SOYIA) a community-based youth group made up of 7 women and 13 men seeks to confront both unemployment and environmental problems in the neighborhood. The group earns income by collecting waste from households at a fee of US\$ 0.3 per household per week. On land along the railway line, they separate organic and inorganic waste. The organic materials are used for compost-making while the inorganic materials were either burned or collected by the municipal council. Through this waste

management initiative for both income generation and environmental management, as well as their earlier involvement in 2003-2004 in an action-research project involving organic waste management (Njenga *et al.*, 2007), SOYIA was identified as an excellent partner to pilot income enhancement, and environmental health through good quality energy fuel briquette production.

2.0 STUDY OBJECTIVES AND APPROACH

The study objectives were to (i) develop innovative partnerships and a sustainable organization for fuel briquette enterprise development, (ii) establish opportunities for potential sources of raw materials and markets and (iii) evaluate quality of fuel briquettes produced by SOYIA and improve their skills.

A literature review was carried out on briquette production, utilization and marketing and this information contributed in the design of the baseline survey which was applied to 160 households and 99 institutions/business enterprises. The baseline survey aimed to gain an understanding of existing community-based waste management strategies, including reuse practices and to document types of cooking fuel used. The idea was to identify potential sources of raw materials as well as the potential market for the fuel briquettes made by SOYIA. The total sample of 160 households was divided into forty households from each of the four study locations, namely; Kahawa Soweto, Githurai 44, Jua Kali, and Kamae. Kahawa Soweto is the project site while the other three neighborhoods were chosen to find out about raw material availability and demand for the briquettes. While Githurai 44 is a formal middle income settlement, Kahawa Soweto, Jua Kali and Kamae are informal settlements (slums) occupied by low income households. The informal settlements are characterized by high population density with poor sanitation facilities including limited waste management services. The 160 households involved in the survey were selected randomly. Every tenth household was selected from different starting points distributed across each study site. These starting points were based on the road system, with the central road of each village providing the first point and subsequent roads selected based on their direction South and North from the central road.

Ninety nine questionnaires were administered to institutions and business enterprises that either produces sawdust, charcoal dust or waste paper and or those that used wood charcoal for cooking within the study area.

Through collaboration with TERRA NUOVA, an international NGO and a private equipment manufacturer (Dr. Nick Wood) an appropriate briquette making machine was identified. The Kahawa Soweto village was identified as an appropriate location for pilot testing this briquette machine, and the Soweto Youth in Action group (SOYIA) took leadership of the process, backstopped by an expert from Kenya Green Towns Partnership Association (Green Towns), a national NGO working on urban environmental and agricultural issues. Community capacity building courses were provided to the SOYIA members on community organizational development and institutional strengthening (CODIS) and in briquette production and marketing using training modules developed by Greens Towns, Urban Harvest and TERRA NUOVA. SOYIA youth group constructed the briquette making shed and a store, sourced raw materials and produced the briquettes. The

Department of Chemistry, University of Nairobi, carried out the characterization of the different types of briquettes compared to wood charcoal for calorific value, ash content, moisture content and smoke. Members of the Kahawa Soweto community, including students, were involved in participatory evaluation and demonstrations of the cooking quality of the briquettes. A mixture of green maize and dry beans (*githeri*) were cooked, using a energy saving stove (*jiko*) measuring 20.5cm in diameter and 7.0cm deep. Two briquettes were placed in each *jiko* and lighted. The parameters recorded were: time taken to light; amount of smoke produced; flame characteristics; length of time taken to cook the meal; and length of time taken for the briquettes to burn completely into ashes. Some other types of briquettes were compared with wood charcoal.

A market survey was conducted with 50 respondents compromised of 26 males and 24 females who were customers at supermarkets and charcoal trading places in an attempt to generate information on potential market opportunities. The respondents were shown a sample of the briquette and told how it was produced. Information was collected on preferred packaging units, preferred market outlets and consumers' willingness to pay. Another short survey was conducted using a random sample of 10 charcoal dealers in Kahawa Soweto village to establish their willingness to incorporate fuel briquettes as a commodity in their business. Kahawa Soweto village where the project is located was chosen for this survey of charcoal dealers as it was considered the priority place for introducing the product. Two managers, one from local supermarkets and one from Nakumatt Nairobi-Thika road respectively were also interviewed about potential outlets for sale of the briquettes.

Enumerators, some of whom were from SOYIA youth group with secondary school education, were trained and exposed to a pre-testing exercise. Quality control of the filled questionnaires was carried out every evening by a supervisor from the University of Nairobi and data entry and analysis handled by a database manager based at Urban Harvest. Data collected from the survey and laboratory analysis was entered into the computer using CSpro and Statistical Package for Social Scientists (SPSS) was used for data analysis (International Programs Centre, 2006).

Application of participatory approach to the entire project cycle meant that members of SOYIA youth group were involved in all the activities of the project such as project designing, planning and management, awareness raising, baseline surveys, testing of the cooking qualities of the briquettes and demonstration. The group was able to link to other organizations to access expertise and advice in various components of the project when need arose.

3.0 RESULTS AND DISCUSSIONS

3.1 Partnership Development, Project Organization and Capacity Building

3.1.1 Partnership

The project was coordinated by Urban Harvest while implementation of the various components was led by partner organizations that included Kenya Green Towns Partnership Association (Green Towns), TERRA NUOVA and University of Nairobi while working very closely with SOYIA.

The project has empowered the SOYIA youth group and enhanced partnerships with different organizations. In March 2007 a community awareness-raising meeting was held in Kahawa Soweto village where the youth group in partnership with the implementation team presented to the community the scope of the project and their expectations from the community and the neighborhood (see Plate 1).

During this meeting the need for the SOYIA youth group to work closely with the Soweto Upgrading Project Committee supported by UN-Habitat was emphasized and a good sign of this collaboration was shown through the allocation of some land (free) for the briquette processing plant and subsequent (free) allocation for an unlimited time to the group by the village committee for construction of the structures where briquettes would be produced. TERRA NUOVA, an Italian NGO, was brought on board due to their extensive knowledge of briquette making and construction of briquette presses. They have therefore contributed both training materials on briquette technology and introduced the youth group and the project team to the artisans who fabricate briquette making machines. The SOYIA youth has been linked to the Department of Chemistry, University of Nairobi who will be assisting them from time to time on quality control of the fuel briquettes. The group members have enhanced their skills in governance and management of activities through training and backstopping by the Kenya Green Towns Partnership Association (Green Towns) and Urban Harvest, which will contribute greatly towards the sustainability of this initiative.

3.1.2 Community Based Governance Structure

SOYIA youth group has a gender responsive umbrella management committee comprised of chair, vice-chair, secretary, vice-secretary and treasurer. This committee runs the business of the youth group according to its constitution. SOYIA youth group formed three gender responsive sub-committees each managing specific duties of the project which include production, marketing, sales and financial management and resource mobilization. Group members themselves formed these sub-committees based on their individual skills and qualities for executing the expected duties. The operation of each sub-committee is guided by a set of rules and regulations which were developed in a participatory way, while the overall project activities are implemented following a business plan developed during the Community Organizational Development and Institutional Strengthening (CODIS) training. This process is documented in section 3.1.4.

3.1.3. Energy Briquette Making Pilot Structure

The former SOYIA office was extended to accommodate a briquette making shed, a store and an office for meetings while a mobile drying rack was constructed. Three briquette making presses (one metal and two wooden) and a paper shredder were acquired in



Plate 1. SOYIA group creating awareness of the project at Kahawa Soweto village March 2007



Plate 2. Drying rack, wooden press and paper shredder set up at SOYIA briquette processing plant, Kahawa Soweto.



Plate 3. SOYIA group receiving training on fuel briquette production and marketing



Plate 4. Fuel briquettes production process



Plate 5. SOYIA members demonstrating energy briquettes at Kahawa Soweto village

consultation with TERRA NUOVA and two private equipment makers, Dr. Wood and Mr. Charles Onyando (see Plate 2).

The research team suggested to the equipment manufacturer the idea of adding a water collection plate to the metal press and this was incorporated as an improvement in the design. The metal presses were chosen after women found the wooden press hard to use because it required a lot of physical force. The metal press where force is applied by foot was more gender friendly and women use it with ease. The group members received training in operation and maintenance of the machines to ensure consistency in the quality of the briquettes produced and follow-up visits continued to be made by the project team when the need arose.

3.1.4 Training on Governance and Management of Community Organization

The aim of this training was to strengthen governance within SOYIA and emphasized key issues like leadership, gender, team-building, conflict resolution, project management, including resource mobilization, entrepreneurship and business management skills. The need for sustainable networks or ease in accessing, business services and markets as well as entrepreneurial capabilities was emphasized. Pedagogical teaching methods involving question and answer sessions, lectures, group work, exercises and illustrations/diagrams were adapted from a regional training course on urban agriculture held in Nairobi in 2004 (CIP-Urban Harvest, 2005). This process was participatory and encouraged active and participant-centered learning aimed at developing problem-solving skills and improving long-term retention of knowledge and skills. A learning-by-doing approach was also used where the group developed some rules and regulations to govern roles and behavior expected from group members. To manage the project activities three sub-committees were formed based on individual strengths and skills, namely; (i) production, (ii) financial management, sales and marketing and (iii) resource mobilization. A business plan for the briquette making project was also developed. The training materials were developed and delivered by Kenya Green Towns Partnership Association (Green Towns) and Urban Harvest.

3.1.5. Technical Training in Briquette Production and Marketing

This training course introduced the concepts of environmental conservation and management and the need for recycling appropriate waste materials as sources of energy. The course provided information on the types of raw materials that can be used, their processing into briquettes and techniques for achieving and maintaining good quality energy briquettes and the different types of briquette-making machines, suppliers/fabricators and their maintenance (Plate 3).

The participants were also given information on briquette marketing, including entrepreneurial ideas such as branding to enable them to sell their product in up-market outlets such as supermarkets. A private consultant who has been training CBOs in East Africa on briquette technology was contracted to share his experiences and to deliver a

demonstration using modules developed by TERRA NUOVA, while Green Towns and Urban Harvest made follow-ups to ensure consistency in quality of the product.

3.2 Waste Management and Fuel Use in Households and Institutions/Business Enterprises

3.2.1 Sources of Raw Materials for Briquette Making from Domestic and Institutional Waste

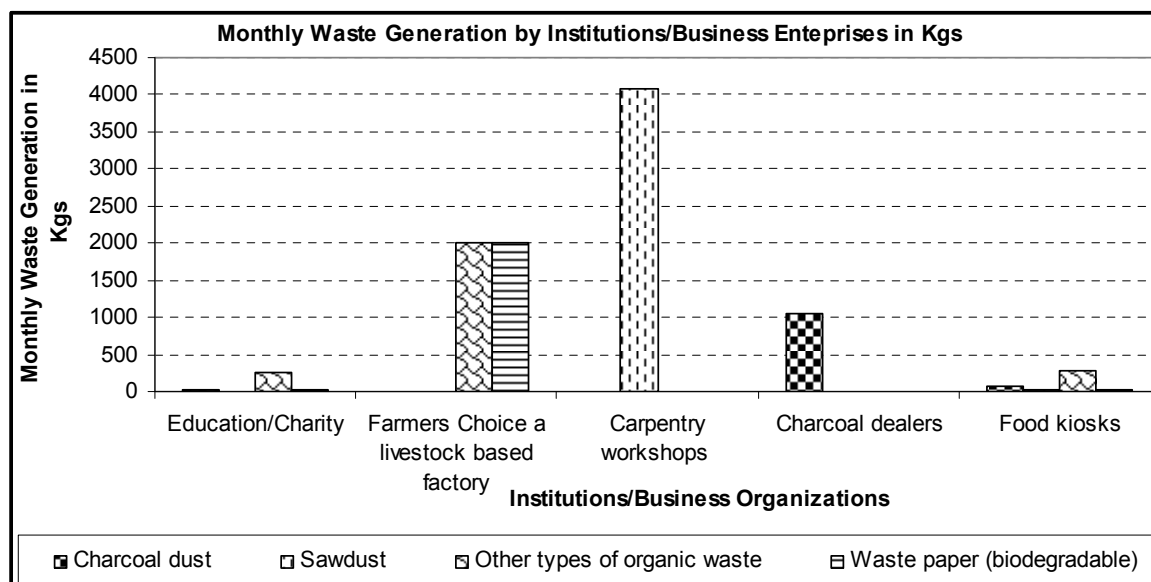
Households

Forty-eight or 30% of the hundred and sixty interviewed households sorted their waste into organic kitchen waste, waste paper, plastic, metal and glass. Organic kitchen waste and waste paper which constitute the main ingredients for briquettes production were commonest. In terms of gender roles in household waste management, in 64% of the household women played the key role in managing waste while in 22% of households children and youth also participated. In 91% of households kitchen organic waste was mainly recycled as livestock feed and compost production. Almost all households (94%) recycled waste paper either for fire lighting or selling to waste paper dealers. Fifty-five percent of the households paid to have their waste collected, but only on an irregular basis by private individuals/groups, most often youths. Access to this service varied from location to location. Out of the 55% of households, Githurai, which is a middle class formal settlement, had the highest (37%) access to waste collection services, followed by Kahawa Soweto (31%); Jua kali (29%) and Kamae had the least (6%). Garbage was collected at Kahawa Soweto slum by the SOYIA and CBOs linked to UN-Habitat.

Institutions/Business Enterprises

The institutions identified in this survey as potential sources of raw materials for briquette making included schools and charity organizations such as children homes. The business enterprises included charcoal dealers, foods kiosks/hotels and butcheries. Of the institutions and business enterprises interviewed, wood charcoal traders constituted 25%, food kiosks/hotels/butcheries/vegetable groceries 42%, education/charity 19%, sawmills/carpentry workshops 12% and agro based industries such as Farmer's Choice 1%. Twenty percent of the institutions/business enterprises sorted waste at source. The waste types produced by the institutions/business enterprises included charcoal dust, sawdust, kitchen organic waste and biodegradable waste paper. Charcoal dealers presented the most important source of charcoal dust each producing on average one tonne per month while sawmills/carpentry workshops could supply four tonnes of sawdust per month in average (Figure 1).

Figure 1. Waste Generation by Institutions/Business Enterprises in Kilogram's per Month



The Farmer's Choice pork processing industry that is less than a kilometer from the SOYIA fuel briquette producing plant generates two tons per month of organic waste, mainly slaughterhouse remains. The factory could also supply another two tons of biodegradable waste paper which is used as a binder of the briquetting materials (Figure 1).

About 56% of the charcoal dealers were not using the dust which accumulated in large piles in the neighborhoods. Only one charcoal dealer sold the dust in Githurai 44 to a group that made briquettes. Ten out of the 12 sawmills/ furniture workshops sold sawdust but the demand was very low and huge amounts were piled around the workshops.

3.2.2 Wood Charcoal Utilization by Households and Institutions/Business Enterprises

Households

More households used wood charcoal in the slums than in the middle income Githurai 44 location (Table 1).

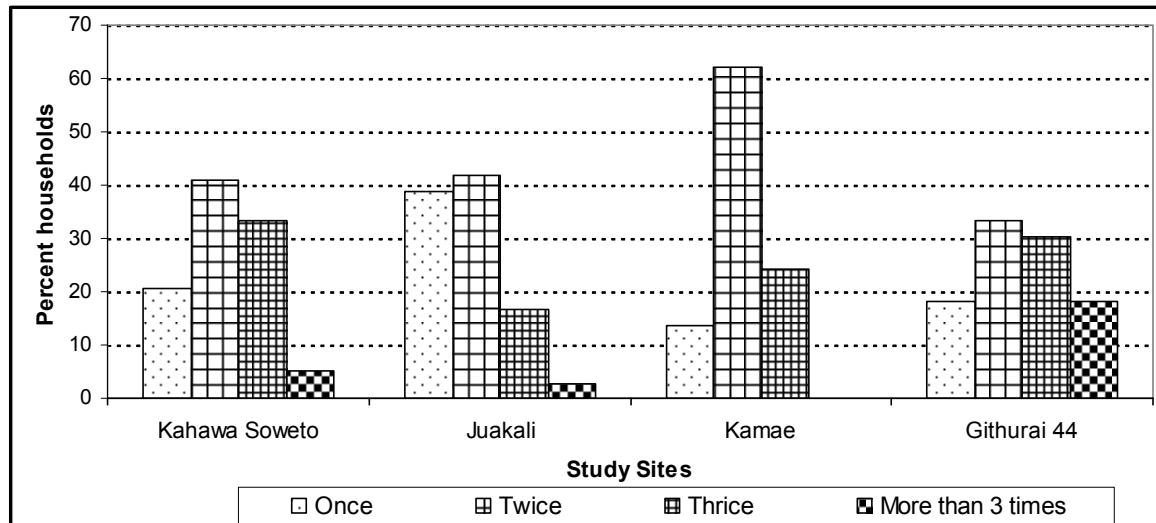
Table 1. Percentage of households using different types of fuels*

| Type of fuel | Githurai 44 N=40 | Jua Kali N=40 | Kahawa Soweto N=40 | Kamae N=40 |
|---------------|---------------------|------------------|-----------------------|---------------|
| Wood charcoal | 83 | 90 | 98 | 93 |
| Kerosene | 84.1 | 78.0 | 77.8 | 75.5 |
| LPG gas | 9.1 | 16.0 | 15.6 | 4.1 |
| Firewood | 4.5 | 6.0 | 4.4 | 16.3 |

*Some households used more than one type of fuel

The vast majority of households in all the four sites used wood charcoal for cooking (Table 1). In terms of daily use, wood charcoal is very commonly used for lunch and dinner, particularly among those in the low income neighborhoods, namely Kahawa Soweto, Juakali and Kamae (Figure 2).

Figure 2. Frequency of wood charcoal use in a day by households



The middle income neighborhood of Githurai 44 had quite a high percentage of households using wood charcoal more than three times in a day, such as for making simple meals like tea and snacks in between main meals while kerosene was used mainly for making breakfast as well as for lighting the wood charcoal stoves (Figure 2).

Fifty-six or 35% percent of households purchased wood charcoal in 2kg units and 90kg bags respectively while the rest bought in 4kg units.

On average households used between 0.88 and 1.5 (90kg) bags of wood charcoal per month costing between 392.5 and 474.3 Ksh /bag (Table2).

Table 2. Annual Household Consumption of Wood Charcoal

| Site | Githurai 44 N=33 | Jua Kali/Kongo N=36 | Kahawa Soweto N=39 | Kamae N=37 | Mean N=145 |
|----------------------------|---------------------|------------------------|-----------------------|---------------|---------------|
| Monthly bags weighing 90kg | 1.13 | 1.03 | 1.15 | 0.88 | 1.04 |
| Cost per bag in Ksh | 474.30 | 444.28 | 443.70 | 392.50 | 438.69 |
| Bags per year | 13.56 | 12.36 | 13.8 | 10.56 | 12.48 |
| Cost per year | 6431.5 | 5491.3 | 6123.1 | 4144.8 | 5474.85 |

The lower use of wood charcoal by people living in Kamae informal settlement compared to other settlements may be associated to their complementing fuel sources with firewood (Table 1: Table 2). From the monthly data presented in Table 2, it was estimated that on average households used 1.12 tonnes of wood charcoal per year with an annual cost of Ksh

5474.85 (US\$73). If we assume that about 60% of the 600,000 households in Nairobi live in similar slum conditions to those in Jua Kali, Kahawa Soweto and Kamae, with similar charcoal usage, then almost 400,000 tons of charcoals are being used annually by Nairobi's low income residents, with an expenditure of nearly 2 billion Ksh (US\$25.2 million).

Institutions/Business Enterprises

From the 41 food kiosks that responded to the question on use of wood charcoal, it was established that they consumed on average sixteen 90kg bags per month while the 19 education/charity organizations consumed 4 bags per month on average which translates to Ksh21,057.12 to Ksh84,228.48 or (US\$281 to US\$1123) annually. Eighty two percent of institutions/enterprises purchased their charcoal in 90kg bags.

3.3 Briquette Production and Marketing

3.3.1 Briquette Production

The SOYIA youth group adopted a well-established model for briquette production. After sourcing materials, the waste paper is shredded and soaked in water overnight. This is used as the binder. Charcoal dust alone or mixed with saw dust/maize cob dust (see section 3.4.2 below) is sorted manually to remove impurities such as pieces of wood, bone, metal and also separate the dust into large and fine pieces. These two types of charcoal dust are mixed at a 1:1 ratio then soaked in water for a few minutes. The wet charcoal dust and fermented paper slurry are mixed at a ratio of 4:1 (charcoal dust: waste paper). Two hundred and fifty grams of the mixture are placed in a PVC pipe (10cm in diameter and 30cm long) with a metal pipe placed in the middle to make a central hole that produces a doughnut-shaped briquette. Three portions of the mixture are placed separated by a metal ring to produce three briquettes. The long arm of the press is then depressed to squeeze the materials in the PVC pipe to remove the water and compact the solid matter (Plate 4). With this briquette press, the production rate is about 150 briquettes per person per day. The final product is dried for 6-7 days on wire mesh shelves on a wooden rack (Plate 2) and then stored in sacks.

3.2.2 Characterization of Briquette and Determination of Cooking Qualities

Three types of briquettes were tested, with different composition mixed at the ratio of 4:1 of principle raw materials and waste paper as a binder. Types I and III contained equal amounts of charcoal dust and maize cob or sawdust:

- Type I: Charcoal dust, maize cob dust and waste paper
- Type II: Charcoal dust and waste paper
- Type III Charcoal dust, sawdust and waste paper

The parameters measured were; ash content, moisture content, level of volatile matter and calorific value. This was replicated three times and the means are presented in table 3.

Table 3. Characteristics of the three types of energy briquettes

| Characteristics | Type I | Type II | Type III | Wood charcoal |
|---------------------------------|-----------|-----------|-----------|----------------|
| Percentage ash content (%) | 33.58 | 37.15 | 53.4* | 2.4** |
| Percentage moisture content (%) | 5.45* | 5.83 | 5.24 | 7.135** |
| Percentage volatile matter (%) | 15.87 | 17.6 | 17.57 | 21.15**** |
| Calorific value (Kj/g) | 15.11KJ/g | 18.68KJ/g | 15.79KJ/g | 25-33',**',*** |

*Mean value has a significant difference at 0.05 probability level from the other values, **Fuwape (1993)
 Terra Nuova, (2007), * (Oduor et al, 2008)

Fuel briquettes Type III produced the highest ash content (53.4%), followed by Type II (37.15%) while Type I produced 33.58% (Table 3). The ash content which is the non-combustible residual was much higher in the briquettes compared to the wood charcoal made from *Leucana leucocephala* and *Tectona grandis* as studied by Fuwape (1993). The characteristics of the briquettes are likely to be associated with amounts and types of waste used, for example, combining waste paper and sawdust results in higher production of ash (Type III). Briquette Type II had the highest calorific value of 18.68KJ/g followed by Type III while the lowest was Type I as presented in Table 3 which meant that Type II briquettes had the highest thermal heat energy. Type I briquette had low energy value compared to the other two types which could have resulted from the low lignin value of maize cob. The energy value of the briquettes produced by SOYIA ranged from 15.11KJ/g to 18.68KJ/g which was comparable to those produced by community groups in the country (TERRA NUOVA, 2007). Energy value of briquettes was lower than that of wood charcoal which could be associated to the high 22-26% value of lignin in wood (Campbell, 1983) and the fact that sawdust and maize cob were not carbonized to enhance fixed carbon. Despite briquettes having a lower energy level than charcoal, their levels of volatile matter and moisture content were better than charcoal indicating potential for quality enhancement.

Participatory testing of cooking and heating qualities was demonstrated as shown in Plate 5.

The results presented in Table 4 showed that briquettes had a longer burning time than wood charcoal by over 1 hour.

Table 4. Participatory briquette testing and demonstration at Kahawa Soweto village

| Type of Briquettes and Experiment procedure | Average time taken to fully Ignite/light (minutes) | Smoke produced by the Briquettes | Flame characteristics | Time taken to cook | Time taken to burn into ashes |
|--|--|----------------------------------|------------------------|--------------------|-------------------------------|
| Type I: Charcoal dust + maize cobs + waste paper weighing 420g (two briquettes) | 12 | Very Little smoke | Small hot yellow flame | 3hr 4 min | 3hr 24 min |
| Type II: Charcoal dust+ waste paper weighing 418g (two briquettes) | 11 | No smoke | Small hot yellow flame | 2hr 16 min | 3hr 09 min |
| Type III: Charcoal dust + saw dust +waste paper weighing 433g (two briquettes) | 15 | Very Little smoke | Small hot yellow flame | 2hr 07 min | 3hr 11 min |
| Wood charcoal weighing 400g | 11 | Very Little smoke | Hot yellow flame | Not available | 1hr 57 min |

Type I briquettes with an average weight of 210g each took 12 minutes to ignite and burned with short tongues of hot yellow flame with very little white smoke. The average cooking time was 3hours and 4minutes while they took 3hours and 24minutes to burn to ashes. Type II briquettes weighing 209g each took 11 minutes to ignite and burned with hot yellow flame without smoke and took 2hours and 16 minutes to cook the meal and 3 hours and 9 minutes to burn to ashes. Type III briquettes weighing 216.5g each took 15 minutes to ignite, burned with hot yellow flame and produced very little white smoke. These briquettes took 2 hours and 7 minutes to cook the meal and 3hours and 11 minutes to burn to ashes. Wood charcoal weighing 400g took 11 minutes to ignite, burned with a hot yellow flame and took 1hour 57 minutes to burn to ash (Table 4).

In terms of briquette quality and sourcing of raw materials, the ordering of briquette types is as follows: Type II \geq Type III > Type I.

Community members of Kahawa Soweto village including SOYIA group were amazed at the comparative cooking qualities that the briquettes had against the traditional wood charcoal in cooking *githeri*. One man commented, “*I am very glad to have witnessed how two pieces of briquettes cooked githeri with minimal smoke and I am now convinced of its value and will have no problem giving money to my wife to buy them*” The participatory testing and demonstration process proved to the community that fuel briquettes can be a good source of energy. The exercise also strengthened the partnership between SOYIA and the community where the latter felt good being part of the innovation and were happy that it was taking place in their village.

3.4 Commercialization and Market Linkages

3.4.1 Households as Potential Customers

Of the 50 respondents who participated in the survey, 55% were aware of the fuel briquettes, especially those from Kahawa Soweto village and at the Nakumatt Thika Road supermarket both of which could be due to current project in the former case and exposure for the later. Source of the awareness was through media (television), research and development agencies or friends/relatives. However of those who had heard about the energy briquettes, 57% had never used them possibly because they were not in the market. For those who had used the briquettes they identified the preferred qualities as: length of burning time, high thermal heat, less smoke, price and shorter time to ignite. The survey showed that 96% of female respondents and 86% of male respondents were willing to switch over to using fuel briquettes to meet their cooking and heating needs. On the packaging sizes, 45% with equal numbers of men and women preferred the briquettes packaged in sealed bags containing 4 pieces and this was mainly found at charcoal dealers and supermarkets and the low income Kahawa Soweto village. This was followed by a package containing 10 pieces (33% of respondents) and 17% chose 50 pieces per bag mostly at the Nakumatt Supermarket and, a 20-piece package chosen by 5% of the respondents. Women were willing to pay Ksh5.5 to 8.5 (Ksh7 = US\$0.09) and men Ksh3 to 6 (Ksh5 = US\$0.07) for one piece of the fuel briquette. The least price quoted by supermarkets customers was Ksh6 (US\$0.08) while charcoal buyers proposed Ksh3 (US\$0.04) for each piece of the fuel briquette.

With respect to outlets for the briquettes, the survey found out that both men and women preferred to buy briquettes from the charcoal dealers (55%) followed by supermarket (34%) while retail shops or wholesale dealers were chosen by 10% of the respondents. Eighty-seven percent of those who preferred charcoal dealers as the best outlets were their customers and local supermarkets customers around Kahawa Soweto village. Supermarkets were chosen by those shopping at the Nakumatt Supermarket, Thika road Branch. Reasons for the choice of the outlets included; price, proximity to the home and assurance of good quality.

3.4.2 Institutions/Business Enterprises as Potential Customers

A market survey was carried out with 10 charcoal traders at Kahawa Soweto village regarding their willingness to trade in fuel briquettes. Results showed that charcoal selling in informal settlements was dominated by women where eight out of the ten interviewees randomly selected were women. Women would thus be appropriate targets for small-scale selling of briquettes. In addition to the charcoal traders, three supermarket managers were interviewed and out of the 13 respondents, 11 showed interest in stocking fuel briquettes and over half of them preferred them being packaged by fours. When asked why they did not stock fuel briquettes, the traders gave the follow reasons; they did not know about them, customers had never asked for them and they are not available.

4.0 ACHIEVEMENTS

4.1 Outputs

- A CODIS training manual produced and used in training SOYIA youth group
- A market plan for SOYIA fuel briquettes production enterprise was developed
- A revised version of fuel energy briquette production and marketing training manual
- A marketing brand for the SOYIA fuel briquettes
- Project activities contributed towards adapting machines to conditions on the ground
- Poster presentation by Mary Njenga, Nancy Karanja, Beatrice Mwasi, Gordon Prain Kuria Gathuru and John Malii (2009) at the Alliance for Global Sustainability (AGS) Annual Meeting, 26-29 January 2009, Swiss Federal Institute of Technology ETH Zurich. <http://www.cces.ethz.ch/agsam2009/>
- This Urban Harvest-CIP working paper
- PhD proposal on “Organic Waste Recovery for Sustainable Energy Fuel Briquette Production and Healthy Environment, Nairobi City and its Environs, Kenya”

4.2 Outcomes

SOYIA youth group produced 600 briquettes and sold half of them at Ksh3 to 5 in the first two months. The demand is expected to rise through the market survey and promotions exercises carried out among institutions such as schools, charcoal dealers, meat roasting places (*choma zones*) and supermarkets in Nairobi. Through increased sales the 20 young men and women of SOYIA will benefit through income generation and a source of employment while the communities within the village and its environs will have a source of affordable good quality fuel. The enterprise will contribute to management of organic waste in the neighborhoods.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. About half of households in the survey had no access to waste management services and the majority of those who had access were from the middle income Githurai 44 area where this service was provided by the private sector mainly by youth groups and carried out on an irregular basis. Women and children played the greatest role in household waste management. Despite there being some form of waste reuse efforts in over 90% of households, most of the waste was dumped in pits and open spaces and either burned or left to rot, either way affecting environmental health.
2. Dialogue during the different forums between the SOYIA and other CBOs at the Kahawa Soweto village resulted in formation of partnerships that agreed to push ahead with waste recycling activities in order to clean up the neighborhoods, create employment and earn income. A need for establishing linkages with the business sector and with research and training institutions for assurance of quality and sustainability was identified.

3. Institutions/business enterprises such as charcoal dealers, sawmills and carpentry workshops produced most of the charcoal dust and sawdust while agro-based industries such as Farmers Choice, schools and food kiosks produce food-based organic wastes and waste paper for fuel briquette enterprises.
4. The youth group jointly with interested stakeholders succeeded in adapting high-cost briquette making technology to local conditions; paying attention to gender needs was noted to be integral part of the process
5. Consumers were willing to use fuel briquettes, more women than men. The low income households chose local charcoal dealers as the outlets while middle income households selected supermarkets as outlets for the briquettes.
6. Both men and women from low income households preferred small packages of four pieces while those from the middle income households wished to buy large packages containing 50 pieces.
7. Once quality is assured, fuel briquettes is a potential substitute for wood charcoal which could be widely adopted among urban households where, for instance, over 80% of interviewed households in both poor and middle income neighborhoods were found to use wood charcoal, the majority of them using it to prepare main meals, namely, lunch and dinner. Institutions/business enterprises such as schools and food kiosk are other potential customers of briquettes.

Further Actions

There is limited information/data on the likely contribution of this technology, once it is in use, to greenhouse gases hence air quality and its potential health risks to those exposed to indoor emissions. There is need for in-depth quality characterization studies to understand the influence of types and amounts of raw materials on the quality of the fuel briquettes. Hard data on contribution of the technology to urban waste management is also required. Information generated from the above two areas need to be linked to tradeoff analysis which would then feed into the development of relevant policies that would take into consideration urban-rural dependencies and their potential role in ecosystem management at national and regional scales. There is limited choice of briquetting machines whose efficiency in terms of volume and quality produced need to be enhanced. Efficiency in utilization need to be linked to the stoves and market value chain strengthened.

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