MARKET POTENTIAL AND FACTORS LEADING TO THE ACCEPTABILITY OF FAECAL SLUDGE BRIQUETTES IN LOW-INCOME AREAS OF LUSAKA- A CASE OF KAMANGA COMPOUND

By

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DECLARATION

I, Chisha Kaulungombe, solemnly declare that this dissertation represents my work which has not been submitted at this or another University. All published works or materials from other sources that have been incorporated were acknowledged and adequately referenced.

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CERTIFICATE OF APPROVAL

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ABSTRACT

Excreta ought not to be viewed solely as a problem but as a potential resource from which valuable resources can be obtained and sold to consumers. One of the resources that can be recovered from faecal sludge is briquettes. Briquettes can be processed from faecal sludge and used as a sustainable energy source at the domestic, institutional and industrial levels. Despite faecal briquettes being a good sustainable energy source produced from an abundant resource, end-user acceptability is still a challenge. This is mainly attributed to the perception that faecal sludge is a waste, not a resource. The perception of end users influences the future success of the faecal briquettes as an energy source. Therefore, this study aimed to determine factors leading to acceptance of faecal sludge briquette based on views of potential users and market potential. The market potential is based on an available energy source the briquettes could replace, referred to as a substitute product. Qualitative methods, employing focus group discussions were suitable for determining the acceptability of the product through participant response. Quantitative methods were employed when determining the market volume potential of the product and the cost compared to other energy sources. An interview guide, guided the Focus group discussions (FGD), which resulted in identification of themes related to factors leading to acceptability of faecal sludge briquettes. Household heads were purposively sampled through a list of household heads, provided by community heads of each of the six zones that make up kamanaga. A total of six focus group discussions were carried out. Total sampling was used to sample charcoal traders who provided both quantitative for market potential and qualitative data in line with FS briquette acceptance. Both the quantitative data and the qualitative data from the charcoaltraders was collected with the use of a survey tool for key informants. Chi square was carried out, no associations were found between acceptability factors and individual factors such as religion, gender etc as suggested by other studies.Market Driven Approach (MDA) calculation tool was used to analyse the market potential of faecal sludge briquettes based on the substitute product. Findings on market growth potential revealed that factors such as; an increase in the number of traders, increase in the daily purchase of charcoal were good indicators of growth. Calculation of the market volume revealed that 50kg bags of charcoal had the largest market volume ($1356.6) while 1.5kg plastics of charcoal had the lowest market volume ($694.4). The application of a 1.1 adjustment factor resulted in a total adjusted market volume for all the charcoal quantities to be $5809.078. Major FGD themes included; Current energy sources used in Kamanga and factors leading to the acceptability of faecal sludge briquettes in Kamanga compound. Sub themes included; Perceived usefulness, ease of use, affordability, smoke production, awareness creation, availability, and perceived performance of faecal sludge briquettes. A comparative cost analysis of currently used energy sources in the area was carried out where it was found that faecal briquettes cost ZMW 0.5 more than charcoal. Despite the ZMW 0.5 cost difference between charcoal and faecal sludge briquettes, the longer burning time of briquettes would make them more cost-effective. Based on participant responses, acceptability for faecal sludge briquettes is achievable if the product can meet the expectations of the users. Positive user response coupled with better or similar growth trends of charcoal will make for good market potential. Product development and user education will be required to bring awareness to potential market participants as they are key in the success of the briquettes.

Key Words: faecal sludge briquettes, market-driven, acceptability, market growth, market volume, excreta, themes, market potential, substitute product

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LIST OF ABBREVIATIONS

BMGF : Bill and Melinda Gates Foundation

CBO : Community Based Organisation

COVID19 : Corona Virus 2019

EED : Energy Environment and Development

EERE : Energy Efficiency and Renewable Energy

EIA : Energy Information Administration

ERB : Energy Regulation Board

FAO : Food and Agriculture Organisation

FSM : Faecal Sludge Management

GRZ : Government of the Republic of Zambia

ICCO : Inter-Church Cooperation

IEC : Information Education and Communication

JMP : Joint Monitoring Programme

LWSC : Lusaka Water supply and Sanitation Company Limited

MDA : Market Driven Approach

MLG : Ministry Local Government

MLGH : Ministry of Local Government and Housing

MWDSEP : Ministry of Water Development Sanitation and Environmental Protection.

NAWASSCOAL : Nakuru water and Sanitation Services Company Limited

NREL : National Renewable Energy Laboratory

NUSS : National Urban and Peri-Urban Sanitation Strategy

NWASCO : National Water Supply and Sanitation Council

SANDEC : Sanitation, Water and Solid Waste for Development

SNV : Stitching Nederlandse Vrijwilligers,

TAZAMA : Tanzania Zambia Pipeline

TPPL : Tanzania Petroleum Products Limited

UN : United Nations

UNHCR : United Nations Human Rights Commission for Refugees

UNICEF : United Nations International Children's Emergency Fund

WARMA : Water Resources Management Authority

WASH : Water Sanitation and Hygiene

WHO : World Health Organisation

WRC : Water Research Commission

WSUP : Water and Sanitation for the Urban Poor

ZABS : Zambia Bureau of Standards

ZDA : Zambia Development Agency

ZEMA : Zambia Environment Management Agency

ZESCO : Zambia Electricity Supply Cooperation

CHAPTER ONE

INTRODUCTION

1.1 Background

In 2018, about 55 percent of the world's population was living in urban areas, with 68 percent predicted urbanites by the year 2050. This population boom mostly occurs in urban and peri-urban areas of Africa and Asia. Most of these cities lack adequate sanitation infrastructure to support this population growth, especially among many poor populations (United Nations, 2018).

In Zambia, only about 33 percent of the population has access to a basic sanitation service, with 41 percent in urban areas and 28 percent in rural areas. At the household level, it is estimated that 54 percent use an improved sanitation facility, with a pit latrine being the most used at 37 percent (Zambia Statistics Agency et al., 2019).

Zambia's capital Lusaka is inhabited by approximately over three million people, 70 percent of whom live in peri-urban areas (Zambia Statistics Agency, 2022). It is estimated that more than 90 percent of people living in these peri-urban areas use pit latrines for the disposal of their excreta, generating about 1.5 litres of excreta per day per capita (Koné and Peter, 2008).

Faecal Sludge Management (FSM) globally has not been prioritized when tackling improved sanitation, especially in underdeveloped nations (Strande et al., 2014). In low-income urban areas, FSM has been excluded from comprehensive sanitation plans, with sanitation investment only concentrated on either household toilets or sewer system construction. As a result, rather than the public sector dealing with FSM, it is left to the household level (Strauss and Montangero, 2002). Undoubtedly, this leads to poor management of faecal sludge, so much that contents from pit latrines end up being buried in the nearby open environment, such as open drains. This is done in avoidance of high costs on transportation where sludge was to be transported to designated disposal sites. For instance, in Lusaka city, 47 percent of the sludge generated by onsite waste treatment facilities ends up in the source environment (Ministry of Local Government and Housing, 2014).

In Zambia's low-income areas, some positive advances in FSM have been noticed, despite some challenges that persist. For instance, Lusaka's Kanyama compound has seen the introduction of an FSM project by Lusaka Water supply and Sanitation Company Limited (LWSC), supported by the Water and Sanitation for the Urban Poor (WSUP). The aim was to address desludging, transportation, treatment and the ultimate utilization of faecal sludge. Value was to be added to the faecal sludge by feeding it into digesters, generating biogas and sludge to be dried and sold for fertilizer (Linyama et al., 2014). However, a gap exists in widely implementing technologies that contain and treat excreta on-site. The need for safe management of faecal sludge from onsite facilities remains in almost all the towns and cities across the world in underdeveloped nations. Effective treatment must be provided to enhance the safe management of faecal sludge, whether reuse or disposal. To that end, organisations like the Bill and Melinda Gates Foundation (BMGF) have urged that excreta should not be viewed solely as a problem but as a potential resource. They have highlighted what they call the 'sanitation value chain', Instead of the mere sanitation service chain. The emphasis should be that a valuable product can be recovered from faecal sludge. The chain consists of five stages: capture/storage, emptying, transport, treatment, and reuse (Tayler, 2018).

Within a sanitation value chain context, a portion of running cost is expected to be offset by resource recovery, but not entirely. One of the primary forms of resource recovery from faecal sludge is briquetting. Faecal sludge briquetting has lately provoked interest because of the room it provides to effectively use agricultural and municipal solid waste, which could result in reduced environmental pollution. In addition, these faecal sludge briquettes can be used as a sustainable energy source at the domestic, institutional, commercial or industrial levels, especially in places where access to sustainable energy sources is limited (Nikiema et al., 2017).

Due to differences across markets in product selection for resource recovery, there must be restrain on deducing from the experiences of other regions. This is why the market-driven approach offers a skeleton for exploring market potentials for faecal sludge treatment products. The market-driven approach can universally be applied across different regions and settings, offering a way to establish potential market

implications consistently and comparably. This information can evaluate the applicable market and business model strategies (Schoebitz et al., 2016).

Among other factors, mindset change towards human excreta is a prerequisite to achieving or marketing ecological sanitation solutions. However, there is considerable variability in the acceptability of such kind of technology across countries. In some cultures or social groups, it is unacceptable to handle or directly use human excreta. Consequently cultural taboos have to be changed in these parts of the world to promote acceptability in the use of human excreta products (Duncker et al., 2007).

1.2 Statement of the problem

Many African countries have witnessed massive urbanisation, which has ultimately mounted pressure on the available sanitation services. This has led to poor and unsafe faecal sludge management, especially in poor urban areas. To help resolve this challenge, recycling faecal sludge into useful products is one way to ensure environmental sustainability and protection (Gitau et al., 2020). Different forms of resource recovery technologies have come up in the recent past, with briquetting having caught the attention of many. It offers a great deal of opportunity to use ofuse agricultural residues and organic fractions of waste efficiently and sustainably, resulting in reduced environmental pollution. These products can range from modern heating to cooking fuels for domestic, institutional, commercial and industrial settings, especially in parts of the world where sustainable sources of energy are scarce (Nikiema et al., 2017).

Despite faecal sludge briquettes seemingly being a good sustainable source of energy produced from an abundant resource, end-user acceptability is still a challenge. This is mainly attributed to the perception that faecal sludge is a waste, not a resource, and its management through FSM service provision lacks incentives (Daniel and Reed, 2010). Changing this perception calls for awareness of the perceived benefits of resources recovered from excreta through mindset change of end-users to make FSM a success.

The perception and attitude of potential end users influence the future success of a treatment product, in this case, faecal briquettes. Therefore, water and sanitation companies looking for more innovative ways to convert faecal sludge into valuable

products, such as faecal briquettes, need to cut through the misconceptions surrounding their use. Therefore, this study aims to assess the potential market for faecal briquette in Lusaka's Kamanga compound based on the views and acceptance of potential end users.

1.3.0 Research objectives and questions

1.3.1 General objective

To determine the market potential and factors leading to the acceptability of faecal sludge briquettes in low- income areas of Zambia.

1.3.2 Specific objectives

i. To assess factors leading to the acceptability of faecal sludge briquettes in low-income areas of Zambia.

ii. To evaluate the market potential of faecal sludge briquettes based on a substitute product used in low-income areas.

iii. To undertake a comparative cost analysis of faecal sludge briquettes with other energy sources used in the study area.

1.3.3 Research questions

i. What factors can influence the buying/using of faecal sludge briquettes by households in low-income areas?

ii. What factors can influence the selling of faecal sludge briquettes by retailers in low cost areas?

iii. What is the substitute product of faecal sludge briquettes in low-income areas, and why is its usage preferred to other energy sources in low-income areas?

iv. What factors describe the market growth potential of faecal sludge briquettes based on a substitute product in low cost areas?

v. What is the market volume potential of faecal sludge briquettes in low-income areas based on a substitute product?
vi. What is the cost of faecal briquettes compared to other energy sources

1.4 Justification

In Zambia, there is little information about people's perceptions and attitudes towards faecal sludge treatment products like briquettes and their market potential. This study will help predict future market trends for faecal sludge briquettes by determining their market and acceptability. Ultimately, faecal sludge treatment companies looking into the production of faecal briquettes will be able to use the information to know whether their products are likely to be accepted by potential users and do well on the market. Furthermore, identifying potential markets for faecal sludge briquettes will reduce environmental pollution. A safe and healthy environment is a precursor of good public health because of reduced disease incidents, especially diarrhoeal diseases such as cholera that have in the past hit Zambia. It is hoped that the study's findings will add to the existing body of knowledge on faecal sludge treatment products market and acceptability.

1.5 Definition of terms

Market-Driven approach: The Market-Driven Approach (MDA) is a quantitative method developed by Sanitation, water and solid waste for development (SANDEC) to evaluate the market for potential products resulting from the treatment of faecal sludge (Schoebitz et al., 2016).

Faecal Sludge briquette: These are briquettes made from carbonisation and briquetting of faecal sludge with a binder (Schoebitz et al., 2016).

Substitute product: A product currently sold in the market with the potential to be replaced by a faecal sludge treatment product (Schoebitz et al., 2016).

Faecal sludge: This is a slurry containing solid and liquid waste that accumulates in onsite sanitation systems (Schoebitz et al., 2016).

Onsite sanitation (decentralised): Sanitation in which excreta and waste water are collected stored /treated on the plot where they are generated. (Tilley et al., 2014).

Septage is the liquid and solid material pumped from a septic tank (Schoebitz et al., 2016).

Resource recovery: Using of waste inputs in order to create new and valuable outputs (Schoebitz et al., 2016).

Sanitation service chain: This is the order of services in which excreta and waste water from onsite/offsite sanitation systems are handled (Tilley et al., 2014).

Biomass: this is renewable organic material that comes from plants and animals (National Geographic, 2022).

Faecal sludge management: Collection, storage, transportation and treatment of faecal sludge (Tilley et al., 2014).

Excreta: This relate to urine and faeces (Tilley et al., 2014).

Sanitation: The disposal of excreta and waste water in a safe and hygienic manner (Tilley et al., 2014).

Market growth: Growth in sales for identified substitute products for one potential faecal sludge treatment product. (Schoebitz et al., 2016).

Market volume: Multiplication of the number of units sold per available substitute product with the given price over a specific period (Schoebitz et al., 2016).

Market participant: Stakeholders that play a role in the supply chain and use of substitute products and/or faecal sludge treatment products, for example, producers, wholesalers, retailers, and customers of products (Schoebitz et al., 2016).

Bio char: This charcoal-like substance is made by burning organic material from agricultural and forestry wastes in a controlled process called pyrolysis (Spears 2018).

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter begins with a historical context of the use and development of on-site wastewater treatment facilities. Then focuses on types of energy sources in Zambia, with much focus on charcoal because of its role as the substitute product for faecal sludge briquettes in this study. Substitute is as defined in Section 1.5 of chapter 1. This is then followed by the main focus of this study, the faecal sludge briquettes, highlighting various qualities of briquettes that would create a positive market response. market-driven approach is explained, specifically how it is used in the resource recovery stage of FSM. Then attitudes towards faecal treatment products and awareness creation are also looked at through various literature works. The chapter concludes with comparing production cost for briquettes, wood and charcoal, then various legislature and bodies that are relevant in FSM and finally, a chapter summary.

2.1 Historical Context of On-Site Wastewater Treatment Facilities

King Minos installed the first known water closet in Knossos Palace in Crete in 1700 BC. This has been followed by the pursuance of improvement by societies and governments in both the removal of human waste from indoor areas and its treatment to reduce threats to public health and ecological resources. Unfortunately, the noticeable progress made by the Greeks, Romans, British, and French from 800 BC to AD 1850 on the removal of waste often meant discharging into surface waters, resulting in severe environmental contamination. This was a recipe for frequent outbreaks of diseases like cholera and typhoid fever (Gilbert, 2008).

Currently, onsite sanitation technologies take many forms, including septic tanks and soak away, aqua privies, biogas latrines, composting or dehydrating toilets and pit latrines (Strande et al., 2014). These on-site systems are designed to keep most of the solid component of excreta in the pit or tank while, in most cases, allowing the effluent to percolate into the ground. The accumulated solids (sludge) can expose people to unsanitary conditions and require emptying. In order to protect the environment and public health, the material removed has to be safely transported away from the

residential areas for treatment or otherwise dealt with in a way that allows for its subsequent safe reuse or disposal (Tyler, 2018).

2.2 Energy sources used in Zambia

Firstly it is essential to understand the structure of the energy sector in Zambia, to note where the deficits are and how alternative sustainable resources such as faecal sludge briquettes can help meet some of the current energy needs in Zambia. According to Energy Regulation Board (2020), Zambia's energy sector comprises mainly; electricity, petroleum and renewable energy. These sources of energy are briefly discussed below:

2.2.1 Petroleum

The demand for national petroleum products in Zambia is met through the importation of petroleum feedstock and finished petroleum products through private suppliers by road and rail to INDENI Refinery Company Limited. Petroleum is crucial in running particular areas of the economy such as; transport, agriculture and mining. Since the Corona Virus 19 (Covid 19) outbreak, the demand for petroleum products declined by 8.6 percent. The outbreak caused reduced global economic activity due to the lockdowns (International Energy Association, 2020). The petroleum sector in Zambia comprises three main players; Tanzania-Zambia crude oil Pipelines (TAZAMA), INDENI Petroleum Refinery Company Limited and Tanzania Petroleum Products Limited (TPPL).TAZAMA is responsible for pumping petroleum feedstock and ensuring receipt and storage of imported products in Government depots, while INDENI is responsible for processing petroleum feedstock into finished petroleum products (ERB, 2020). Due to the Covid 19 outbreak, INDENI and TAZAMA experienced increased shutdowns. INDENI was on shutdown for 190 days of which 162 days were due to a lack of imported feedstock, while TAZAMA experienced a cumulative period of 196 days of unplanned shutdowns (ERB, 2020).

i. Production and use of petroleum

Petroleum is formed from the remains of dead plants and animals, it is a mixture of many substances such as; gas, petrol, diesel kerosene, etc. To obtain the Petroleum oil required for energy and manufacturing various products, the petroleum must be refined. Petroleum refineries are large industrial complexes involving many

processing units. Crude oil is extracted from the ground and converted at the refinery in a three step process; separation, conversion and treatment (BYJU'S, 2022). Petroleum is referred to as black gold aside from being an important energy source it is very important in manufacturing many products, these products include pharmaceuticals, plastics, gasoline, synthetic fibres, fertilizers etc. (BYJU'S, 2022).

2.2.2 Electricity

In Zambia the most important energy after wood fuel is hydro power. National access to electricity for Zambia is at an average of 31 percent; with 67 percent of the urban and only four percent of the rural population having access to electricity.The Government of Zambia is aiming to provide electricity for all Zambians by 2030 (USAID, 2022). Demand for electricity has grown rapidly and continues to grow due to increased population and economic activities. (International trade administration, 2021). Zambia's electricity sector includes the public utility company, Zambia Electricity Supply Corporation (ZESCO), as the major player covering generation, transmission and distribution. It is supported by Independent Power Producers that sell its power. Some other players are engaged in the transmission and supply of electricity to end-use customers (ERB, 2020).

i. Production and use of electricity

In Zambia our electricity comes from Hydropower, in hydro power water is stored at higher elevation and led downstream to a lower elevation. The difference in the higher elevation and lower elevation is known as the head (Power Technology, 2020). The head water turns Turbines and generators convert kinetic energy of flowing water into electricity which is then fed into an electrical grid to power homes, businesses and industries. The greater the flow and the higher the water head, the more the electricity that can be produced (Energy Efficiency and Renewable Energy, 2022)**.** People use electricity at different levels; in homes, industrially and commercially. It is mainly for; cooking, lighting, heating, cooling, refrigeration, operation of appliances, for computers, machinery etc. (Energy Information Administration, 2021).

2.2.3 Other renewable energy Source

In light of issues like the climate crisis, there have been positive advances towards the large-scale development of other renewable energy sources being observed

worldwide, aside from hydro power generation. Such advancements hold many benefits, especially for countries that are susceptible to the impacts of climate change, such as Zambia, due high dependence on natural resources. Renewable energy development in Zambia is supported not only by several strategies that promote low emissions, but also the implementation of sustainable practices in land management (ERB, 2020). Zambia has a number of potential sources of renewable energy such as; agricultural land to support bioenergy production, abundant wind to support wind energy generation as well as intense hours to support solar energy generation. Despite this scenario, traditional wood fuels still dominate the energy markets (ERB, 2020).

i. Production and Use of other renewable energy sources:

In order to enjoy the benefits of solar energy, solar panels capture the sunlight then solar cells convert the sunlight directly into electricity. In more scientific terms; photons in light from the sun are converted to voltage (National Renewable Energy Laboratory, 2020). For wind to be as an energy source, a wind turbine turns wind energy into electricity using the aerodynamic force from rotor blades. When wind flows across rotor blades the air pressure on one side of the blade decreases. The difference in air pressure across the two sides of the blade creates a lift and drag, the lift is strong enough to cause the rotor connected to the generator to spin. This translation of aerodynamic force to rotation of a generator creates electricity (Energy Efficiency and Renewable Energy, 2020).

The use of these renewable sources of energy is the same as those mentioned under hydroelectric power; they are also used domestically in homes to power simple appliances or for industrial processes.

2.2.4 Charcoal

Research on charcoal use by Arnold et al., (2003) showed that a major trend related to charcoal utilisation was that it was mainly consumed in urban areas attributing to 85 percent of all charcoal consumed. In contrast, rural areas accounted for the remaining 15 percent of charcoal consumption. This charcoal is used for various reasons and is regarded as an essential source of energy in Zambia, ranking second to firewood. The study went further to state the various uses/reasons why the population are dependent on charcoal, such as for cooking, boiling water and space heating. In terms of

consumption patterns, households accounted for 95.8 percent industry and commerce four percent and mining 0.2 percent. At the household level charcoal ranked as the second dominant energy source after fuel wood and it meets about 21 percent of the energy needs of all the households in the country. Apart from being a widely used energy source, Arnold et al., *(*2003) also brought out the fact that Charcoal production was also an important economic activity which provides employment and a source of livelihood for many rural households. According to Kalumiana et al., (2003) reasons why people were engaging in charcoal production included the following; In order to avoid wastage of wood from cleared fields, secondly to get money for paying off debts, payments/funerals; as payment for field clearing; lastly to obtain money for children's school uniforms, household use and for buying farming requirements such as fertilizer.

i. Charcoal production

The charcoal production process in Zambia involves five main steps, which have briefly been explained below by different researchers. The steps include: felling trees and cross-cutting them into short logs, piling the logs into a clamp, covering the clamp with soil lumps, ignition of the kiln, carbonization of wood into charcoal, harvesting and packaging the charcoal into bags.

The whole charcoal production process was discovered to be very labour intensive and involved the use of basic tools. Table 1 below specifies the tools that are used in the various stages of the charcoal production process.

Table 1: Tools used at various stages of charcoal production

Production stage	Tool
Felling and cross-cutting	Axe, power saw
Log haulage and piling	Wheel barrow, crow bar
Digging soil lumps	Hoe, shovel
Harvesting and bagging	Shovel, rake

Source: (Hibanjene et al., 2003).

1. Felling/cutting of trees and cross-cutting them into short logs

This is the first step in the production process. Trees are selected for charcoal production are felled with an axe at about 30 cm above ground. To promote regeneration of the stump, the cutting is done in a slanting Manner. This helps ensure no water collects on the stump resulting in rotting. The short logs into which trees are cross cut measure about one to three meters (World Bank, 1990; Ranta and Makunka, 1986; Sawe, 1993).

2. Clamp Building

Next, the logs are moved to an already selected site where they are piled into a clamp. The selected site must be close to the wood source to reduce the transporting distance. It should be a levelled out area which can then be cleared using a hoe and all material that can burn removed (Ranta and Makunka, 1986). The cleared area should be much bigger than the kiln size measuring about three meters beyond the boundaries of the kiln so as to act as a guard against fire. Another advantage of using a large cleared area is to provide enough clean surface where the charcoal can be spread during harvesting (Boutette and Karch, 1984). Before pile formation, several meters long logs called stringers are placed on the ground (World Bank, 1990; Ranta and Makunka, 1986). The job of the stringers is to ensure good air circulation and efficient heat transfer in the kiln. The clamp logs are usually piled crosswise on the stringers. In some cases, the logs are placed lengthwise with the stringers crosswise in the general direction of the kiln (World Bank, 1990; Ranta and Makunka, 1986). The pattern of piling logs onto a kiln is as follows: medium logs are put first, followed by the biggest logs available, medium logs and lastly the small logs are placed at the top (Food Agriculture Organisation, 1987).

3. Covering of the kiln

After the piled clamp has been built with the logs, as described above in 'clamp building', Soil lumps, called guards are used to cover the piled clamp. The lumps are dug with a hoe or shovel up to a depth of 15 cm (Sawe, 1993). In a situation where the soil is not very loose, digging deeper is advised. The disturbed area should be such as can be covered by soil and ash from the kiln after charcoal has been harvested. The soil lumps are used to build the clamp wall. The top of the kiln is first covered with

any leafy material and then soil lumps. Loose soil is also applied on top of the kiln. The thickness of the covering varies between 10-45 cm (Ranta and Makunka, 1986; World Bank, 1990; Sawe, 1993; Boutette and Karch, 1984) but the top soil cover should not be too thick (not more than 20-30 cm). The clamp is sealed completely to prevent uncontrolled air entry into the kiln which could lead to wood burning to ashes. A firing point is either left uncovered. Sandy or loamy soils which do not shrink on drying are best suited for covering the clamp (Food Agriculture Organisation, 1987).

The igniting of the kiln is through the firing point that is left uncovered or is opened up after covering the kiln. Firing can be done in the following two ways (Boutette and Karch, 1984; FAO, 1987):

(i) The producer starts a fire in the firing point this requires some skill so that fire is established in the kiln without burning a large amount of the wood.

(ii) Alternatively, some burning wood or charcoal is pushed through the firing point. Fire may be established in about 10-20 minutes after lighting, depending on the conditions of the kindling material used.

When the fire has been ignited, dense white smoke comes out from the kiln at which stage the firing point is then closed with soil. After closing of the firing point, the amount of smoke reduces, giving the impression that the kiln is no longer active. However, the kiln adjusts to the lower oxygen levels and heat loss to the rest of the charge, and starts to pick up (Boutette and Karch, 1984).

4. Wood Carbonization

The process occurs in four main stages, namely; combustion, dehydration, exothermic reaction and cooling.

i) Combustion: After igniting of the kiln, the kindling material together with some of the wood burns. The oxygen supply is high and the temperature rises from ambient to over 500°C (Boutette and Karch, 1984). When the fire is established, the point of firing is closed and oxygen supply reduces and the kiln temperature drops to about 120°C.

ii) Dehydration: In this phase the water molecules that are free in the wood are completely dried out. This is achieved at a temperature of about 100°C, the wood dries to zero moisture content resulting in a thick moist steam, white looking steam (FAO, 1987).

iii) Exothermic reaction: The kiln temperature then rises to about 280°C. The energy which causes the temperature to rise is from partially combusted wood (FAO, 1987).This temperature causes wood to spontaneously break down to produce charcoal, water vapour, methanol, acetic acid and other complex chemicals and condensable gases such as hydrogen, carbon monoxide and carbon dioxide (Hibanjene et al., 2003).

iv) Cooling: When carbonization is completed, the kiln cools and charcoal can then be removed. When the temperature is approximately below 100°C, charcoal is dug out from the kiln, and spread out on the ground. It is then covered by loose soil to prevent it catching fire when it comes into contact with air (Hibanjene et al., 2003).

Table 2 below summarises the four main stages of the wood carbonisation process from combustion to cooling. The wood must undergo all four stages in order to successfully be carbonised to form charcoal.

Table 2 : summary of wood carbonization in an earth kiln

Carbon-ization stage	Smoke type	Kiln temperature	Kiln activity	Kiln product	Kiln management
Combustion	White & dense	Ambient - 500 °C 500 - 100 °C	Burning of wood/	-	Close ignition point after fire establishes
Dehydration	White, thick & moist	100 - 300 °C	Wood dries	-	-
Exothermic reaction	Yellow, hot & oily	100 - 300 °C 300 -700 °C	Wood breaks down; wood partially burns; heat production	Charcoal, water, vapour, acetic acid, methanol, complex chemicals	Controlled air admission through vents in kiln, kiln repair, may need external air provision
Cooling	-	700 - 100 °C 100 °C -lower	Inside kiln Outside kiln	-	Charcoal removed

Source: (Hibanjene et al., 2003).

a) Negative impacts of charcoal production

The negative impacts of deforestation due to increased charcoal production affect the environment and direct beneficiaries of these forests, such as the wildlife and nearby communities. According to Dlamini (2013), these forests sustain livelihoods of local inhabitants and other forest-dependent communities and contribute to other ecosystem goods and services. For example, forests are an important source of food and income that contribute to livelihoods and dietary diversity for rural households (Mukuka and Simoloka 2015). According to Tembo and Sitko (2015), Zambia has an alarming deforestation rate estimated between 250,000 and 300,000 ha per annum. The rate of deforestation highlights the importance of understanding the increased use of charcoal on forest degradation and deforestation and finding ways to mitigate further negative impacts.

According to Federal ministry for economic cooperation and development, Germany (2022), Zambia now has one of the largest rates of deforestation in the world and is increasingly faced with climate change issues. One of the main drivers of the increased deforestation is due to the cutting of trees for the production of charcoal (Gonzalez, 2021). An example of the impact of climate change in Zambia is the irregular precipitation patterns which have led to droughts and flooding. According to a report by International Federation of Red Cross (2021), during 2019/2020 Zambia experienced -normal rainfall, resulting in flooding and dry spells in western province particularly.

b) Environmental Impacts of Charcoal Production

According to Hibanjene et al., (2003), environmentalists expressed great concern about the need to do away with the traditional method of charcoal production because of the environmental destruction it causes. However, it has been established that rural and urban residents rely heavily on charcoal use, resulting in failed attempts to ban its production. Below are some of the charcoal production steps and the resulting effects of the step:

1. Environmental impact of tree felling

It was learned from Chidumayo (1984) that during the tree felling step, 90 percent of the basal area is cleared, representing about 95 percent of the above ground wood biomass leaving behind small stems. Felling that occurs in, for example, Miombo woodlands, the tree density of the first regrowth is two to three times higher than in the old-growth woodland. Species density in regrowth Miombo is 20.55 per 0.1 ha compared to 17.13 in old growth. Diversity is therefore impacted positively. Grass production increases two years after felling and remains high until tree canopy is re-established in about 1015 years. According to Hibanjene et al. (2003), tree felling is known to disturb wildlife habitats, but current production areas have small populations of large mammals, so the effect caused is minimal. Despites the slow rate of woodland regeneration, impacts on wildlife would be temporal.

2. Environmental impact of brushwood burning

(Hibanjene et al., 2003) revealed this step of wood burning is known to destroy habitats which brush wood piles may provide to small fauna like reptiles and invertebrates; unfortunately, quantifying such impacts is not possible. However, considering the small areas affected by brushwood burning, its impact on water is likely to be insignificant.

3. Environmental impact of kiln covering

It was also learned from Hibanjene et al. (2003) that covering the kiln destroyed vegetation at the dug-up site and plant roots up to 15cm deep. The roots that survive regenerate within a matter of weeks. On the other hand, the herbaceous vegetation from seed took several years to re-establish. The affected site, about five percent of the cut-over area, was small, and its impact on species diversity will be insignificant. The same applied to faunal habitats which were destroyed in the process. The kiln covering created uneven surfaces, which may slow down the surface drainage and trap rain water, which as a result, improves water infiltration and lessened the risk of soil erosion. This was considered as a positive feature of kiln covering despite the researcher noting the destruction of vegetation at the dug site.

4. Environmental impact of wood carbonization

Malaisse (1978)'s research on wood carbonisation showed that carbonization resulted in a lot of heat generation over several days due to the high temperatures attained (500-700°C). This heat destroyed plants at the kiln site though some herbaceous vegetation from seed dispersal could be established within a few years. Seeds of miombo trees which were dispersed by the exploding of wood pods were dispersed for short distances (10 - 20cm) as compared to wind dispersed seeds of herbs (28 - 103m). Therefore, it was found that for large clear-cut areas, miombo trees will fail to colonise kiln sites. Also seedling development of the majority of miombo trees was very slow (Chidumayo, 1991 b). Hence the negative impact was long term although the affected area was small.

c) Health risks associated with charcoal production:

The production of charcoal is a very labor intensive process which may result in a number of physical ill health risks. Table 3 below outlines all possible health risks that charcoal producers are faced with.

Table 3: Health risks associated with charcoal production

Felling and cross cutting	Sore hands, backache, general exhaustion, chest pains
Log haulage/clamp building	Backache, chest pains, general exhaustion
Kiln covering/tending	Cough, chest pains, heat, burns, exposure to smoke, gases, eye tearing
Kiln breaking	Heat, burns

Source: (Ellegård, 1993).

Charcoal being the most widely used energy source in Zambia, it is important to have an overview of the extent of reliance on charcoal, the labour-intensive production process and the possible environment and associated health risks. This is helpful in order to compare and contrast the production process, uses and characteristics of

charcoal to that of faecal briquettes to note if they are any similarities and have a better standing on why faecal briquettes would be a good alternative energy source.

iv. Opportunities for charcoal substitution in households

Research by Hibanjene et al., (2003) noted that available urban household energy sources were: kerosene which was used for lighting, cooking and fire ignition; electricity for lighting, cooking, water and space heating and firewood for cooking, water & space heating. Though many urban households used Kerosene, research showed that it could not be considered as an ideal charcoal substitute due to the fact that it was an imported energy source. It was also learned from Hibanjene et al., (2003) that, the fact that charcoal was locally available and used by a majority of households in urban areas, substitution of charcoal by other energy sources was targeted at this sector. Although charcoal is a preferred energy source by many households in Zambia, its production comes with undesirable impacts discussed in sections (a) and (b) under charcoal production. These negative impacts have led to the need to come up with mitigation measure, according to Gonzalez (2021) the best measure would be to restrict and ban charcoal production. Due to lack of better alternatives such a measures have proven no to be possible. This helps justify the selection of charcoal as a substitute product for faecal sludge briquettes in this study. Faecal sludge briquettes could possibly be an alternative that can be used instead of charcoal, but its marketability and acceptability were not explored in the Zambian setting. For the purpose of this study, charcoal is the substitute product. According to the MDA, the substitute product is one that is currently sold in the market with the potential to be replaced by a faecal sludge treatment product (Schoebitz et al., 2016).

2.3 Faecal sludge briquettes

Faecal sludge briquettes are a rich source of biomass and their use can be likened to charcoal as an energy source. They are made from carbonised or uncarbonised faecal sludge mixed with a binder such as molasses, cassava meal, agriculture waste, or saw dust. The dry ingredients are mixed with water to create the final product, which can be used industrially, domestically or commercially for various energy needs (Water Sanitation Hygiene Institute, 2016).

Several countries both within Africa and outside Africa have taken the initiative to use faecal sludge as an alternative energy source, through the production of faecal sludge briquettes. The introduction of faecal sludge briquettes has been received with mixed reception, which will further be looked at in this section. In Kenya, Nakuru Water and Sanitation Services Company Limited (NAWASSCOAL) tasked it upon themselves to produce faecal sludge briquettes and carried out a community trial with households in low-income areas. The community trial confirmed the willingness of the people to use the fuel source (Stitching Nederlandse Vrijwilligers, 2021). Water for People, with support from Water Research Commission (WRC), Inter-Church organization for development cooperation (ICCO) and United Nations International Children's Emergency Fund (UNICEF) Finland, has been carrying out research in the production of faecal sludge briquettes for over two years and is presently promoting its production in Kampala Uganda (water for people, 2019). In India, the WASH institute developed briquettes from faecal sludge, which can be used as an alternative energy source to wood fuels /charcoal (WASH, 2016).

So it is clear that using faecal sludge as an energy source is not new. It has been tried and tested in other countries and is still being tried and tested. Zambia is yet to see the use of faecal sludge as an energy source. This research is meant to fill the market gap and people's views on using faecal sludge briquettes in Zambia to determine if there is a niche for such a product.

Overall it has been discovered that dried faecal sludge can indeed be turned into an energy source, such as fuel briquettes, for industrial or household use. In research by Taylor (2018), several pilot-scale initiatives were used, which focused on the possible use of bio char to produce solid fuel briquettes. The study also noted, as is the case of Zambia, that many people in urban areas of low-income countries, especially in Africa, rely on wood or charcoal produced from wood as their energy source. There is a possibility that briquettes produced from a faecal sludge or a mixture of faecal sludge and solid waste would be a cheaper alternative. An advantage of switching to briquettes produced from faecal sludge would be a reduction in deforestation around towns and cities, which has been noted to be a major adverse effect resulting from wood-based fuels (WASH, 2016).

According to Asamoah et al. (2017), in recent years, briquetting has captured the interest of many people worldwide. Briquettes made from biomass can provide a sustainable and alternative energy source for domestic, institutional, commercial and industrial purposes. The briquettes can be made of different qualities and dimensions all dependent on technology and the raw materials available and used during production. The various target market segments can also influence the quality of briquette. It is important to note that the quality and burning efficiency of fuel briquettes depend on the characteristics of the raw materials used to produce the briquettes. Therefore, the raw materials must use and the briquetting processes should meet desired characteristics to obtain the required briquette quality.

2.3.1 Briquette production

According to Supatata et al., (2013) for successful briquette production and marketing, there is a need for consistent supply of raw materials of good energy quality, and applicable technology and ultimately will result in briquettes of good quality consistently being supplied. Supatata et al., (2013) also highlighted important drivers in the briquette production chain such as creating of strong partnerships with key stakeholders, like the municipality, financiers and other important players and an enabling policy as key for the success of briquette businesses.

Briquette production can involve using sludge, such as sewage sludge and faecal sludge. Sewage sludge is waste from domestic, municipal or industrial settings treated at treatment plants applying biological treatment methods (Supatata et al., 2013). Many developing countries generate faecal sludge, which only about 20 – 50 percent ends up at treatment plants. The production of faecal sludge briquettes is an option for the treatment and recycling of this faecal sludge, alongside biogas which is also produced from faecal and sewage sludge (Diener et al., 2014).

Figure 1: below shows the technical steps carried out in order for faecal sludge briquettes to be produced.

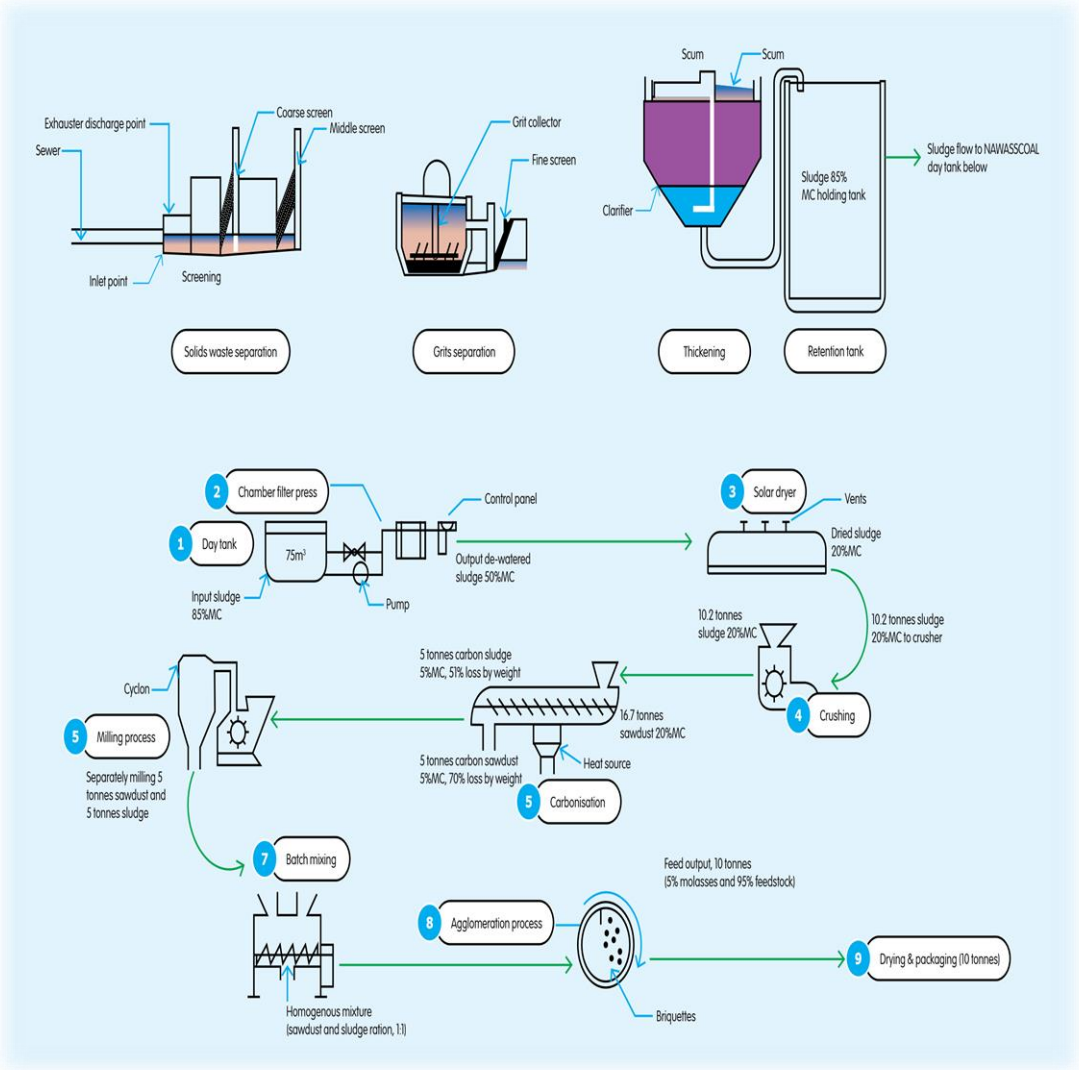

Figure 1: Faecal sludge briquetting process Source: (SNV, 2021)

i. The Basic faecal sludge briquette production process

Figure 2 below shows the basic steps that must be carried out when making Faecal sludge briquettes.

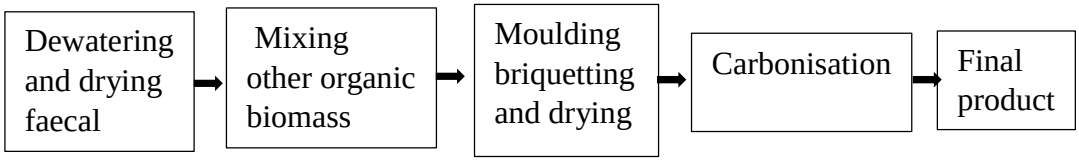

Figure 2: Briquette-making process. Source: (WASH Institute, 2016).

According to WASH Institute (2016), the following are the steps prescribed for the making of faecal sludge briquettes:

1. Obtaining the treated sludge from Sludge Treatment Plant (STP), this is in the case that a private company/enterprise independent of a sludge treatment plant is engaged in resource recovery
2. Sludge drying.
3. Carbonizing the Faecal sludge by using a kiln.

a) Hand Made Pellets

- Crushing the sludge to get fine particles.
- Mixing of binding materials with the treated sludge to
- The Faecal sludge was mixed with other biomass materials for the given ratios.

Table 4 below shows different combinations.

b) Machine made briquettes

- Powdering of the faecal sludge and organic materials
- Sieving the powdered materials to filler small particles for making pellets
- Filtered and dried mixture is then added water to make a paste
- Making pellet using pellet machine.

5. Drying of the briquettes from here, the final product is obtained.

Faecal sludge briquettes can be made from various combination of raw materials according to availability, accessibility. Table 4 below, outlines these various combinations for making the faecal sludge briquettes.

Table 4: The Various combinations that can be used to make faecal sludge briquettes

No	Biomass Materials used	Ratio
1	Faecal Sludge + Cow dung	50 : 50
2	Faecal Sludge + Saw Dust	50 : 50
3	Faecal Sludge + Coir dust	50 : 50
4	Faecal Sludge + Ground nut husk	50 : 50

Source: (WASH Institute, 2016).

2.3.2 Operation and maintenance during faecal sludge briquette production

Treatment technologies which optimise production processes are chosen when designing the briquette production facility. For example, a carboniser is suitable to enable the carbonisation of faecal sludge instead of a metallic drum or kiln, which would increase the carbonisation process. A solar dryer is also required to accelerate the drying of the faecal sludge prior to carbonisation (SNV, 2013). Key considerations when operating the facility include; sufficient staffing and occupation and safety outlined by the company operating the facility are followed, and all training requirements are fulfilled, which includes operation and maintenance of machinery. Key maintenance includes repairs to machinery by stuff (SNV, 2013).

2.3.3 Challenges of operation and maintenance during large scale briquette

According to Musabe (2015), some of the general challenges experienced by both the large and small-scale briquette entrepreneurs include effective drying of faecal sludge, the minimal rate of carbonisation, difficulty and high cost of accessing transport for dried faecal sludge.

SNV (2013), through their experience with faecal sludge briquettes, was able to come up with key considerations to put in place if briquette production was to be done at a large. It was also found that the carbonizing machines required some preparation work before installation. Preparatory work included ensuring sufficient water tanks and cooling tanks, building a framework for conveyors, building channels for the floor, installing the pillar required for the carboniser to sit on, and installing electricity cables (SNV, 2013). If sufficient sunlight and solar drying are available the dryer element is not required, helping save considerable amounts of energy. Professional hammer mills that deal well with carbonised materials are also advisable if the plant moves to large-scale operations, as are dewatering devices. Generally, the suitability of various machines depends on the scale and the budget available (SNV, 2013).

2.3.4 Briquette production vs. charcoal production

From the literature that has been reviewed on charcoal production and briquette production. The literature has shown that there are many differences in the way charcoal and faecal briquettes are produced. Firstly charcoal production is very - intensive and involves the use of elementary tools such as an axe, pick, shovel and this

is large-scale production. In the case of briquettes the large-scale process is much mechanised and involves big costly machinery such as; caboniser, mills etc. The mechanised production process results in fewer health effects for those making the products like those noted in the charcoal production process in section 2.2 of this chapter.

2.3.5 Carbonized and Uncarbonised briquettes

An alternative pathway under this scenario is the production of non-carbonized briquettes for industrial or institutional use. Thermal-intensive factories have been keen on reducing the use of firewood by substituting it with briquettes. The fluctuating costs of furnace oil have led to these factories looking for alternative thermal energy sources. Tea factories are among these end users of solid biomass. Unlike carbonized briquettes, production of non-carbonized briquettes does not require carbonizing equipment, binders and mixers are not required. Since the briquettes are sold to large scale consumers of briquettes no packaging machines or associated packaging cost is required (European Endowment for Democracy, 2020).The cost of large-scale production of carbonized briquettes is high compared to that of noncarbonized briquettes holding all factors constant. Additional processes such as carbonization of the feedstock, mixing the feedstock with the binders, packaging of the briquettes and awareness creation to a large consumer base are added to the production chain of carbonized briquettes. The use of additional distribution points to reach consumers who may be located further from the production site requires the cost of the briquettes to be marked up for the distribution agent to earn a profit margin. These factors influence the pricing of the briquettes and may result in higher prices for them, making them less competitive to the cost of charcoal. Though few consumers of non-carbonized briquettes take up large quantities of briquettes for industrial usage, for example, in tea-making factories in India. This makes it easy to supply the fuel to them as they can directly source the briquettes from the production facility and extensive awareness creation is not required as in the case of household users (EED, 2020).

Table 5 below shows the comparison between carbonised and uncarbonised faecal sludge briquettes, clearly outlining target market of both briquettes type and their strengths and weaknesses.

Table 5: Comparison of the types of faecal sludge briquettes.

Type of briquettes	Target market	Strengths	Weakness
Carbonized briquettes	- Mainly Households - Small enterprises such as eateries and hotels	- Added solution to the energy options at the household level	- Relatively expensive to produce compared to noncarbonized briquettes - Requires improved charcoal stove to burn without smoke is costly compared to the traditional charcoal stove - Existing fuels readily available, affordable high quality
Non-carbonised briquettes	- Industrial (tea factories) - Institutions (schools, prisons etc.)	- Less cost of production compared to production cost of carbonized briquettes - Ready market as industries add sources of thermal energy to their energy mix to be energy secure - Existence of incentives in the uptake of products that are sustainably produced	- - Industrial boilers may need to be retrofitted or new boilers that can efficiently burn briquettes acquired.

Source: (EED, 2020).

2.3.6 Market for faecal sludge briquettes

The use of faecal sludge briquettes has the possibility of providing benefits such as affordability, income generation and savings. The Briquettes could provide an alternatively cheaper and somewhat cleaner source of cooking fuel, generate income through sales, and reduce household expenditure on energy for cooking. Generating income and reducing household expenditure are essential aspects to help reduce poverty and as a result, the money earned from briquette sales can be invested in other productive activities such as agriculture and commercial enterprises (Asamoah et al., 2017). Asamoah et al.,(2017) went on further to state that briquettes have low emissions, which can reduce illnesses and premature deaths associated with smoke in the kitchen, which ultimately improves the welfare of women and children as they spend more time cooking food for the family. Briquettes are more economical compared to other fuels like charcoal, which can help contribute to food and nutrition security. Families can cook food types of their choice, especially traditional food, which take long to prepare and consume much fuel. Families can also cook at the frequency they require, cook the amount of food they need and cook food properly according to their preferences.

In order to catch the attention of potential users of faecal sludge, briquettes have been outlined in table 6 below. Potential challenges that may be faced in trying to establish the faecal sludge briquette market have also been outlined in table 6 below.

Table 6: Key marketing points and challenges for briquettes.

Key marketing points	Potential challenges
Burning time: briquettes can burn 1.5 times longer than traditional charcoal	Local perception: products made from faeces may be rejected based on religion or culture. Solution: work closely with the community to demonstrate the product is safe and clean
Less smoke: the briquettes produce less smoke than wood and charcoal	Local producers: product may compete with traditional charcoal and effect the livelihood of the local population

Table 6, Cont.

	Solution: ensure product demand is higher than product supply and employ charcoal producers as sales representatives
Cost: the briquettes are sold at the same price as traditional charcoal but because they last longer, they save users money	NIL

(Source: Hakspiel et al., 2018).

2.3.7 Calorific value of charcoal compared to faecal sludge briquettes

The efficiency of faecal briquettes is critical to maximise the benefits of faecal briquettes when marketing them to potential consumers. A number of studies have been carried out by (WASH institute, 2016) to determine the efficiency of briquettes compared to charcoal. In many of the tests, the faecal sludge briquettes were found to be more efficient in that the heat generated from the briquettes lasted for more than 2hours compared to charcoal. A study by Raude and Maina (2020) revealed after a comparative analysis between the faecal sludge briquettes (made from faecal sludge and cow dung) and charcoal that the briquettes had a minimum calorific value of 19MJ/Kg, while that of charcoal was at 18.2 MJ/Kg. The study concluded that the high heating value indicated the remarkable energy potential of the briquettes compared to other recognised energy sources.

2.3.8 Emission of toxic gases

Another notable characteristic of the faecal sludge briquettes was that it had a lower nitrogen and sulphur content, indicating a lower risk of emission of toxic gases from its pyrolysis (Raude and Maina, 2020).

2.4 Comparison of production cost for briquettes, wood and charcoal

It is difficult to compare the cost of wood and charcoal with the production of briquettes. For example, for household, wood can easily be collected from family farms or nearby woodlands at no cost and in many cases, the households use dry twigs and not the felling of an entire tree. Factories that require wood sources are known to get it from private farms or acquire it from government forests, such is the case regarding Kenya with the Kenyan Forest Service. In many scenarios, Charcoal production is known to be an informal sector and is not capital intensive as briquette

production (EED, 2020). The whole process of pre-treatment, drying of waste, mixing with a binder and compacting are mechanized processes in briquette production and taxations adds to the capital for start-up businesses and the daily operation of the business. This is the main reason why briquette prices fail to compete with charcoal and wood; however, if the charcoal regulations are enforced, there is an opportunity for the briquette sector to compete effectively (EED, 2020).

2.5 Attitudes/barriers affecting the use of faecal sludge treatment products

It was learned from Duncker et al., (2007) that it was important to understand attitudes and perceptions about health hazards and people's revulsion against faeces and urine, which vary from culture to culture across the world. Duncker et al., (2007) also noted that people ould usually respond differently towards urine than faeces. It was further observed that societal norms for disposing of human excreta varied across factors such as age, marital status, sex, education, class, religion, locality, employment and physical capacity. An example is; a Koranic edict which considers urine to be a spiritual pollutant, and Islamic custom demands that Muslims reduce their contact with human excreta. Then in some other cultures, urine is believed to have a disinfectant property, as seen in the Kagera area in Tanzania. When someone has inhaled poison, urine is given to the person to take as a neutraliser. Some people also use it as a pesticide to kill banana weevils (Duncker et al., 2007). More Literature from World Health Organisation (WHO), et al., (2017) suggests that there is indeed an attitude towards the reuse of faecal waste and it is influenced by factors such as culture, taboos, religion, region, as well as individual characteristics such as gender, age, and education. A Study by Candiracci and Syrjanen (2007) revealed that the appearance of faecal-based fertilizer in Ghana influenced its usage among farmers. Therefore, it was important to note that acceptance and usage of faecal sludge products also depend on how the product appears and the packaging. In some areas where faecal products were introduced, there was a need for interventions related to religion due to religion-related views in the area (Duncker et al., 2007). Religion-related barrier towards faecal sludge re-use identified in these areas implies the need to educate the community with appropriate Information, Education, and Communication (IEC) interventions suitably under the guidance of religious and local leaders of that area. Some contradicting opinions were identified relating to the usage of some of the products like briquettes,

fertilizers and biogas. Some members were not comfortable with the safety of the products and expressed their discomfort in using faecal sludge fertilizers on their crops or briquettes for their cooking, while some other members were very open to their use. Under socio-cultural and religious factors Duncker et al., (2007) also identified that cultures such as the Muslims regard any money associated with faecal sludge emptying and reuse as unclean, and they avoided being associated with such money.

2.6 Awareness creation of faecal sludge briquettes

According to research by Lamichhane and Babcock (2013) and Forbis-stokes et al. (2016), it is clear that there is a considerable deficit and low appetite for briquettes at the household level. It is essential to consider what challenges hinder the growth of the briquette market from both the supply and demand sides. For example, some of the major challenges on the demand side include; poor quality of briquettes, social stigma, and lack of awareness. In addressing barriers related to acceptance of faecal sludge briquettes, evaluating faecal sludge products is necessary to ensure they meet safety standards and are of good quality. These safety standards can then be communicated to consumers through appropriate IEC channels, this will make more consumers more welcoming to use the products if they fully understand the safety of the products (Lamichhane and Babcock, 2013; Forbis-stokes et al., 2016). Roma et al., (2013) and Brief (2013) cited social stigma associated with faecal sludge as a major hindrance to the success of the faecal briquettes and its widespread usage was still low. More uptake of the products can be achieved through awareness creation and addressing barriers to their use through public sensitization forums, to increase the communities' knowledge base on the safety of products. Media platforms, public forums like chiefs' public meetings or even outreach activities like campaigns were identified as good channels for such public engagement. In developing countries, acceptance and demand for sustainable sanitation solutions can be achieved more quicker through campaigns (Jewitt 2011, Cofie et al., 2016). Engaging relevant stakeholders is also very important to bring the key players in the faecal sludge field together for a sustainable solution (Mitullah, 1899). According to EED (2020), the next course of action after addressing the main challenges facing the briquette market is to create awareness among the end-users/potential consumers. Briquette end-users can be grouped into domestic (households), commercial-institutional (small/medium businesses, educational and health institutions) and industrial consumers (large

thermal energy users, including tea factories). A clear and -defined consumer education program must be developed to reach the different types of end-users. The target group will determine the specific techniques applicable in awareness creation. For example, large-scale end-users such as manufacturers can be approached directly while households can be reached through road shows, television advertisements, billboards and fliers. In low-income areas, awareness campaigns can be held in Community-Based Organizations (CBOs), women groups and youth groups. During their monthly meeting sessions, information dissemination and demonstrations on the use of briquettes can be carried out. The main program objectives could be centered around; (i) creating awareness of different briquettes types, (ii) highlighting the benefits of briquettes relative to other fuels and, (iii) demonstrating how briquettes are best used and the right technologies to use the briquettes such as braziers. The program can also make use of community centres or halls as places to create awareness of the use of briquettes as an alternative fuel, and its benefits and conduct demonstrations on how to use the fuel. The community centers can also be demonstration points for the briquette production technologies to the briquette producers (EED, 2020).

2.7 Market-Driven Approach (MDA)

Diener et al., (2014) revealed that the market studies for faecal sludge treatment products had been designed such that they can identify the best treatment products for a particular area. For example, a particular market study identified a higher demand for energy in Kampala, Uganda and Accra, Ghana, compared to the demand for soil amendments.

For the current study the particular faecal treatment product was preselected after learning the particular characteristics of the study area. It was decided to go with an energy source type of faecal treatment product as it has already been stated and learned that they rely much on charcoal. For example a faecal treatment product such as a soil amendment would not be suitable because farming/ agriculture is not characteristic of that area.

It was learned from Schoebitz et al., (2016) the importance of knowing the characteristic of a selected study area, more information about the requirements of consumers should be gathered to evaluate the suitability of treatment products to meet specific demands. Sales of treated products is highly dependent on the available or

potential market. If there is no demand for a product, it cannot be sold and so will generate no revenue. Therefore, market research will be required to assess current and potential demand for various end uses. This should include the following:

a) Identify any modifications required to existing technologies to allow them to use treated bio solids (For example, would kilns need modification to allow the use of bio solids as a fuel).

b) Assessment of treated bio solids availability in relation to demand, taking account of seasonal variations in production and demand and likely supply shortfalls. Options for supplementing bio solids with other materials, for instance agricultural or municipal wastes, should be explored to reliably meet user demand.

c) Assessment of marketing, distribution, and sales systems (what changes in existing systems will be required to ensure that treated bio solids can be sold to their intended users?)

(Schoebitz et al., 2016).

Schoebitz et al., (2016) has identified The MDA as a good tool for establishing how well a faecal treatment product would do in a particular area, depending on the acceptance by the end users. In the case of this study, the market-driven approach is appropriate to determine the acceptability of faecal briquettes. Unlike in other research studies where a suitable faecal sludge product must first be determined, the faecal sludge treatment product of choice has been predetermined based of the characteristic of the study area. Considering a large number of the population use charcoal, if accepted the briquettes has the potential to replace or be used as an alternative to the dependence on charcoal. The MDA is a quantitative method developed by SANDEC to evaluate the market for potential products resulting from the treatment of faecal sludge. (Schoebitz et al., 2016).

2.7.1 Market growth potential and market volume potential

Assessing the market growth and volume of a specific substitute product is intended to estimate the potential for increasing demand the future. The market potential is approached by analyzing the industry of the substitute products and applying the data to the faecal treatment product (Schoebitz et al., 2016). Considering the lack of existing markets for faecal sludge treatment products, the methodology uses substitute products

as proxies to determine the market potential of treatment products. Substitute products are currently existing (and used) products that faecal sludge products could replace. For example, charcoal could be replaced with faecal sludge briquettes; therefore, charcoal is a substitute product. To help prevent over or underestimation, an adjustment factor is included in the methodology to adjust for the differences between the treatment product and the proxy used (Andriessen et al., 2017).

2.8 Institutional arrangements for end-use / Resource recovery

It is important to identify and involve key stakeholders at different levels that would possibly play an important role in the success of faecal sludge briquettes. According to Klingel (2001), an institutional framework needs to encourage sustainable business models for the entire faecal sludge service chain. Therefore, end products of good quality that are safe for consumers must be ensured. Faecal sludge treatment and resource recovery require a high level of skills for operating maintenance and monitoring, according to selected technology. The products need to be made safe and processed, and there is also a need to create value products for the local market. This requires a prior market assessment, proper marketing and the provision of a high-quality service. Strande (2014) also stresses that a multi-level approach should be implemented to protect workers, customers and final users from health risks linked to pathogens. Below are some of the stakeholders important for faecal sludge reuse as noted by various researchers.

i) National or municipal utilities

According to Strande (2014), the resource recovery process can be managed by a national or municipal utility and can also be responsible for delivering the end products to customers. Where national or municipal utilities are in charge of the resource recovery plant, they are also likely to be involved in faecal sludge management, directly or by delegation management. Delegation management brings into play private companies/businesses that are involved in resource recovery.

ii) Private companies

It was learned from Jeuland et al., (2004) that small private companies involved in resource recovery services and treatment end products are found worldwide. Their main strengths are based on the fact that they are run or owned by dynamic private

entrepreneurs. Bolomey (2003) also notes the existence of these private companies; they require capacity strengthening and close coordination to ensure efficient management, operation and maintenance of the facility. Contracts or agreements can be signed with the stakeholder in charge to define the agreement, the price and the quality of the end products to be processed and marketed.

iii) Associations

Klingel (2001) also found an important stakeholder in associations. Associations can also be involved if the technologies used in the processing, treatment and packaging of the end product are low, and if customers come to the plant to buy the products. This solution can be used where people are living next to the treatment plant, more especially if the end products are used directly by the community members like for example as building material or in the case of this research energy source. The management rules of an association stipulate the need for sustainable operation and Maintenance and transparent financial transactions, and therefore licenses can be provided by local authorities (Strande, 2014).

2.8.1 Regulations guiding the reuse of faecal sludge

The FSM is governed by a specific regulatory framework that is also essential in creating an enabling environment for the reuse prospects of faecal sludge. Table 7 below outlines some important institutions and their regulations for managing faecal sludge.

Table 7: Regulations Guiding Use of Faecal Sludge

ELEMENT OF REGULATION	RESPONSIBLE	ROLE	RESOLUTIONS FOR FRAMEWORK
LICENSING AND PERMITS	National Water and Sanitation Cooperation (NWASCO) and Zambia Environmental Management Agency (ZEMA)	Stipulate conditions which service providers follow As well as the delineation of their operating area.	Sanitation Service providers should do so with licence. Develop new sanitation standards take account of the Entire sanitation chain. Develop limits to include faecal Sludge recycling activities; limits for treatment products such as fuel use

Table 7, cont.

ELEMENT OF REGULATION	RESPONSIBLE	PURRPOSE/ROLE	RESOLUTION FOR FRAMEWORK
MONITORING AND PERFORMANCE	NWASCO	In line with its mandate to inform the public on Water and Sanitation Service issues, NWASCO publishes an annual report	Update annual sector reporting to include onsite sanitation
POLICY	Ministry of Water Development Sanitation and Environmental Protection (MWDSEP)	Setting policy statements	Promote sustainable Water resources management and development with a view to facilitate equitableprovision of adequatequality of water supply and sanitation in timely manner.

Table 7, cont.

STANDARDS	Zambia Bureau of Standards	Defines the technical standards that must be utilized by the various actors in the sanitation sector to enable the installation of sanitation systems that provide affordable but good quality services.	Regulating wastewater by certifying inspectors and administering fines when established effluent standards are not followed.

Source: (NWASCO, 2018).

2.8.2 Legal framework for sanitation regulation in Zambia

In Zambia there are two main instruments that are the foundation of the existing sanitation regulations, namely:

i) Statutory Instrument No. 63 of 2000 under the Water Supply and Sanitation Act; and
ii) ii) Statutory Instrument No. 112 of 2013, under the Environmental Management Act.

Statutory Instrument No. 63 of 2000 prescribes the regulations relating to licensing water supply and sanitation utilities and service providers. These regulations outline the general license conditions, which shall apply to all water supply and sanitation service providers. It is all a requirement of the regulations through NWASCO to establish guidelines for the tariffs charged for water supply and sanitation services (Government of the Republic of Zambia, 2000). In terms of the safe re-use of waste, the instrument must be amended to include the standards that will guide the use of faecal sludge.

Statutory Instrument No. 112 of 2013; this instrument allows ZEMA to regulate the transportation and disposal of wastewater into the environment and to set criteria for the classification of effluent. It also establishes that ZEMA may prescribe the requirements and standards for effluent treatment facilities, mainly to ensure that effluent discharge operations "are conducted in a way that ultimately protects human health" (GRZ 2013, p.751).

One of the strategy's formulated in line with sanitation is the National Urban and Peri-Urban Sanitation Strategy 2015–2030. The National Urban and Peri-Urban Sanitation Strategy 2015-2030 (NUSS), under the Ministry of Local Government (MLG), is the guiding document for sanitation. This plan aims to ensure that sanitation is adequate in regard to all new developments and upgrade sanitation to ensure that the sanitation facilities are adequate in the areas where sanitation services or infrastructure are available. NUSS (2015) defines adequate sanitation as "A sanitation system that is accessible and available; located at a distance not more than 100 meters away from home and is easy to access for children, elderly and handicapped at any time during the day, it is accepted by the user and provides a safe, convenient, private, secure and dignified place and complies with the socio-cultural norms of society in regard to smell and reuse.

2.9 Summary

From the introduction to problem statement, it is evident that the world and, more specifically, Lusaka needs more innovative ways to use faecal sludge to reduce filled-up pit latrines in low-income communities. The positive use and reception of faecal sludge briquettes have been noted in other countries, but what about in Zambia. Zambia is yet to make such strides in using a material such as faecal sludge as an energy source. Looking also at heavy reliance on wood fuels by households in Zambia for day-to-day cooking and heating, a further increase in the demand for charcoal is expected, as forecasted by the growing population and slow electrification rate, demand for diverse energy sources is on the rise.

Regarding the potential market of the selected faecal sludge treatment product, it cannot be overstressed that one size does not fit all. There must be restrain on deducing from experiences of other regions. This is why the market-driven approach , as prescribed by Schoebitz et al. (2016), offers a skeleton for exploring market potentials for faecal sludge treatment products. The market-driven approach can universally be applied across different regions and settings, offering a way to establish potential market implications in a consistent and comparable way.

2.10 Conceptual framework :

The market driven approach provides the means of exploring potential markets for faecal sludge treatment products, prior to them existing on the market. The challenge in determining the market of faecal sludge treatment products is that due to the deficiencies in faecal sludge treatment, the market for treatment products does not yet exist. Therefore to determine the market of faecal sludge treatment products, the market dynamics of a proxy (substitute product) that could potentially be replaced is analyzed (Schoebitz et al., 2016). Figure three below illustrates the concept behing the market driven approach.

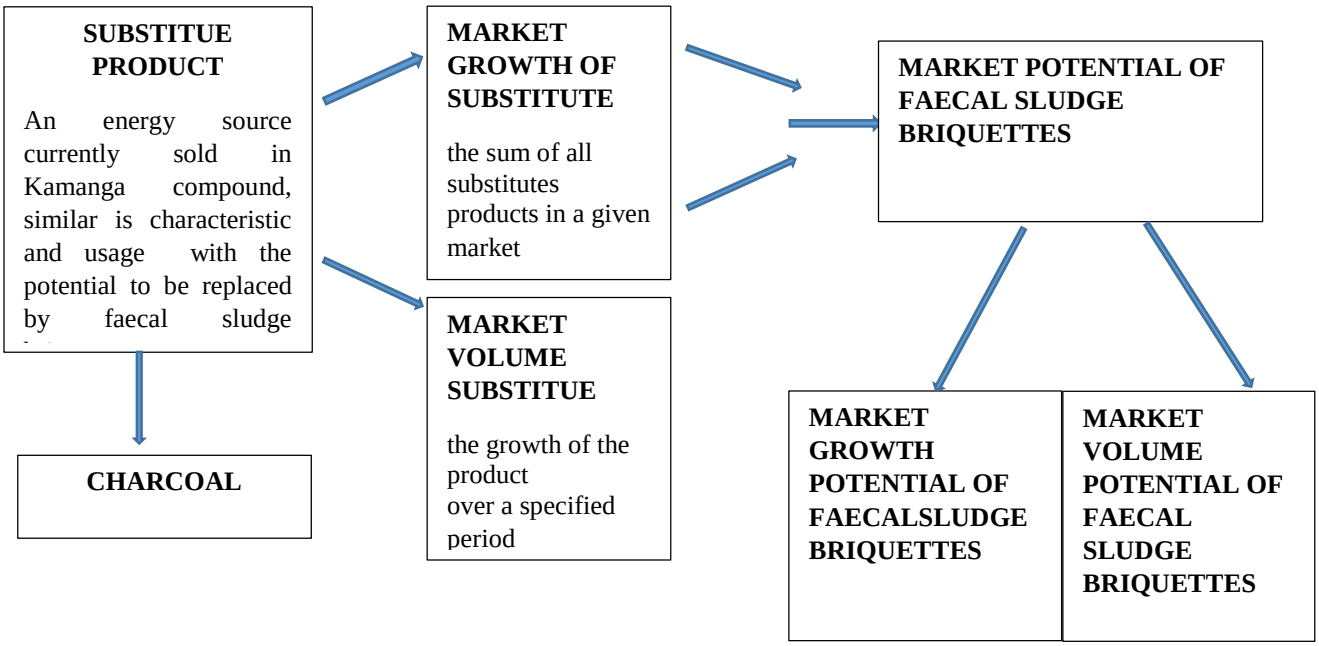

Figure 3: conceptual framework on market potential of faecal sludge briquettes

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter outlines the research methods that were employed in this study. The researcher first described the study design chosen and the reason for choosing that design. It also provides information on participants, the criteria for inclusion, who the participants were and how they were sampled. The data collection tools and procedures followed to carry out this study are also described. Finally, the researcher discusses the methods used to analyse data and all ethical considerations that were followed.

3.1 Study Design

The Embedded mixed methods design was used in this study. The main reason for using mixed methods was to ensure that quantitative results werecomplemented and clarified by qualitative results (Greene et al., 1989). Qualitative methods were suitable for determining the acceptability of the product through participant response. The quantitative methods were employed when determining the market (volume/growth) of the product and the cost compared to other energy sources. These methods made it possible to capture all variables of interest at one specific time, providing preliminary data from the potential market participants identified from secondary data.

The preliminary data was important because it was anticipated that participant responses would give insight into possible strengths and weaknesses in the faecal briquetting business. This also helped narrow down faecal sludge briquette niches.
An experimental design was also employed as there was a need to make the faecal sludge briquettes to carry out a demonstration for participants. This assisted in familiarising the participants with the product and a better understanding of customer requirements and expectations.

3.2 Study area description

Potential market participants were selected from Kamanga compound found in Lusaka, Zambia. Kamanga is located 14km east of Lusaka town at -15, 37 latitudes and 28, 28 longitudes. It lies between Munali and Chelston, as depicted in Figure 3.3 .

Figure 4: Map of Kamanga Compound. Source: (Map data, 2022)

The study site was selected because wood fuels remain the principal source of energy for most households (Monga, 2011). The introduction of another fuel source, such as the faecal sludge briquettes, would offer an alternative fuel source and possibly reduce dependence on wood-based fuels.

3.3 Target population

- Household heads for Focus Group Discussion (FGD)
- Charcoal traders for key informant interviews

3.3.1 Inclusion criteria

- All Charcoal traders/retailers in Kamanga compound
- All Heads of household in Kamanga compound

3.4 Data collection method and tool

3.4.1. Secondary data review

The literature review was used to help identify what is referred to as the substitute product of this research: charcoal. The literature review also informed the design of

primary data collection tools and the identification of gaps that needed to be filled during primary data collection.

3.4.2. Focus Group Discussion (FGD)

Six FGD'S were carried out in Kamanga compound. Each FGD comprised six household heads from each zone that makes up Kamanga compound, resulting in a total of 36 participants. The FGD were guided by a series of questions from a structured interview guide, which has been included in Appendix 2. The interview guide was administered by the researcher, who also used a voice recorder to capture the responses from each of the FGD'S.

3.4.3. Key informant Surveys

Individual interviews were carried out with charcoal traders by the principal investigator with the use of a survey tool comprising of some closed-ended questions. The Survey tool was contextualized and localized to the research objectives related to assessing the market potential and attitude of participants to faecal briquettes. The survey tool has been included in Appendix 2.

3.5 Sampling technique and sample size

Two sampling types were used, purposive sampling and total sampling. Purposive sampling was used for the selection of household's who participated in the FGD. Household heads were purposefully selected because they are forefront on organising the household resources, including what energy source to use in their household.

One focus group discussion was carried out in each of the zones of Kamanga compound, giving a total of six focus group discussions, after which saturation was reached. This agrees with other studies where five group discussions were enough to reach saturation (Coenen et al., 2012). Another study by Guest et al., (2006) showed that in FGD'S, the most important themes were identified in the first three focus groups.

Each group consisted of six participants in order to adhere to current Covid 19 guidelines, which restricted large gatherings. Household heads were purposively sampled through a list of household heads, provided by community heads of each of

the six zones that make up kamanaga. It is recommended to have between six and twelve participants so a group is small enough for all members to talk but large enough to have diverse views (Lasch et al., 2010).

Total sampling was used for the selection of participants who fell under the charcoal trader's category, all charcoal traders who were available in Kamanga during the study were interviewed individually by the researcher. This resulted in a sample size of 32 charcoal traders interviewed for the study. According to (Laerd, 2012), total sampling is best used when a small group of the target population has a particular characteristic of interest.

3.6 Pre-testing

The -ended structured questionnaire was pre-tested to determine if it would allow the collection of reliable information regarding market potential. An informal type of pretesting was carried out by reading questions aloud to identify the difference in written and spoken language, then the researcher played the role of the respondent to try and answer the questions and finally, a mock interview was carried out with a colleague.

3.7 Data processing and analysis

A Microsoft Excel based spreadsheet (tool) was developed by SANDEC, which provided a template for documenting the results obtained from the step-wise implementation of the market-driven approach. The tool included five sheets with a specific sheet which assisted in deriving the market volume of a substitute product. The recordings from the focus group discussions were transcribed verbatim and reviewed. The transcripts were then coded according to themes identified by participant responses. Chi-Square test was also used to determine any association between participant characteristics and the acceptability of faecal sludge briquettes.

3.7.1 Market volume potential

The template formulated by SANDEC to calculate the potential market volume of faecal sludge treatment product, was employed in this study to calculate the market volume of the faecal sludge briquettes. The template required daily sales input and the substitute product's cost, which in this case was charcoal. Before the final volume (estimated volume) can be calculated from the market volume template below, an

adjustment factor should be calculated as explained in section 3.7.2 of the methodology.

3.7.2 Adjustment factor

From the MDA tool, an adjustment factor must be calculated using a spreadsheet template explicitly created for the adjustment factor. Table 8 below shows the factors (drivers) to consider to calculate the adjustment factor; each driver must be scored on a scale from 1 to 5 based on secondary and primary data collected from participants.

Table 8: Adjustment factor calculation sheet

Driver	Substitute product 1 (score 1 to 5)	Substitute product 2 (score 1 to 5)	Substitute product 3 (score 1 to 5)	Substitute product 4 (score 1 to 5)	Substitute product 5 (score 1 to 5)
Switching costs					
Investment					
Efficacy/quality					
Geographical					
Distribution					
Entry point					
Demand					
Price sensitivity					
Social Stigma					
Total					

Adapted from: (Schoebitz et al., 2016).

3.7.3 Market growth potential

Market growth potential was calculated based on growth factors from the literature reviewed on similar MDA studies of faecal treatment products. Taking into consideration yearly change (increase or decrease) of a particular quantity of charcoal, for example, 1.5kg as a percentage of the total charcoal sales of all the charcoal quantities (1.5kg, 2.5kg, 25kg, 50kg, 90kg). The percentage of each particular quantity was assessed over the 2019-2021 period.

3.8 Ethical Considerations

Clearance to undertake the study was sought from the University of Zambia, Natural and applied sciences ethics Committee. Informed consent was obtained from participants before data collection, explaining the study's objectives. Participation by

respondents was voluntary and the confidentiality of individuals that participated in answering the questionnaire and assurance that the information given was confidential. Documents to do with ethical consideration have been included in Appendix three.

3.9 Experimental Design:

briquette making for demonstration purposes (adapted from: Water for people, 2018)

1. Obtained treated faecal sludge from Manchinchi Wastewater treatment Plant.
2. Faecal sludge from Manchinchi was dewatered on the drying beds for four to six weeks. In order to attain a visually inspected dry solid.
3. Moisture content of at least 10% is adequate for carbonization. To obtain this 10% moisture content; Weighed two kilograms (kg) of faecal sludge on a scale, and the two kilograms became the "weight of wet sample."
4. The faecal sludge was left to dry for about 4weeks for the month of September with an average temperature of 22.5ºc; Total of 279 hours of sunshine, with daily sunshine of 10hrs
5. After four weeks, the "weight of the wet sample" was measured again on a scale and a mass of 1.8kg was attained, the 1.8kg becomes "weight of dry sample"

   (i) Equation:

   % Moisture = (weight of wet sample –weight of dry sample)/weight of wet sample x 100

   = (2.0-1.8)/2.0 x 100

   = 10% moisture
6. The dried faecal sludge was then carbonised for four hours in a metal drum, ignited with the aid of some paraffin and firewood.
7. After carbonisation, the carbonised sludge was crushed to fine particles
8. Mixed the carbonised faecal sludge with sawdust in a ratio 1:1(measurement as prescribed by; WASH institute, 2020).
9. Addition of water to required consistency
10. Hand-made into round balls
11. Left in the sun to dry for three days and visually inspected

Figure 5 and figure 6 below show the faecal sludge briquettes made from the steps above**.**

Figure 5: Hand moulded faecal sludge briquettes

Figure 6: faecal sludge briquettes, drying in the sun.

3.10 Summary:

This section outlines all the tools and procedures that were employed in the collecting and analysing data that were used to address all the objectives of this study.The procedure followed inorder to make faecal sludge briquettes for demonstration purposes, was also outlined in this chapter.

CHAPTER FOUR

RESEARCH FINDINGS

4.0 Introduction

This chapter presents the findings of the study on the market potential and factors leading to the acceptability of faecal sludge briquettes in low-cost areas. The chapter begins with the demographic characteristics of focus group participants and the household heads, followed by a table showing major themes, categories and explanations of each sub-theme with verbatim quotes used to illustrate the findings from the focus group discussion in a clear manner. The thematic analysis led to identification of two, major themes, seven sub themes (as shown in table 10 below). The acceptability-related findings are then followed by findings on market potential based on findings from charcoal traders.

4.1 Demographic Characteristics

This section describes the demographic characteristics of the two groups of participants used in the study; household heads and charcoal traders.

4.1.1 FGD participants

Thirty-six people participated in the focus group discussion; of this number 20 (56 percent) were female, while 16 (44 percent) were male. Table 9 below further presents the demographic characteristics of the 36 FGD participants.

Table 9: Demographic characteristics of household heads

VARIABLE	CLASSIFICATION	FREQUENCY (%)
GENDER	male	44
	female	56
AGE	<40	39
	40 -50	33
	>50	28
MARITAL STATUS	single	19
	married	61
	divorced	13
	separated	7
EDUCATION LEVEL	primary	28
	secondary	50
	tertiary/university	22
OCCUPATION	business	58
	marketer	22
	carpenter	6
	shopkeeper	8
	maid	3
	teacher	3

4.1.2 Demographic characteristics of Charcoal Traders

The current study included 32 charcoal traders drawn from Kamanga compound, Lusaka. The majority of respondent were women (18) 56 percent and (14) 44 percent were men. Table 10 below further describes the demographic characteristics of the 32 traders who took part in the study.

Table 10: Demographic characteristics of charcoal traders

VARIABLE	CLASSIFICATION	FREQUENCY (%)
GENDER	male	41
	female	59
AGE	30-40	56
	41-50	38
	51- 60	6
MARITAL STATUS	single	16
	married	37
	divorced	22
	separated	25
EDUCATION LEVEL	primary	31
	secondary	44
	tertiary/university	25
RELIGION	Christian	100

4.2 Focus Group Discussion Themes

Table 11 below presents the findings in terms of theme and sub themes, identified after carrying out the six FGDs with the household heads.

Table 9: Themes Identified From The Focus Group Discussion:

OBJECTIVE	THEME	SUB THEME
To determine the market and acceptability of faecal sludge briquettes in Kamanga Compound.	Current energy sources available/used in Kamanga	• Main energy source(substitute) • Affordability of current energy product • Reliability of energy sources • Availability of energy source.
	Factors leading to the acceptability of the	• Perceived usefulness • Perceived ease of use
	faecal sludge briquettes in Kamanga Compound	• affordability • smell/smoke production • perceived performance • Confirmation after use of the faecal sludge briquettes

4.2.1 Factors leading to the acceptability of the faecal sludge briquettes in Kamanga Compound.

The following themes and verbatim quotes from FGD participants were identified to help ascertain factors that can influence buying faecal sludge briquettes in Kamanga compound. The verbatim quotes from the participants were in Nyanja, so they were

also translated into English. In addition, each FGD participant was given a case number, for example, 3/2, which meant that in FGD number three, that particular participant was Number two.

i) Perceived usefulness

A general concern expressed by members from all the focus groups was what they would be able to use the new product for. A desired energy source would be one that they can use for cooking, heating and boiling water for bathing and drinking.

Case of participant 1/1: *Ngati tinga pikilepo vilivonse pa mene pama briquettes, monga tipikila pa malasha*

Meaning: *Can we cook anything on the briquettes, like the way we use to charcoal*

ii) Perceived ease of use

Another factor that could lead to the use of faecal sludge briquettes by potential consumers is how easy it would be to ignite and use the product. Would it be compatible with available cooking technologies such as available braziers?

Case of participant 3/1: *Tinga ya sebenzesa pa ma mbaula or ya fanika special stove, monga inangu product ba natu letela mu ma days ya kumbuyo yenze fanika ku sebenzesa kastove kochokela out of Zambia*

Meaning: *Can we use the briquettes on an ordinary brazier or do they require a special stove, like a product we were introduced to sometime back which required the use of a specialized stove made out of Zambia.*

Case of participant 4/6:

Tifanika kudiziba nanga iyi product ifanika kufaka vintu pamwamba mwameni timayasha malash sometimes natu nkuni or na parafini

Meaning: *we need to know if the products requires something to help ignite, like the way we ignite charcoal with sticks or paraffin*

iii) Affordability

All focus groups agreed that it was of utmost importance to have an energy source that most if not all of the community could afford, even in small quantities.

Case of participant 4/1: Izapezeka muma ‘packages’ yosiyana monga malasha,kuli ya five kwacha, ten kwacha.

Meaning: will it be found in different affordable quantities, like the way charcoal is found for five kwacha, ten kwacha.

iv) Smell/ smoke production

A major concern shared by all participants was the smell /type of smoke that would be produced from the faecal briquettes, considering the primary raw material used.

Case of participant 8/3: *ti fanika kuziba type ya chusi ichokela kuli product, kaili ipangiwa na faecal, tinga isebenzese kupika because sometimes ipezeka ati nanga wapika na malasha and siuna vale pa mpoto vakudiya vinunkila monga chushi ya malasha manje what more iyi product ipangiwa na faecal*

Meaning: *we need to know what type of smoke this product produces considering it is made from faecal, will we be able to use it for cooking because you find sometimes when you cook with charcoal and don’t cover the pot well the food smell and tastes like charcoal now what more if we use this product made from faecal sludge.*

Case of participant 9/5: *tifuna product siyi chosa chusi maningi, chifukwa monga malasha ipezeka that tupi yonse inunka monga chusi*

Meaning: *we need a product that doesn’t produce a lot of smoke, because like charcoal you find your whole body is smelling of smoke*

v) Perceived performance

In order for participants to accept using faecal briquettes over charcoal, the faecal briquettes must be a quality product that lasts or can be used for the intended length of time required to boil water or cook a meal.

Case of participant 9/1: *iyi product ifanika inkale product nanga na yasha ninga pike ma veggie, nkunku na nsima. Not nanga wa yasha wa pika chabe manzi ya zima.*

Meaning: *The product needs to be one that when I ignite it, I can cook vegetables, chicken and nshima, not something where you just boil water it goes off.*

Case of participant 11/6: *nanga ninga pike, beans or sampo or nyama vintu vichedwa po pika then ni product ya bwino*

Meaning: If I can cook beans/ samp /beef, things that take long to cook then it is a good product.

Participant-Unit03/5: *Nanga vi sebenza bwino, ni pamene tinga gula*

Meaning*: when we see that they work well, that's when we will be able to buy*

vi) Confirmation after use of the faecal sludge briquettes

Three out of the six groups were given samples of the faecal briquettes to test at home, in their normal cooking/heating procedures, in order to be able to confirm whether or not the briquettes were something they would be able to use. Feedback from all participants who received the briquettes was received. Of which the three people said they would not use the product because it produced a lot of smoke, eight said they would use it again if the smoke produced was reduced because the product did last a bit longer than the charcoal they combined it with when cooking.

4.3 Individual factors of charcoal traders associated with acceptability of faecal sludge briquettes .

Assessment of the knowledge of sludge among respondents revealed that 93.75 percent (n=32) knew the faecal sludge and the product of the faecal sludge. Manure was the only product of known among respondents. Sixty five point six percent (n=32) of participants would sale fuel from faecal sludge, while 11/32 (34.4 percent) would not as shown in figure 7 below.

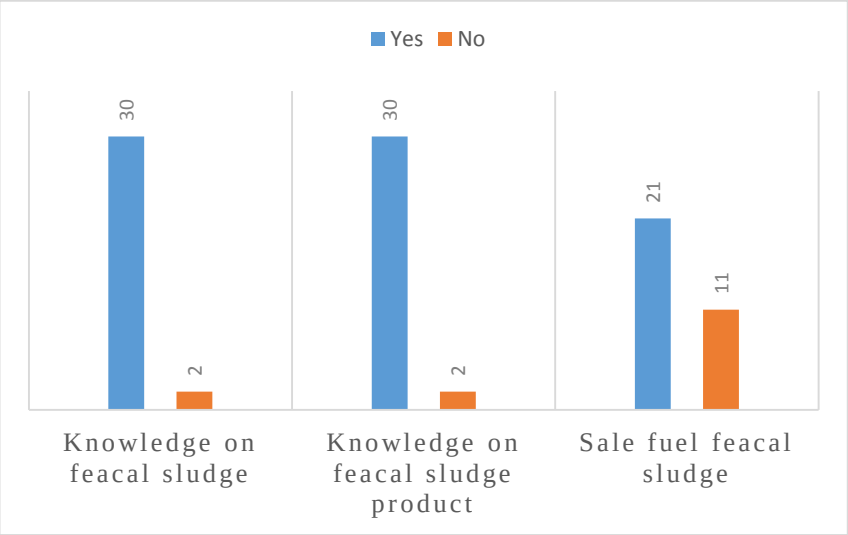

Figure 7: Responses on faecal sludge acceptability.

Literature reviewed on MDA showed that individual factors can influence buying faecal sludge briquettes. According to findings from FGD in this study, individual factors of potential sellers i.e. charcoal traders, were instead tested for any associations as shown in table 12 below.

Table 12: Individual factors of charcoal traders and their relation to the acceptability of faecal sludge briquettes.

Identified Factor	**Acceptance of faecal sludge briquettes**		**total**	****P-Value**
	Yes	no		
Age				
<40years	3	6	9	0.169013
40-50years	7	14		
>50years	2	0	21	
			2	
Marital status				
Single	2	2	4	
Married	3	9	12	0.619783
Separated	5	5	10	
Divorced	2	4	6	
Education level				
Primary	4	5	9	
Secondary	4	12	16	0.111301
Tertiary	5	2	7	
,Gender				
Male	3	10	13	0.163308
Female	9	10	19	

** P VALUE was derived from CHI-SQUARE

A chi-square test of association was performed to determine the association between various individual factors and the acceptability of faecal sludge briquettes as shown in table 12 There were no significant associations, as shown by the P values.

After determining no associations between individual factors of charcoal traders and the acceptability of faecal sludge, as determined in table 12 above. The reasons leading to acceptability by charcoal traders were determined as displayed in Figure 8 below

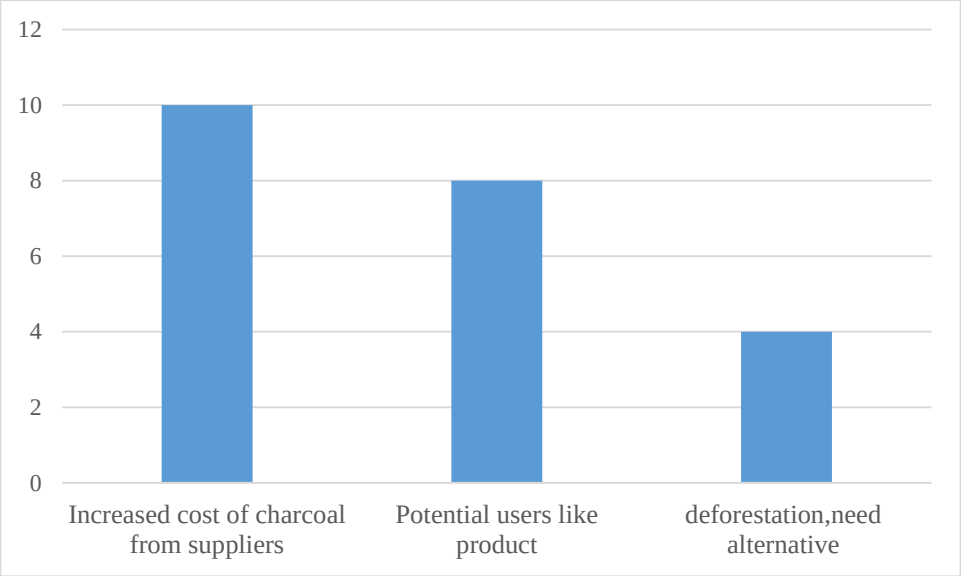

Figure 8: Reasons leading to faecal sludge acceptability among charcoal traders.

4.4 Energy sources used and faecal sludge briquettes substitute

The main energy source used in Kamanga, as noted from all six focus group discussions, was charcoal. All participants confirmed that they mainly used charcoal daily for their cooking /heating needs. Charcoal was selected as what is termed the 'substitute' product according to the MDA for faecal treatment products. Charcoal is similar in appearance and usage to faecal sludge briquettes, so it was suitable to estimate the market potential of faecal sludge briquettes. Electricity was used to supplement the charcoal and was mainly used for lighting purposes, especially at night. Firewood was used in what can be termed 'commercial' use because most households who used the firewood used it to make their local alcohol 'kachasu'. Only three (3) out of 36 participants' confirmed using firewood for Kachasu brewing.

Case of participant 3/2: *Ise benangu tilibe ma stove ku nyumba, so ti sebenzesa malasha kupika vokudya, kupika manzi yokumwa na boila manzi yo samba.*

Meaning: *Some of us don't have stoves at home so we use charcoal to cook and boil water for bathing and drinking*.

Case of participant 4/4: *Ti ma sebenzesa maliti kapena kwafipa*

Meaning: *We use electricity just for lighting, when it gets dark.*

Case of participant 4/4: *Ise be tipanga kachasu ndise tisebenzesa nkuni maningi*

Meaning: firewood is mostly used by those of us who make kachasu.

i) Affordability

It was found that charcoal was widely used in Kamanga compound because, according to most participants, charcoal was something they could purchase within their means. Though prices of charcoal have steadily been increasing as noted from 13% of participants, who even referred to charcoal as becoming expensive.

Case of participants 11/4: *Tikonda ku sebenzesa malasha ndaba tingagule olo tu ngono twamene tinga kwanise kusebenzesa kupikila vokudya, monga ya five kwacha or ten kwacha*

Meaning: *We like charcoal because we can buy small quantities that we can afford and use to cook a meal, for example you can find charcoal for five kwacha, ten kwacha*

Case of participant 3/2: *Tikonda kusebenzesa malasha ndaba chi oneka kwati ndiye yamene tikwanisa but these days yankala yo dula, last year tenze gula malasha na ya two kwacha manje yali monga kusebenzesa maliti chifukwa ise benangu tilibe ma stove, so tichetekela malasha*

Meaning: *We like to use charcoal because it seems more affordable but these days it's becoming expensive, last year we used to buy charcoal for even two kwacha, now it's more like using electricity, just that some of us still don't have stoves so we still rely on charcoal.*

ii) Reliability

During the focus group discussion it was also learned from the participants that they continue to use charcoal because it was something they have all used from childhood. It was a product they were familiar with, and apart from being a familiar product, it

was also consistent in terms of what to expect from it when used for cooking/heating, a point that was echoed by all the groups.

Case of participant 3/3: *Ti ma sebenzesa malasha chifukwa tiziba mwamene isebenza na kuisebenzesa, kuchoka tikali bana namanje tiyi sebenzesa mu ma nyumba yatu. Kwenze product inangu banatiletela mu community yenze monga malasha yenze fanika ku sebenzesa monga ka special stove*

Meaning: *we use charcoal because we know how use it and how it works am and we have used it since childhood and now we use it in our own homes. Unlike this other product like charcoal that was introduced in the community sometime back which required* the use of a special stove

Case of participant 11/1: *Malasha nichintu chamene tiziba nanga na faka malasha pa mbaula naiyasha inga pike beans or manzi yo samba*

Meaning*: Charcoal is something that we are used to, I know once I put my charcoal on the brazier and ignite it I can cooking beans or boil my water for bathing*.

iii) Availability

From the focus group discussion, another advantage charcoal has over other energy sources, is its availability. A general consensus from the focus group participants was that charcoal was easy to find. This was confirmed by the field work done in the community during the interviewing of the charcoal traders who sold charcoal from as early as 06hours to 19hours at night. They were local points of sale and some household sold their charcoal at their gates. Firewood required going to areas outside Kamanga.

Case of participant 4/4: *Malasha siyavuta ku peza kuno kwa Kamanga, ise benangu ba neighbor ba gulisa malasha so sitimayenda nakutali*

Meaning: *Charcoal is easy to find in Kamanga, some of us our next door neighbor sales charcoal so we don't go far to buy it*.

Case of participant 4/6: *Tinga peze malasha pali ponse*

Meaning: *you can find charcoal anywhere*

4.5 Market growth potential and Market volume potential

This section is a presentation of the research findings to determine market volume potential and market growth potential on faecal sludge briquettes based on findings from its 'substitute product', charcoal.

4.5.1 Market growth potential

According to Table 13 below**,** in the year 2019, 35.7 percent (n=14) of charcoal traders sold their charcoal in plastics of 2.5kg, and this was consistent with the record for 2021 where 11/32 (34.4 percent) sold in 2.5kg plastics. In 2020 charcoal traders, 6/22 (27.3 percent) sold charcoal in sacks of 25kg.

Table 13: How many plastics/bags of charcoal were sold in the following years?

Quantity of charcoal in (Kg)	2019	2020	2021
1.5	2 (14.3%)	3 (13.6%)	6 (18.8%)
2.5	5 (35.7%)	4 (18.2%)	11 (34.4%)
25	4 (28.6%)	6 (27.3%)	5 (15.6%)
50	1 (7.1%)	5 (22.7%)	6 (18.8%)
90	2 (14.3%)	4 (18.2%)	4 (12.5%)
Total	**14 (100%)**	**22 (100%)**	**32 (100%)**

There were 14/32 (43.8%) who had been selling charcoal since 2019 and 22/32 (68.8%) were reported to have been selling since 2020 giving an increase of 8 captured traders in a year (Figure 13).

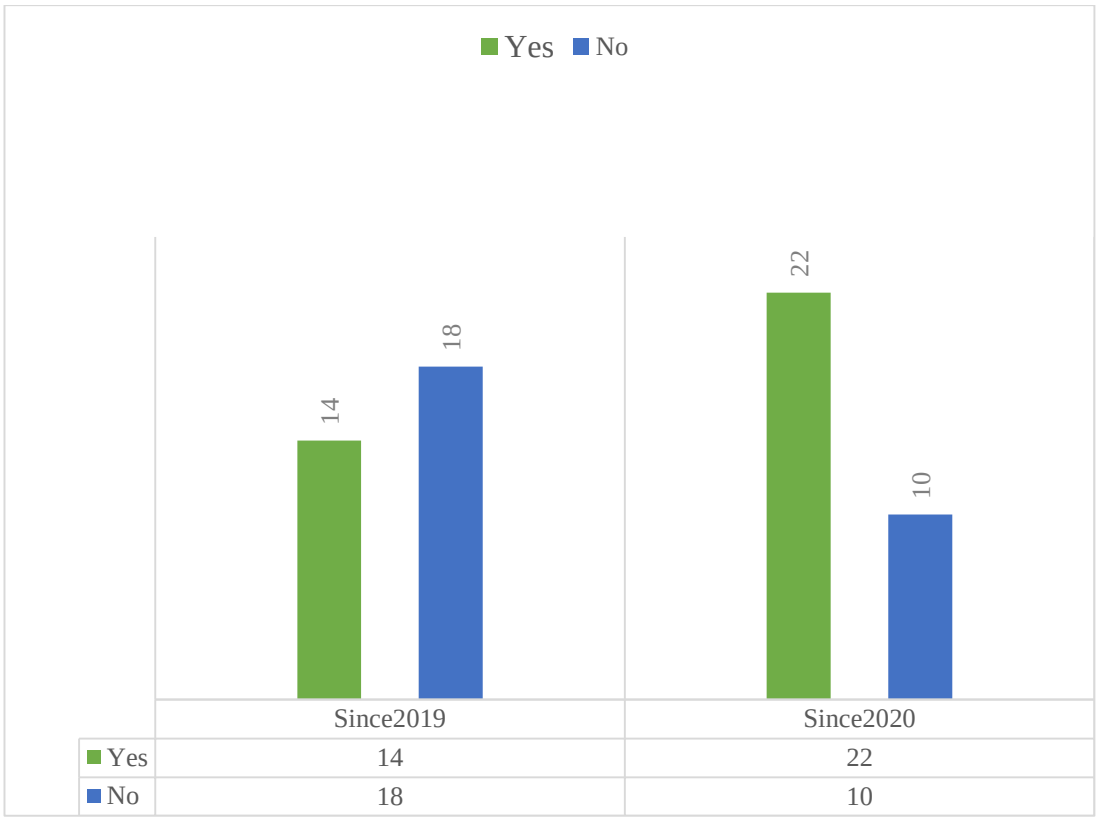

Figure 9: Number of charcoal traders who sold charcoal each year.

Figure 10 shows the seasons when charcoal is sold the most in Kamanga compound. Results indicated that 60 percent of charcoal traders sold the most in the cold season, followed by 28 percent in the rainy season. The least was three percent representing charcoal selling in the hot season while nine percent of traders had a constant selling throughout the year.

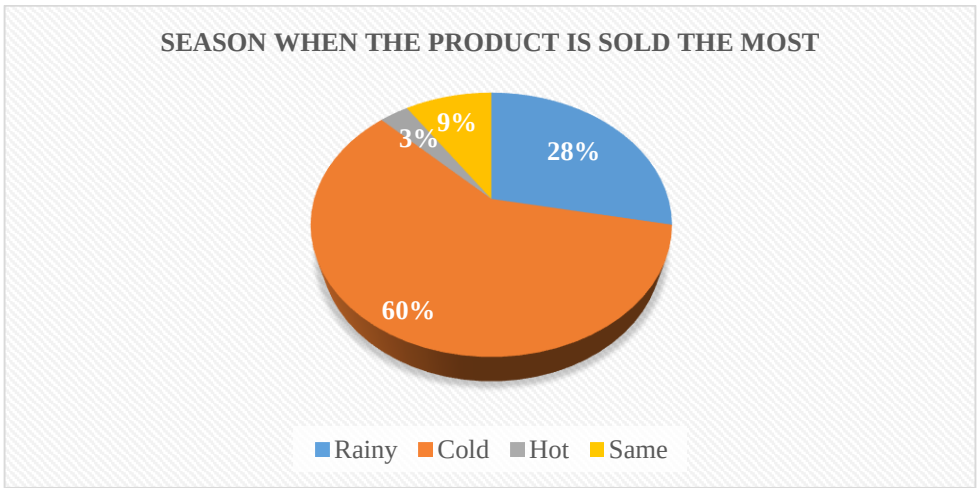

Figure 10: Season when the product is sold the most

4.5.2 Market Volume potential

To evaluate the market volume using the MDA tool, survey respondents were asked to state the number of plastics/bags they sold daily since the year they had begun charcoal trading. The number of plastics/bags they sold were recorded in the ranges of 1-5, 6-10 and 11- 20. Findings revealed that most traders selling 1.5kg of charcoal were selling between six to ten packages in 2020 and 2021. In 2019, the number of traders who sold one to five packages was equal to those who sold six to ten packages. Selling patterns of 1.5kg plastics were similar to 2.5kg plastics in 2020 except for 2019 and 2021 in which one to five packages were sold more than six to ten packages. Table 14 shows the frequency of respondents who sold charcoal within each range in a given year.

Table 14: How many plastics/sacks were/are you selling daily?

		FREQUENCY IN EACH YEAR		
Quantity (kg)	*Range packages*	*2019*	*2020*	*2021*
1.5	1-5	**1**	**1**	**2**
	6-10	**1**	**2**	**3**
	11-20			**1**
2.5	1 – 5	**3**	**1**	**6**
	6-10	**1**	**2**	**4**
	11-20	**1**	**1**	**2**
25	1-5	**2**	**3**	**4**
	6-10	**2**	**2**	**1**
	11-20		**1**	
50	1-5	**1**	**4**	**5**
	6-10		**1**	**1**
	11-20			
90	1-5	**2**	**4**	**3**
	6-10			**1**
	11-20			

Prices for the various charcoal quantities were also necessary in estimating the potential market volume of faecal sludge with the help of the MDA tool. Data collected indicate that prices of charcoal has been increasing in Kamanga compound since the year 2019. Figure 11 below shows that price per plastic/sack from 2019 to 2021.

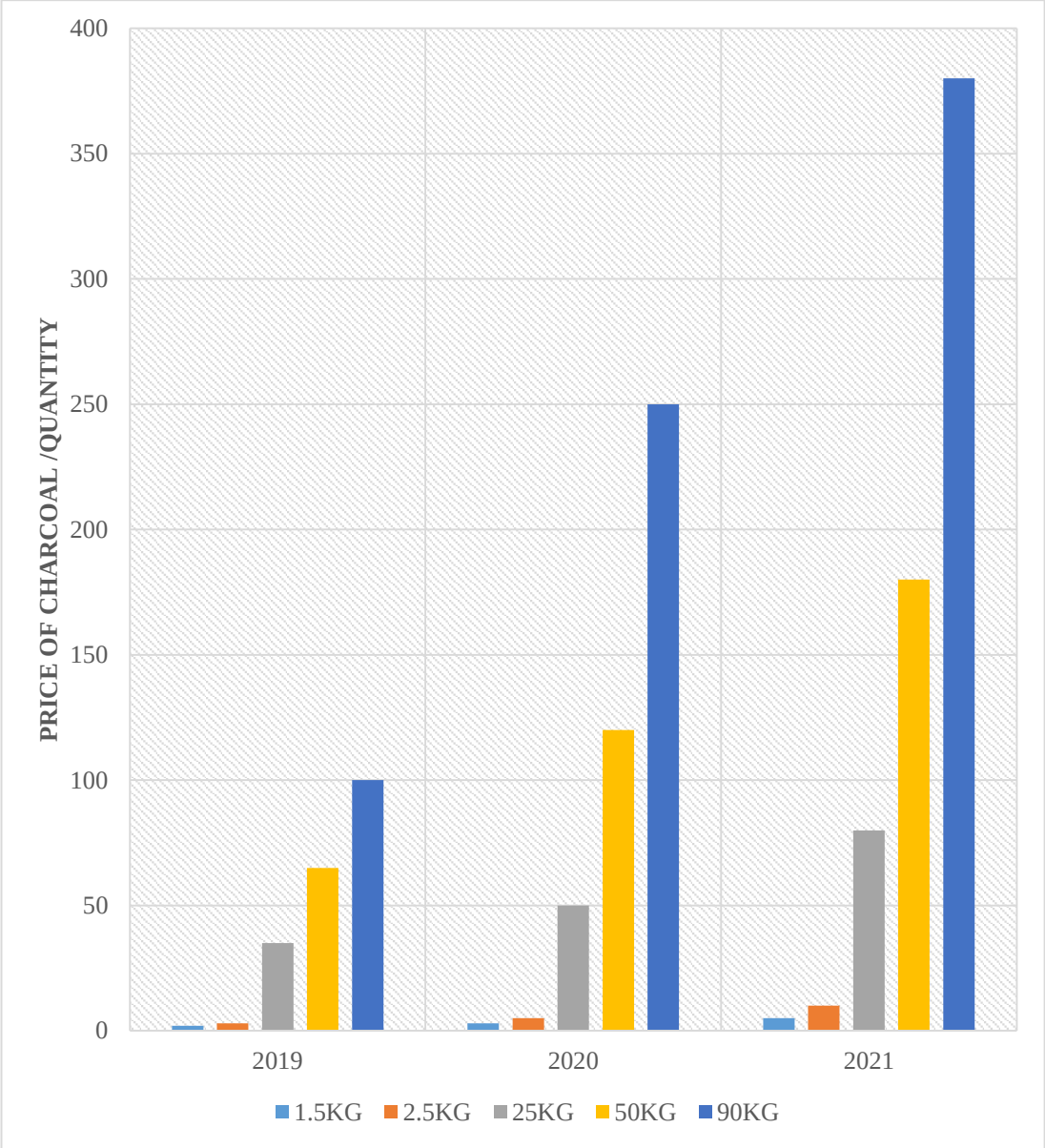

Figure 11: Change in charcoal prices

Table 14 below shows the market volumes for the different quantities of charcoal sold in Kamanga compound, starting with the 1.5kg plastics up to the 90kg sacks. The market volume presented were calculated and extracted in the MDA tool shown in the methodology.

Table 14: Calculated Market Volume

Quantity	1.5kg	2.5kg	25kg	50kg	90kg
Total quantities sold	2240	2058	132	133	42
Unit Cost (ZMW)	5	10	104.3	167.9	441.4
Unit cost (USD)	0.31	0.61	6.4	10.2	26.9
Market volume (USD)	694.4	1255.38	844.8	1356.6	1129.8
Adjustment factor	1.1	1.1	1.1	1.1	1.1
Adjusted market volume (USD)	763.84	1380.918	929.28	1492.26	1242.78
Total Adjusted Market Volume: $5809.078					

Calculation of the market volume from the MDA calculation tool revealed that 50kg bags of charcoal had the largest market volume ($1356.6) while 1.5kg plastics of charcoal had the lowest market volume ($694.4). Therefore, the total adjusted market volume for all the charcoal quantities was found to be $5809.078.

i) Adjustment factor

Prior to calculating a market volume for faecal briquettes (i.e. adjusted market volume). An adjustment factor is necessary, as a substitute product will not have the exact same market volume as a faecal sludge treatment product. This Adjustment factor was derived from the MDA calculation tool as shown in the methodology, and Table 15 below shows how each factor was scored. After ranking each factor with a

score from one (highly negative influence) to five (highly positive influence), an adjustment factor of 1.1 was calculated. An adjustment factor between 1 and 1.5 suggested that the market volume of the faecal sludge briquettes was greater than then the market volume of charcoal.

Table 15: Adjustment factor

Factor	Score
Switching cost	2
Investment cost	1
Efficacy/quality	5
Geographical	4
Distribution	5
Entry point	5
Demand variability	5
Price sensitivity	1
Social stigma	2
Calculated Adjustment factor	1.1

1. Switching costs:

The main switching costs will be incurred from technical trainings that have to be carried out by people with extensive knowledge of the manufacturing of faecal sludge briquettes. Private businesses or public companies will have to engage these experts and have hands-on training workshops.

2. Investment cost:

The main investment costs that were incurred during this study were the cost of the metal drum, which was bought at the cost of k500, 50kg saw dust at k50 and paraffin at k150 .The was no need for any large-scale machinery as available materials were used. For example, large stones were used for crushing the carbonized faecal sludge and the briquettes were handmade, as opposed to if it was large-scale briquette machines would be required.

3. Quality:

Participants who welcomed the use of faecal briquettes were concerned with the quality of the substitute product; charcoal, compared to the faecal sludge briquettes. Important Desired qualities were long burning time, smoke production.

4. Geographical:

Through interviews with some charcoal traders within the area of Kamanga, it was found that 34% of the charcoal traders are willing to sell faecal sludge briquettes. So difficulty in reaching potential customers would not be a limiting factor for the faecal sludge briquette market.

5. Distribution and entry point:

In Kamanga compound they are common points of sale for charcoal traders. Considering some of the same charcoal traders would be willing to sale faecal sludge briquettes, the same sales points can maintained.

6. Demand variability:

Charcoal sales can somewhat be considered seasonal though sales are throughout the year as finding show that peak sales were 60 percent of sales in cold season followed by 28 percent in rainy season.

7. Price sensitivity:

Findings from the comparative cost analysis, taking into consideration adjustment factor. As compared to the lowest costing package of charcoal which is 1.5kg of charcoal for k5, the cost of briquettes cost k 0.5 more than charcoal.

8. Social stigma:

Through the focus group and charcoal trader interviewers it was noted that people did have reservations about using and selling the product on one hand the charcoal traders believed people would not accept the product while focus group participants had some reservation in regards to product safety and smell.

4.6 Comparative cost analysis

Table 17 below shows the three main energy sources used in Kamanga compound, their cost and uses in comparison to 1.5 kg of faecal sludge briquettes.

Table 16: Cost Comparison

Energy	Quantity	Cost (K)	Uses
Charcoal	1.5 kg	5	Cooking, heating
Briquettes	1.5kg	5.5	Cooking, heating
Electricity	9units	5	Lighting
Fire wood	Bundle	Free	Cooking, heating

* Household k 0.560/kwh

*adjustment factor 1.1 for faecal sludge briquettes in this study

The cost for the 1.5kg of faecal sludge briquettes was found after multiplying the 1.1 adjustment factor with the cost of 1.5kg cost of charcoal resulting in k5.5. This indicated that faecal sludge cost k0.5 more than charcoal. Results further indicated the cheapest energy source used in Kamanga was firewood, both electricity and charcoal could be bought at the same price, but the electricity usage was limited to only lighting.

4.6 Summary:

This chapter presents both quantitative and qualitative data that was collected using the methods outlined in chapter 3. This data from focus group discussions and charcoal traders responses, was then translated into inorder to address the study objectives and presented in this chapter as results.

CHAPTER FIVE

DISCUSSION

5.0 Introduction

In this section, the findings relating to determining the market potential and factors leading to the acceptability of faecal sludge briquettes, as presented in chapter four, are discussed. The findings are also compared and contrasted to the findings from similar studies by other researchers**.**

5.1 Factors leading to the acceptability of faecal sludge briquettes

The following are factors that can lead to the acceptability of faecal sludge briquettes in low-cost areas based on the findings of this study.

a) Perceived usefulness of faecal sludge briquettes

A general concern expressed by members from all the focus groups was what they would be able to use the new product for. A desired energy source would be one that they can use for cooking, heating and boiling water for bathing and drinking. Through the respondents of this study, it was noted that a desirable energy product should be one with practical day-to-day uses. In support of this need of the consumers, Nakuru water and Sanitation Services Company Limited (NAWASSCOAL) produces and sells round-shaped carbonised briquettes made from treated sludge as an alternative fuel for domestic cooking and heating (SNV, 2021).

b) Perceived performance of faecal sludge briquettes

Through the present study, it was noted that participants were welcoming of a fuel source that would much up to their expectations, and would work in accordance with their cooking/heating needs. According to a study by Nantambe et al. (2016), two companies that were identified in Kampala as producers of briquettes made from faecal sludge char and organic waste reported much confidence that as long as faecal sludge briquettes have equal or better performance to other briquettes currently on the market, that they will be marketable and attractive to consumers.

c) Smoke production/smell of faecal sludge briquettes

In this study a notable concern was possible smells that the faecal sludge briquettes would produce. According to Gitau H (2020), it was found that some participants of the study expressed their repulsion towards using faecal sludge briquettes as they feared that food might get the smell of faeces and the smell would also be harmful to the health of the user.

5.2 Individual factors associated with the acceptability of faecal sludge briquettes

According to World Health Organisation (WHO), et al., (2017) factors associated with whether or not a particular community accepts faecal sludge briquettes or faecal sludge products in general can be dependent on factors such as age, religion, gender, and education level (WHO, 2017). In this study, no statistical significance was drawn from any of the individual factors assessed, which included; age, gender religion, marital status and religion. This is contradictory to some studies, such as a similar study carried out in Korogocho, Uganda, where Muslim respondents regarded any money associated with faecal sludge emptying and recycling as unclean, and they avoided being associated with such money. Another study by Duncker et al., (2007) showed religion had a huge role in the use of waste faecal products as dictated by how that religion viewed the waste product; An example is; a Koranic edict which considers urine to be a spiritual pollutant, and Islamic custom demands that Muslims reduce their contact with human excreta.

5.3 Identified reasons for using faecal briquettes

Despite not finding any statistically significant individual factors that supported the acceptance of faecal sludge briquettes, the following were noted as important reasons why participants of the study would accept using faecal sludge briquettes.

i) Social stigma and perception of faecal sludge

The reason traders were against supplying or selling faecal sludge briquettes was because they believed that the community would not accept the product. Through literature, it has been learned that people's natural reaction towards faecal matter and, consequently, faecal products is repulsion. This social stigma can be related to another

reason for rejecting faecal briquettes: it is thought to be a waste, something dirty that has no value and needs to be discarded. These findings are consistent with a study by Gitau H (2020) ,which states that due to the stigma associated with faecal sludge, the usage of faecal sludge products is low. An increased market for faecal sludge products can be achieved by creating more awareness among potential users. In support of the fact that people regard faecal sludge as just a mere waste is the fact that big foundations like the Bill and Melinda Gates foundation (BMGF) are championing and supporting sanitation-based programmes and resource recovery because they know the value of faecal sludge. It is more than mere waste but an important resource that can help offset some management costs if a good market for these products is made available (Gitau H, 2020).

ii) Smell

After social stigma, this was the second most common reason why participants did not accept faecal briquettes. The concern was about food possibly smelling like faecal matter. The study by Duncker *et.al* (2007) noted that some participants welcomed the use of faecal sludge briquettes others, of course had negative attitudes. When asked if they would use faecal sludge briquettes for cooking, there was concern that the smell would get into their food. It was compared to when food smelled like smoke when using charcoal for cooking.

iii) Increase cost of charcoal and deforestation

Despite the majority of participants having reservations regarding accepting faecal sludge briquettes, some participants welcomed the usage of an alternative fuel source such as the faecal sludge briquettes.They felt having an alternative would not only divert reliance on trees leading to deforestation but also the possibilities of a fuel source that was more economical than charcoal. According to a study that is in agreement with the findings of this study, the increased charcoal prices are partly a result of the increased demand due to load shedding in the country. This has resulted in forest degradation/ deforestation because of the increased cutting down of trees to meet this increased demand. It has even reached the extent where trees that were not generally used for charcoal production are now being use because the main charcoal producing species are depleting or depleted in some areas (Gonzalez A, 2020). An

article by Lwizi G (2020) particularly noted a k27 kwacha increase of 90kg charcoal which was k132 in February and k159 in March of the same year.

5.4 Main energy source and faecal sludge briquette substitute

The study revealed that indeed the main energy source used in Kamanga compound was charcoal.
Increased demand for charcoal is forecasted to be driven by growing population and the slow rate of electrification.

Knowledge of main energy sources used in low cost areas such as Kamanga compound was important because it helped ascertain that charcoal was a good substitute for faecal sludge briquettes. This assisted in determining the market potential of the faecal sludge briquettes based on substitute products, which has clearly been defined according to the MDA in chapter one. Ideally faecal briquettes would be expected to perform as charcoal does and to that effect replace charcoal on the market. Available energy sources such as firewood, electricity were also important to note in order to make a comparative cost analysis of faecal sludge briquettes to what was currently being used in Kamanga compound.

a) Affordability

According to the present study, charcoal was the most affordable energy source to use. Chando (2021) revealed similar findings, in that demand for charcoal in Zambian households was rising as it was the preferred and primary energy source due to its affordability. Another study by Gonzalez (2020) stated that with iload shedding, families still required to boil water, prepare their meals, but unfortunately they were few alternatives with charcoal being the most affordable and convenient compared to other energy sources such as gas or petrol which cost more. While also on the other hand, it also revealed that charcoal prices were becoming expensive. This is in line with a study by Dlamini et al., (2016) in which charcoal prices were seen to have increased by K15 per 25kg bag. Sikombe (2017) highlights that the price of charcoal has been increasing as more and more people turn to charcoal due to electricity deficits. A 50kg bag was now costing $16 from $9 the previous year.

Considering the affordability of faecal sludge briquettes, it would be desirable if they were as affordable as charcoal to stand a chance on the market. Studies have shown

some faecal briquettes were being sold at the same cost price as charcoal. A study by Hakspiel et al., (2018) showed that faecal briquettes costing the same as charcoal allowed users to save money as they lasted longer, so they could be used for an extended period to carry out basic needs like cooking, preparing water.

b) Availability

The study revealed that charcoal users were inclined more to use charcoal because it was within their reach,. Charcoal could easily be found anywhere, and they did not have to move long distances outside their community to find charcoal. This can be considered a big advantage because there would be no additional transport cost required for them to obtain the energy source. Charcoal is also available to consumers throughout the year at hours traders know consumers will need to use charcoal. According to research by Hibanje (2003) in urban areas, charcoal is traded from homesteads, municipal markets and hawkers and estimated 1.5 percent of urban households are engaged in charcoal trading from their homes. Gonzalez (2020) was able to further highlight that cities like Lusaka are now home to many overcrowded and underserved compounds that are off the grid, making for a thriving charcoal market. Charcoal is easily available to residents in such area because that is what they rely on; such is the case in the study area.

Considering the extensive market held by charcoal, if the faecal sludge briquettes were to replace charcoal it would be at the discretion of faecal sludge briquette producer to decide on whether to take advantage of the current traders, find new sales people/ supply from production site. A study by EED (2020) noted the importance of employing various distribution methods for the briquettes. These included for example: direct sales for the households close to the production site and use of agents such as mini-shops that are already in existence.

5.5 Market growth potential

From the findings in this study, an increase in the amount of charcoal purchased in Kamanga compound for the period 2019 to 2021 was evident. A study by FAO (2017) showed that charcoal was generally an important energy source in many households but more notably in households of low cost areas like Kamanga. The study went on further to state that the increasing demand in charcoal by households was as result of

increasing population and need for an affordable and easily available energy source (FAO, 2017).

In this study, market potential growth was mainly defined through the following factors; increase in the number of traders, sector performance; seasonal changes in sales and increase in sales and price change. According to a similar study carried out in Kampala, Uganda market growth was assessed through the population increase, the number of farmers, and sector performance (Andriessen et al., 2017).

i) Increase In the number of traders

In this study, a yearly increase of charcoal traders was noted from the year 2019 to 2021.This showed that the market was indeed growing because more individuals taking part in the sale of this product. According to Johnson (2014), two reasons why the charcoal market is growing is due to the increase in charcoal trade due to poverty and limited jobs. Katongo (2016) states that charcoal trading has grown exponentially due to the fact that people are able to make a leaving from it and provide for their families ultimately reducing the poverty burden. In some areas, there are few or no alternative businesses to get into, so charcoal trade is the main livelihood (Katongo, 2016).

ii) Season of sales

Seasonality as it related to the market growth potential is important because market growth can be affected by weather, so it helps to understand the motive behind the increase of sales at particular points in the year. According to Kenton (2020) knowledge in seasonality helps in proper planning by producers/suppliers in terms of creating seasonal marketing plans and the amounts to supply to meet demand needs. In this study, most charcoal sales occurred in the colder season, as there is a greater need to have hot water for bathing, making tea and space heating. A study by Phiri (2015) supported this finding, as it was noted from one trader that cold season was very good for business.

iii) Increase in frequency packages

This study showed that there has been an increased demand for charcoal, as seen in the number of times charcoal is purchased on a daily basis. The study by Phiri (2015)

confirmed that indeed there has been an increase in the frequency of charcoal sales/purchases; one trader noted that she went from selling small plastics every other day to selling a whole bag daily. Another trader in the same research stated that he went from selling 100 bags in three days to 100 bags in just one day.

5.6 Market volume potential

A market study carried out in 2014 in Kampala Uganda, with a population of 1.5million people yielded a market volume of about $73million and an adjusted market volume of about $44million and an adjustment factor of 0.6. Another market study also carried out in Kampala estimated market volume including industrial and institutional use in Kampala is $2.8 million (Kakooza et al., 2016). The present study carried out in Kamanga compound with a population of approximately 48, 648 resulted in a lesser yearly market volume, understandably so considering the catchment populations of the studies. Though in the present study the adjustment factor was much higher, and according to the market driven approach, an adjustment factor between > 1 and 1.5 suggests that the market volume of the faecal sludge treatment product is greater than then the market volume of the substitute product. The adjustment factor was calculated as a result of the information gathered from trader interviews, focus group discussions and literature review. Factors resulting in the calculated adjustment factor are as explained below:

5.6.1 Adjustment factors

i) Switching costs

According to this study, the cost incurred by switching from charcoal to faecal sludge briquettes will come from the need to train an individual who will be involved in the production of the briquettes by experts. Whether it will be a private business or a government company interested in briquette production. According to EED (2020), switching costs associated with using faecal briquettes instead of charcoal will result from technical, mentorship trainings to be carried out by technology experts. In addition, costs for adjusting the labelling of the products to a new raw material will also attract switching cost. For the present research labelling cost were not considered because it was thought to be unnecessary because it was found that participants were

comfortable with the briquettes appearing on the markets just the way charcoal appears; either in plastics or sacks.

ii) Investment costs

According to this study, only a total of k600 was required to make the briquettes to carry out the demonstration and for participants to test their own at home. If done on a larger scale the producer will need to invest capital in acquiring new machinery to produce the faecal sludge treatment product (Schoebitz et al., 2016). According to EED (2020), the following equipment would be required for large-scale production of faecal sludge briquettes; a carbonization furnace $15000, electric mixer $2000 and a high capacity briquetting machine $100,000.

iii) Quality

In this study, round-shaped briquettes were made for demonstration purposes, which according to Nyaanga et al., (2017) round-shaped briquettes are better quality because they have better combustion characteristics compared to other shapes such as triangular and cylindrical briquettes. Saw dust was mixed with the faecal sludge when making the briquettes; faecal briquettes with saw dust binder were found to have a calorific value of 22.001 MJ/kg (SNV, 2021). According to WASH institute (2016), various combinations and binders can be used to make briquettes of higher calorific values the highest calorific value of 4.5 kcal/g for the combination of faecal sludge and charcoal dust. According to Hakspiel et al., (2018). The two advantages of using faecal sludge briquettes are namely; (i) Burning time: briquettes can burn 1.5 times longer than traditional charcoal, and (ii) Less smoke: the briquettes produce less smoke than wood and charcoal.

iv) Geographical/ Distribution/ Entry Point

According to the guide for assessing these three adjustment factors, the basically are pointers as to how well the product will be able to reach consumers or if the already available markets which can be used to distribute the briquettes (Schoebitz L et al., 2016) and according to charcoal trader response of those who are welcoming the product the points of distribution or already established markets are

available within Kamanga compound. it would be at the discretion of the producer on whether to maintain the current traders, find new sales people/ supply from production site A study by EED (2020) noted employing various methods of distributing the briquettes, such as; direct sales for the households close to the production site; use of agents such as mini-shops that are already in existence; door-to-door agents and a mobile distribution truck that sets up during a designated market day and digital marketing on different platforms.

v) Price sensitivity

In this study, faecal sludge briquettes cost slightly more than charcoal. According to EED (2020), the cost of briquettes was marked up because the use of additional distribution points to reach consumers who may be located further from the production site required the cost of the briquettes to be marked-up for the distribution agent to earn a profit. Another market cost analysis of faecal sludge briquettes by Hakspiel et al., (2018) noted that the briquettes are sold at the same price as traditional charcoal but because they last longer they save users money.

vi) Social stigma

In this study, it can be noted that some participant had their reservations about faecal sludge briquettes. Most charcoal traders would not accept to sell the product because they believed people would not buy it. According to Gitau (2020), a lack of awareness f the economic benefits of the recycled faecal sludge products is among some of the barriers documented in that study. As a result of the lack of awareness, there was a perceived unattractiveness in selling such products because of the general social stigmatization which is related to faeces.

5.7 Cost comparison

According to this study, a cheap energy source would be fire wood though according to findings, obtaining this product requires foraging in woodlands outside the study area. This makes firewood an unattractive energy source for many households. The cheapest energy source was charcoal which from only a small quantity can be used for cooking/heating .when the adjustment factor is applied to the cost of the charcoal to obtain the price of briquettes of the same quantity, it is found to cost slightly more, but given that faecal sludge briquette last longer than charcoal, it would be more

economical to buy the briquettes. Electricity for the same price as charcoal would only be suitable for lighting a household.

According to EED (2020), comparing the cost of wood and charcoal with the production of briquettes is difficult. For example, wood can easily be collected from family farms or nearby wood lands at no cost and in many cases, the households use dry twigs and not felling an entire tree. The whole process of pre-treatment, drying of waste, mixing with a binder and compacting are mechanized processes in briquette production and taxations adds to the capital for start-up businesses and the daily operation of the business. Understandably this if the main reason as to why briquettes prices fail to compete with charcoal and wood, however, if the charcoal regulations are enforced, there is an opportunity for the briquette sector to compete effectively (EED, 2020).

5.8 Limitations

- Lack of already existing product on the Zambian market.
- Covid19 restrictions reduced contact time with each group to fully demonstrate and get their feedback on the demonstration**.**

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The need for a good alternative energy source with a positive market as dictated by consumers' willingness to buy and use the product, is very important. More so for an alternative energy source that is made from faecal sludge. The objectives of this study were achieved in that factors leading to acceptability of the faecal briquettes was assessed both on the side of the potential consumers and traders. It can therefore be concluded that both the charcoal traders and the household heads had some reservations towards the faecal briquettes but also some individuals accepted the alternative energy source, mainly because of the increased cost of charcoal. While some traders thought that potential consumers would not accept using the product because of the social stigma that comes with faecal matter. It cannot be emphasized enough that although faecal sludge briquettes are not a product on the market in Zambia, there was a need to use a 'substitute product'. The substitute product, charcoal for this particular study, helped to understand the market through two main aspect; market volume and growth. The findings from charcoal helped to give a picture of market in hopes faecal briquettes would also meet the needs of user in a similar way when introduced onto the market. The market potential in terms of growth was described and the briquettes volume was estimated through calculating the charcoal market. Taking into consideration the adjustment factor to account for the difference in the actual market uptake of the briquettes due to factors such as social stigma. The briquettes would to quite well if they follow the trends set out by charcoal. Finally, a comparative cost analysis of currently used energy source in the area was carried out where it was found that faecal briquettes cost slightly more than the most used energy source, charcoal but according to the longer burning time of briquettes they would prove to be more cost effective**.**

6.2 RECOMMENDATIONS

i. Recommendation for Zambia Development Agency (ZDA), Ministry of Water Development, Sanitation and environmental protection (MWDSEP).

- Create an enabling environment that supports the market attractiveness of faecal sludge briquettes.

ii. Recommendation for Zambia Environmental Management Agency (ZEMA), Ministry of Water development, Sanitation and Environmental Protection (MWDSEP).

- Advocate for alternative energy sources that do not deplete available natural resources.

iii. Recommendation for Lusaka Water supply and Sanitation Company Limited (LWSC).

- Explore innovative ideas that can produce incentives through the resource recovery such as faecal sludge briquetting.
- Engage private businesses/entrepreneurs interested in resource recovery from faecal sludge.

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APPENDICES

Appendix 1: Information Sheet

NASREC FORM 1b

THE UNIVERSITY OF ZAMBIA

DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

NATURAL AND APPLIED SCIENCES RESEARCH ETHICS COMMITTEE

Telephone: +260-211-290258/293937 P O Box 32379

Fax: +260-211-290258/293937

Lusaka, Zambia

E-mail drgs@unza.zm

PARTICIPANT INFORMATION SHEET

"Informed Consent Form for head of households in Kamanga compound, who are being invited to participate in the research titled "market and acceptability of faecal sludge briquettes in Kamanga compound, Lusaka.''

Chisha Kaulungombe,

University of Zambia,

Student.

This Informed Consent Form has two parts:

- **Information Sheet (to share information about the study with you)**
- **Certificate of Consent (for signatures if you choose to participate)**

You will be given a copy of the full Informed Consent Form

Part I: Information Sheet

Introduction

My name is Chisha Kaulung'ombe, I am a student at the University of Zambia studying a Master of Science in Sanitation. I am carrying out a research which is focused on assessing the market and acceptability of sludge briquettes in Kamanga compound. I am inviting you to be a participant in the study. Before I explain more on the purpose of this study, I would like to let you know that your participation in this study is entirely voluntary and you are not under any responsibility to take part in it. A consent form will be provided for you to sign to show your agreement to participate in this study. If at any point there are words or concepts you do not understand please stop me and I will clarify to the best of my ability.

Purpose of the research

Filled up pit latrines is a common issue in your community. They are companies/organizations that are looking for ways to improve sanitation service delivery, which includes the emptying of pit latrine up to the point where the waste from these pits can be safely disposed of. One of the upcoming ways which has been identified is by turning the waste found in the pit latrines into products of value which people can use in their day to day lives. One of these products that can be made from pit latrine waste is faecal briquettes. This product can be likened to energy sources such as charcoal. It is from

this study we will learn if the faecal briquettes are a product that can do well on the market, if it is a product you as an individual would use. From the information you will give, also qualities that will make the product more suitable for your acceptance and use of the product will be identified.

Type of Research Intervention

This research will involve your participation, a focus group discussion with other house hold heads, from the five (5) units in Kamanga. The discussion will be guided by a questionnaire that will be administered to you, in a language you are comfortable with, by the principal investigator or a research assistant. The discussion will take one hour.

Participant Selection

You are being invited to take part in this research because as a Household head, you are at the forefront of organizing the household resources, which includes what energy source is to be used by the household. Your important opinion on what factors you look for when choosing a day to day energy source can contribute to determining the potential market for faecal sludge briquettes.

Voluntary Participation

Your Participation in this research is completely voluntary and confidential .If at any point during the interviews you feel uncomfortable or unable to continue, you will be at liberty to withdraw from the exercise.

Procedures

Provide a brief introduction to the format of the research study. The focus group you are invited to take part in will have at least 8 other household head from your particular unit. For example if you are from unit 03, expect to see other household heads from that unit. The discussion will be guided by Royd Moonga or Myself.

The group discussion will start with me or the appointed moderator Royd Moonga, considering they are many technical terms such as the name of the actual product ‘faecal briquettes’ we will try as much as possible to break down the terms to simpler words and in a language you can understand. The questions will be about what energy sources are currently being used in Kamanga and what are your views of being introduced to a new product made from pit latrine waste (faecal sludge) and what factors can guide the acceptance of such a product in your community. You are free to ask as many questions as possible, but keeping in mind the 1hour time period allocated for each focus group discussion. You do not have to share any knowledge that you are not comfortable sharing.

The discussion will take place at the council community hall, and no one else but the people who take part in the discussion and guide or myself will be present during this discussion. The entire discussion will be recorded using a digital recorder, but no-one will be identified by name on the tape. The recordings will be kept by myself. The information recorded is confidential, and no one else except myself will have access to the recordings.

Duration

The group discussion will be held once and will take about one hour. If you agree to take part you can stop participating at any point you feel, you cannot continue with the discussion.

Uses of information

You will be required to describe the potential uses for the personal information or survey, interview inter alias including any commercial uses if possible.

Risks

Explain and describe any risks that you anticipate or that are possible. The risks depend upon the nature and type of qualitative intervention, and should be, as usual, tailored to the specific issue and situation.

Uses of information

The information obtained from you will be used to help making decision by water/ sanitation companies or individual on how best they faecal briquettes can be received by you the traders and how big the market would be if the event that these briquettes replace charcoal.

Risks

The study will not be expected to expose any of the participants to any known risks. However there is likely to be loss of time during the interviews. If at any point the participant feels uncomfortable or unable to continue with the interview they can to withdraw from interview.

Benefits

Identifying a favourable potential market as dictated by participant response will propel the developing of a viable faecal briquette business, providing alternative energy source for the community and reducing dependence on wood fuels. The will also be improved sanitation and services delivery for the community due to the pursuit of obtaining a valuable resource from faecal sludge.

Reimbursements

We will provide a meal/some refreshments for you during or after the discussion, as a way to appreciate the time from your, that you have to sit and share your views.

Confidentiality

The information will not be shared with anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except I, Chisha Kaulungombe will have access to the information.

Sharing the Results

Nothing that you tell us today will be shared with anybody outside the research team, and nothing will be attributed to you by name. The knowledge that we get from this research will be shared with you and your community before it is made widely available to the public. Each participant will receive a summary of the results. There will also be small meetings in the community and these will be announced. Following the meetings, we will publish the results so that other interested people may learn from the research.

Right to Refuse or Withdraw

You do not have to take part in this research if you do not wish to do so, and choosing to participate will not affect you in any way. You may stop participating in the discussion at any time. At the end of the discussion, if you so wish we can go through points on which you need more information/clarity.

Who to Contact

If you have any questions, you are free to ask them now. If you wish to ask questions later, you may contact any me: Chisha Kaulungombe on 0969469028

This proposal has been reviewed and approved by NASREC, which is a committee whose task it is to make sure that research participants are protected from harm. If you wish to find about more about the NASREC, contact +260-211-290258/293937

Dr. Erasmus Mwanaumo, Chairperson, Natural and Applied Sciences, Research Ethics Committee,

University of Zambia

P O Box 32379

LUSAKA

OR

Professor. Henry M. Sichingabula Director, Directorate of Research and Graduate Studies

University of Zambia

P O Box 32379

LUSAKA

Approval to conduct this research has been provided by the University of Zambia, in accordance with its ethics review and approval procedures. Any person considering participation in this research project, or agreeing to participate, may raise any questions or issues with the researchers at any time.

In addition, if you are/ or any person is not satisfied with the response of researchers may raise ethics issues or concerns, and may make any complaints about this research project by contacting the NASREC on the address sated above.

All research participants are entitled to retain a copy of any Participant Information Form and/or Participant Consent Form relating to this research project.

Part II: Certificate of Informed Consent

I have been invited to participate in research about Market and acceptability of faecal sludge briquettes in Kamanga practices.

(This section is mandatory)

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my

satisfaction. I consent voluntarily to be a participant in this study.

Print Name of Participant_____

Signature of Participant _____

Date _____

Day/month/year

If illiterate [1]

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Print name of witness_____ **Thumb print of participant**

Signature of witness _____

Date _____

Day/month/year

If vulnerable or incapacitated like pregnant women, children, people with mental illness, people with disabilities, prisoners and minority groups form instance, the investigator must ensure that there is a well-educated and motivated surrogate or proxy decision maker. When comprehension is an issue the research plan should include means of testing the participants' understanding of the important information prior to enrollment.

[1] A literate witness must sign (if possible, this person should be selected by the participant and should have no connection to the research team). Participants who are illiterate should include their thumb print as well.

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands. I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

Print Name of Researcher/person taking the consent_____

Signature of Researcher /person taking the consent_____

Date _____

Day/month/year

CONTACTS FOR QUESTIONS (Names, addresses and phone numbers of the following):

1. **Principal Investigator (Must be a local person and a Zambian).**

Names:

Phone:

E mail:

Physical address:

NASREC FORM 1b

THE UNIVERSITY OF ZAMBIA

DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

NATURAL AND APPLIED SCIENCES RESEARCH ETHICS COMMITTEE

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Lusaka, Zambia

E-mail drgs@unza.zm

PARTICIPANT INFORMATION SHEET

Informed Consent Form for Charcoal traders in Kamanga compound, who will be interviewed in the research titled '' market and acceptability of faecal sludge briquettes in Kamanga compound, Lusaka.''

Chisha Kaulungombe,

University of Zambia (UNZA),

Student.

This Informed Consent Form has two parts:

- **Information Sheet (to share information about the study with you)**
- **Certificate of Consent (for signatures if you choose to participate)**

You will be given a copy of the full Informed Consent Form

Part I: Information Sheet

Introduction

My name is Chisha Kaulungombe, I am a student at the University of Zambia studying a Master of Science in Sanitation. I hereby request you to be a participant in the earlier mentioned study. The study is focused on assessing the market and acceptability of sludge briquettes in Kamanga compound, Lusaka. Before I explain more on the purpose of this study, I would like to let you know that your participation in this study is entirely voluntary and you are not under any responsibility to take part in it. A consent form will be provided for you to sign to show your agreement to participate in this study. If at any point there are words or concepts you do not understand please stop me and I will clarify to the best of my ability.

Purpose of the research

Filled up pit latrines is a common issue in your community. They are companies/organizations that are looking for ways to improve sanitation service delivery, which includes the emptying of pit latrine up to the point where the waste from these pits can be safely disposed of. One of the upcoming ways which has been identified is by turning the waste found in the pit latrines into products of value which people can use in their day to day lives. One of these products that can be made from pit latrine waste is faecal briquettes. This product can be likened to energy sources such as charcoal. It is from this study we will learn if the faecal briquettes are a product that can do well on the market, if it is a product you as an individual would use. From the information you will give, also qualities that will make the product more suitable for your acceptance and use of the product will be identified.

Type of Research Intervention

This research will involve your participation, through a questionnaire that will be administered to you, in a language you are comfortable with, by the principal investigator or a research assistant. The interview will take about 30-40minutes.

Participant Selection

You are being invited to take part in this research because it is felt that your beneficial position as a charcoal trader can help estimate the size of the market faecal briquettes can potentially have if they are to replace charcoal

Voluntary Participation

Your Participation in this research is completely voluntary and confidential .If at any point during the interviews you feel uncomfortable or unable to continue, you will be at liberty to withdraw from the exercise.

Procedures

You are being asked to help the interview gather information and learn more about the charcoal market size in Kamanga compound, therefore you are invited to take part in this research project .If you accept you will be asked to talk about your experience as a charcoal trader in connection to sales of the product, challenges faced and willingness to sale a product like charcoal but made from pit latrine waste (faecal sludge), this will be done through asking you a series of questions in a questionnaire.

With the use of the questionnaire, I Chisha Kaulungombe will ask you some question at the place you are stationed as a charcoal trader, so to not take you away from your customers. I will note down all your responses, on the questionnaire I will mark with your specific participant number. If need be the interview can be paused for you to attend to your clients, but the interview should not take more than 30minutes of your time. If you do not wish to answer any of the questions during the interview, you are free to say so and I will move on to the next question. No one else but the interviewer will be present unless you would like someone else to be there. The information that is taken down by the interviewer is confidential, and no one else except I Chisha Kaulungombe will have access to the information documented during your interview.

Duration

If you decide to take part in the study, the interview will take no more than 30minutes. If there is need to attend to customers during our short interview, you are free to do so. Questions that do not wish to answer will not be responded and the interview can be stopped at any point if you so wish. If you have any questions, you are free to ask.

Uses of information

The information obtained from you will be used to help making decision by water/ sanitation companies or individual on how best they faecal briquettes can be received by you the traders and how big the market would be if the event that these briquettes replace charcoal.

Risks

The study will not be expected to expose any of the participants to any known risks. However there is likely to be loss of time during the interviews. If at any point the

participant feels uncomfortable or unable to continue with the interview they can to withdraw from interview.

Benefits

Identifying a favourable potential market as dictated by participant response will propel the developing of a viable faecal briquette business, providing alternative energy source for the community and reducing dependence on wood fuels. The will also be improved sanitation and services delivery for the community due to the pursuit of obtaining a valuable resource from faecal sludge.

Reimbursements

As a result of your participation, we will purchase some charcoal from you for allowing us time to ask you questions for the research.

Confidentiality

The information will not be shared with anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except I, Chisha Kaulungombe will have access to the information.

Sharing the Results

Nothing that you tell us today will be shared with anybody outside the research team, and nothing will be attributed to you by name. The knowledge that we get from this research

will be shared with you and your community before it is made widely available to the public. Each participant will receive a summary of the results. There will also be small meetings in the community and these will be announced. Following the meetings, we will publish the results so that other interested people may learn from the research.

Right to Refuse or Withdraw

You do not have to take part in this research if you do not wish to do so, and choosing to participate will not affect your selling of charcoal in any way. You may stop participating in the interview at any time that you wish without your sales being affected. At the end of the interview, if you so wish we can go through your responses and make any addition or subtraction if need be.

Who to Contact

If you have any questions, you are free to ask them now. If you wish to ask questions later, you may contact any me: Chisha Kaulungombe on 0969469028

This proposal has been reviewed and approved by NASREC, which is a committee whose task it is to make sure that research participants are protected from harm. If you wish to find about more about the NASREC, contact +260-211-290258/293937

Dr. Erasmus Mwanaumo, Chairperson, Natural and Applied Sciences, Research Ethics Committee,

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LUSAKA

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"Approval to conduct this research has been provided by the University of Zambia, in accordance with its ethics review and approval procedures. Any person considering participation in this research project, or agreeing to participate, may raise any questions or issues with the researchers at any time.

In addition, if you are/ or any person is not satisfied with the response of researchers may raise ethics issues or concerns, and may make any complaints about this research project by contacting the NASREC on the address sated above.

All research participants are entitled to retain a copy of any Participant Information Form and/or Participant Consent Form relating to this research project."

Part II: Certificate of Informed Consent

I have been invited to participate in research about Market and acceptability of faecal sludge briquettes in Kamanga practices.

(This section is mandatory)

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study.

Print Name of Participant_____

Signature of Participant _____

Date _____

Day/month/year

If illiterate [2]

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Print name of witness_____ **Thumb print of participant**

Signature of witness _____

Date _____

[2] A literate witness must sign (if possible, this person should be selected by the participant and should have no connection to the research team). Participants who are illiterate should include their thumb print as well.

Day/month/year

Statement by the researcher/person taking consent:

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands.

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

Print Name of Researcher/person taking the consent_____

Signature of Researcher /person taking the consent_____

Date _____

Day/month/year

CONTACTS FOR QUESTIONS (Names, addresses and phone numbers of the following):

1. **Principal Investigator**

Names: Chisha Kaulungombe

Phone: 0969469028

E mail: chishakayz@gmail.com

Physical address: 255 gclose Avondale, Lusaka.

Appendix 2: DATA COLLECTION TOOL (QUESTIONNAIRE)

Questionnaire number ……

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INTERVIEW SCHEDULE FOR CHARCOAL TRADERS IN KAMANGA COMPOUND

Date of interview…….

Name of interviewer…….....

INSTRUCTIONS TO INTERVIEWER

1. Introduce yourself to the respondent

2. Explain the purpose of the study

3. Assure the respondents of confidentiality so that respondents are free to give accurate information to the best of their knowledge

4. Do not write respondents name on the questionnaire

5. Ask all questions in the order they are arranged.

6. For questions with responses, tick (√) appropriate responses in the boxes provided

7. For questions without alternatives, write responses clearly on the spaces provided

8. Respondents should be free to ask questions during interview

9. Do not write in the spaces marked "For Official Use Only" this is for coding.

10. Thank the respondent at the end of each interview

A) DEMOGRAPHICS:

Gender

1. Male ☐ 2. Female ☐

2. What is your age? .....

1) <40 years ☐ 2) 40-50 years ☐ 3) >50 years ☐

2. What is your marital status? .....

1) Single ☐ 2) Married ☐ 3) separated ☐ 4) Divorced ☐

3. What is your education level? .....

1) Primary ☐ 2) secondary ☐ 3) university/tertiary ☐

4. What is your religion? .....

1) Christian ☐ 2) Muslim ☐ 3) Hindu ☐ 4) other (specify) ☐

B) MARKET GROWTH

9. What quantities do you sale your charcoal in plastics? (Select all appropriate answers) ☐

1) 1.5kg (k5) 2) 2.5kg (k10) ☐

10. What quantities do you sale your charcoal in sacks? (Select all appropriate answers) ☐

1) 25kg ☐ 2) 50kg 3) 90kg ☐

11. Have you been selling charcoal since 2019?

1) Yes ☐ 2) No ☐

If yes; proceed with question (12)

12. How many bags/plastics were you selling daily in 2019? (Please specify for trader who sales both e.g. used to sale 5; 1.5kg plastics, 3; 50kg sacks)……

……

……

……

……
……

13. How many bags/plastics were you selling daily in 2020? (Please specify for traders who sales both e.g. used to sale 5; 1.5kg plastics, 3; 50kg sacks)……
……
……
……
……
……
…….

14. How many bags/plastics are you selling daily in 2021? (Please specify for trader who sales both e.g. used to sale 5; 1.5kg plastics, 3; 50kg sacks)……

……
……
……
……
……
……
……..

If No;

15. Have you been selling since 2020?.....

1) Yes ☐ 2) No ☐

If yes proceed with question (16)

16. How many bags/plastics were you selling daily in 2020? (Please specify for trader who sales both e.g. used to sale 5; 1.5kg plastics, 3; 50kg sacks)……

17. How many bags/plastics are you selling daily in 2021? (Please specify for trader who sales both e.g. used to sale 5; 1.5kg plastics, 3; 50kg sacks)……

If No;

18. How many bags/plastics are you selling daily in 2021? (Please specify for trader who sales both e.g. used to sale 5; 1.5kg plastics, 3; 50kg sacks)……
……
……
……
……

19. When do you sell this product the most?.....

(1) Rainy season ☐ (2) cold season ☐ (3) hot season ☐ (4) same throughout the year ☐

20. Is there a constant supply of your product from the source?.....

(1) Yes ☐ (2) no ☐

21. If not, why does the supply vary throughout the year?.....

C) MARKET VOLUME:

For charcoal traders who had sells from the year 2019(Please specify for trader who sales both e.g. used to sale 1.5kg plastics at 3, 50kg sacks at k100)

22. How much did you sell the plastic/bags of charcoal in 2019?.....

23. How much did you sell the plastics/bags of charcoal in 2020?.....

24. How much are you selling the plastics/bags of charcoal now, in 2021?.....

For charcoal traders who had sells from 2020(Please specify for trader who sales both e.g. used to sale 1.5kg plastics at 3, 50kg sacks at k100)

25. How much did you sell the plastics/bags of charcoal in 2020?.....

26. How much are you selling the plastics/bags of charcoal now, in 2021?.....

For charcoal traders who had sells from 2021(Please specify for trader who sales both e.g. used to sale 1.5kg plastics at 3, 50kg sacks at k100)

27. How much are you selling the plastics/bags of charcoal now, in 2021?.....

D) ACCEPTABILITY OF FACECAL SLUDGE BRIQUETTES

28. Do you know what faecal sludge is?

1) Yes ☐ 2) no ☐

29. If Yes, Do you know any products made from faecal sludge? .....

1) Yes 2) No

30. Would you sale fuel (faecal briquettes) made from faecal sludge?

1) Yes ☐ 2) no ☐

31. If yes, why (specify)……
…

32. If no, why not (specify)……

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Focus group discussion guide:

Meeting Data	**participant data**
Date:	**no. participants scheduled:**
Start time:	**no. participants attended:**
Meeting location:	**no. male:**
Meeting conductors:	**no. female:**
End time:	**(attendance register attached)**

THEME	QUESTIONS
INTRODUCTION **(welcome participants and Familiarising group with faecal sludge)**	1. Do you know what faecal sludge is and where it comes from? 2. If yes, what products are made from faecal sludge? 3. Do you use any products made from faecal sludge?
Substitute product	4. What do you use for cooking or heating? 5. Why do you prefer to use that fuel source? (exhaust all possible reasons)
Market volume	6. How many units of that fuel do you buy daily? 7. How much do those units cost? 8. Is that fuel easily obtainable throughout the year?
BRIQUETTE MAKING PROCESS	Briefly explain the briquette making process
Acceptability factors	9. Would you use a fuel made out of faecal sludge? 10. If no, why wouldn't you use faecal sludge briquettes (exhaust all possible reasons) 11. If yes, what would you use it for (cooking meals, boiling water etc) 12. What qualities of faecal briquettes would make it more marketable as a product to you?(e.g. constant supply, availability, smoke production, cost, portability, burning time etc)
CONCLUSION	Closing remarks, Thank participants for their participation

ATTENDANCE REGISTER:

participant id	age	religion	marital status	education level	Occupation

THE UNIVERSITY OF ZAMBIA

DIRECTORATE OF RESEARCH AND GRADUATE STUDIES
HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE

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Fax: +260-211-290258/293937
Lusaka, Zambia
E-mail drgs@unza.zm

APPROVAL OF STUDY

23rd August, 2020.

REF NO.NASREC-2020-AUG-001

Chisha Kaulungombe,
The University of Zambia
School of Engineering,
P.O. Box 32379.
LUSAKA.

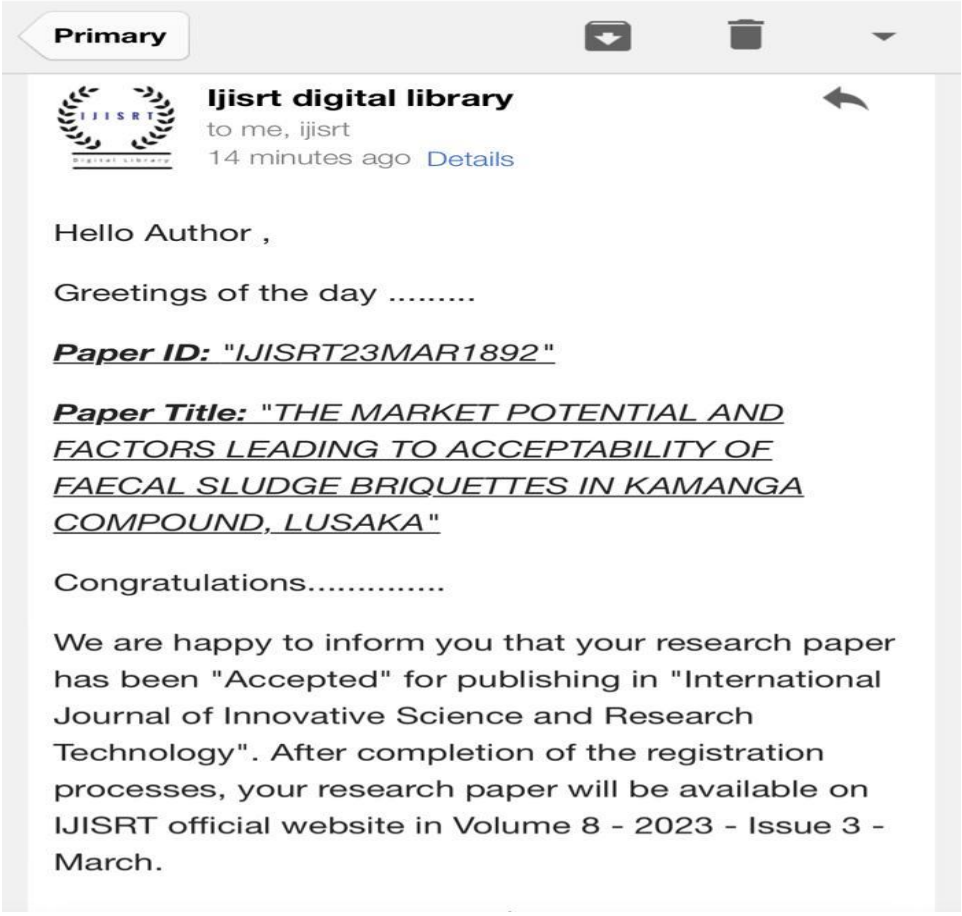
Dear Ms. Kaulungombe,

RE: "MARKET AND ACCEPTABILITY OF FAECAL SLUDGE BRIQUETTES IN KAMANGA COMPOUND, LUSAKA"

Reference is made to your protocol dated as captioned above. NASREC resolved to approve this study and your participation as Principal Investigator for a period of one year.

Review Type	**Ordinary Review**	**Approval No. NASREC-2021-AUG-001**
Approval and Expiry Date	Approval Date: 23rd August, 2021	Expiry Date: 22nd August, 2022
Protocol Version and Date	Version - Nil.	22nd August, 2022
Information Sheet, Consent Forms and Dates	• English.	To be provided
Consent form ID and Date	Version - Nil	To be provided
Recruitment Materials	Nil	Nil
Other Study Documents	Questionnaire.	

Proof of intent to publish journal article



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Greetings of the day .....

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Paper Title: *"THE MARKET POTENTIAL AND FACTORS LEADING TO ACCEPTABILITY OF FAECAL SLUDGE BRIQUETTES IN KAMANGA COMPOUND, LUSAKA"*

Congratulations.....

We are happy to inform you that your research paper has been "Accepted" for publishing in "International Journal of Innovative Science and Research Technology". After completion of the registration processes, your research paper will be available on IJISRT official website in Volume 8 - 2023 - Issue 3 - March.