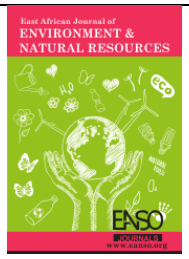


East African Journal of Environment and Natural Resources
eajenr.eanso.org
Volume 7, Issue 1, 2024
Print ISSN: 2707-4234 | Online ISSN: 2707-4242
Title DOI: https://doi.org/10.37284/2707-4242

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Factors Influencing Management of Human Excrement through Biogas Technology in Mukuru Kwa Njenga Slums, Nairobi City County Kenya

Lilian Munyigi[1*] *& Dr. Daniel Mang'uriu, PhD*[1]

[1] Kenyatta University, P. O. Box 43844-00100, Nairobi, Kenya.
[*] Correspondence ORCID: https://orcid.org/0009-000-9832-78991; Email: munyigilily@gmail.com

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

Date Published: *12 May 2024*

Keywords: *Biogas, Sustainable Sanitation, Human Health, Waterborne Diseases, Bio-Digesters, Renewable Energy, Human Excrement.*

ABSTRACT

One of the factors influencing the achievement of sustainable sanitation is the proper disposal of human excrement. The problem is most prevalent in informal settlements, where sewerage systems are rare. One of the approaches considered sustainable is the conversion of human excrement into renewable energy via biogas technology. The purpose of the study, which was guided by Roger's theory of innovation diffusion, was to investigate the key factors that influence human excrement management through biogas technology. Mukuru Kwa Njenga slums were chosen as a study area. A sample of 100 people was selected using systematic random sampling. Data were analysed using a social science statistics package. Multiple linear regression was used to determine demographic factors that influence technology adoption. The Chi-square test was used to examine the relationship between various variables. Tables and charts were used to present the data. The study revealed that gender (p=.001) and education level (p=.000) significantly influence the use of biogas technology in the management of human excrement. Technology failure ((χ2= 10.301, p=.036) and lack of technical skills ((χ2= 7.518, p=.128) have no significant effect on the technology adoption rate. Cultural beliefs (χ2= 23.665, P=.000) have a significant effect on the use of biogas produced from human excrement. The ability of technology to prevent overflowing of faecal matter during heavy rainfall (χ2= 23.937, P=.000) and the prevention of odour from sanitation facilities (χ2=17.983, p= .001) has encouraged many residents to use the technology. The study concludes that technical and socio-economic factors, as well as its relative advantage over other excrement disposal methods, influence its adoption rate.

APA CITATION

Munyigi, L. & Mang'uriu, D. (2024). Factors Influencing Management of Human Excrement through Biogas Technology in Mukuru Kwa Njenga Slums, Nairobi City County Kenya. *East African Journal of Environment and Natural Resources*, *7*(1), 141-156. https://doi.org/10.37284/eajenr.7.1.1918.

CHICAGO CITATION

Munyigi, Lilian and Daniel Mang'uriu. 2024. "Factors Influencing Management of Human Excrement through Biogas Technology in Mukuru Kwa Njenga Slums, Nairobi City County Kenya". *East African Journal of Environment and Natural Resources* 7 (1), 141-156. https://doi.org/10.37284/eajenr.7.1.1918.

HARVARD CITATION

Munyigi, L. & Mang'uriu, D. (2024) "Factors Influencing Management of Human Excrement through Biogas Technology in Mukuru Kwa Njenga Slums, Nairobi City County Kenya", *East African Journal of Environment and Natural Resources*, 7 (1), pp. 141-156. doi: 10.37284/eajenr.7.1.1918.

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

IEEE CITATION

L., Munyigi & D., Mang'uriu. "Factors Influencing Management of Human Excrement through Biogas Technology in Mukuru Kwa Njenga Slums, Nairobi City County Kenya", *EAJENR*, vol. 7, no. 1, pp. 141-156, May. 2024. doi: 10.37284/eajenr.7.1.1918

MLA CITATION

Munyigi Lilian & Daniel Mang'uriu. "Factors Influencing Management of Human Excrement through Biogas Technology in Mukuru Kwa Njenga Slums, Nairobi City County Kenya". *East African Journal of Environment and Natural Resources*, Vol. 7, no. 1, May 2024, pp. 141-156, doi:10.37284/eajenr.7.1.1918.

INTRODUCTION

One of the most important aspects of achieving sustainable sanitation is the proper management of human excrement. This is because of its negative impact on human health. There are about 3.6 billion people around the globe who lack access to properly operating sanitation systems (UNICEF, 2023). According to a World Health Organization report, more than half of the world's population, 4.2 billion people, rely on sanitation facilities that leave human excreta untreated, posing a threat to human and environmental health. Six hundred and seventy-three (673) million people lack access to toilets and defecate in the open, while approximately 698 million school-aged children do not have access to basic sanitation (World Health Organization, 2020).

One of the issues with the informal settlement is the risk to public health and the environment, which is mostly due to the lack of suitable human excrement disposal facilities (Kasala *et al.,* 2016). Most slums are vulnerable to environmental risks such as flooding due to their geographical location, such as Mukuru Slums. The lack of coordination in the home development strategy exacerbates the problem. The lack of basic sanitation facilities and a sewerage system, as well as improper waste disposal and drainage channels, have all led to the current state of poor sanitation in informal communities. Notably, there are issues with the onsite sanitation that is frequently employed in informal settlements to reduce the spread of diarrhoea-related illnesses (Colombo *et al*., 2023)

One of the promising solutions to human excrement disposal is to view it as a resource and not a waste. A report by Schuster-Wallace *et al.*, 2015, reveals a potential opportunity to utilize human excrement as a source of energy. Such technology can bear positive fruit, especially in informal settlements where sewerage services rarely exist. Since it is combustible, human excrement contains a thermal value. Josue *et al.*, 2023 research concludes that biogas reactors slurry compost offers positive nutrient values and can be used to replace inorganic fertilizers.

Conversion of human excrement through anaerobic digestion by the use of biogas digesters can satisfy the needs of locals such as lighting, cooking, and heating, in addition to solving sanitation problems associated with poor disposal of human excrement (Josue *et al.,* 2023). Anaerobic digestion offers a simple and effective way of dealing with organic waste, including human waste (Donacho *et al*., 2023). Despite the potential energy of human excrement, it has been given less value and the benefits are undervalued.

Climate change concerns and traditional energy supply challenges have created an interest in renewable energy sources (Amoah *et al*., 2020). Sustainable Development Goal number 7 calls for access to modern energy that is sustainable, reliable, and affordable for all by 2030 (General Assembly, 2015). As a result, the consumption of renewable energy has increased. Renewable energy sources will contribute to approximately 35% of the global energy supply by the end of 2030 (Amoah *et al.,* 2020).

While the conversion of human excrement is seen as a sustainable approach to solving sanitation issues in informal settlements, its contribution to solving existing sanitation challenges has not been fully explored. With proper control measures, we can be able to protect human health and the environment while at the same time earning economic gain from technology. It was, therefore, important to carry out this research to explore the factors that influence the use of biogas technology in solving the sanitation challenges in informal settlements associated with poor disposal of

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

human excrement. It also involved testing hypotheses which were; H_a sociodemographic factors have a significant effect on the use of biogas technology in the management of human excrement, H_a Technical factors have a significant effect on the use of biogas technology to manage human excrement, H_a cultural beliefs have a significant effect on the use of biogas from human excrement

EMPIRICAL REVIEW

Obstacles to Using Biogas Technology for Human Excrement Treatment

One of the biggest technical challenges to biogas energy extraction is infrastructural impediments. Access to biogas refuelling stations, for example, is limited in developed countries. This makes promoting biogas-powered vehicles difficult, limiting the growth of biogas technology (Nevzorora & Kutcherov, 2019). The availability of feedstock for bio-digesters based on human faeces is restricted. As a result, they're only used in densely crowded regions like jails, educational facilities, and informal settlements. This is due to the fact that human faeces from a single home are insufficient to generate biogas (Onojo *et al.*, 2013).

Concerns have been raised about the safety of using energy obtained from human faeces, particularly for cooking. Market demonstrations may be used to reassure the community that fuels made from human waste do not affect the taste and quality of food (Schuster-Wallace *et al*., 2015). The use of fuels derived from human waste necessitates the removal of long-held societal and cultural stigmas linked with the disposal of human excrement. The upscaling of bio-centres in Kibera slums has been hampered by some residents' refusal to accept meals prepared with energy derived from human waste (Wamuchiru & Moulaert, 2017. According to Francois *et al.*, 2023, the acceptance of biogas produced from human excreta varies regarding its origin, with more people preferring to use biogas produced from their excreta.

Lack of proper maintenance and lack of quality materials for construction are among the factors that limit the use of biogas technology (Jadhav *et al.,* 2015). Technical problems such as pipe blockages have been reported. This is due to poor drainage on the construction sites and also increased sludge pressure, which sometimes exceeds the capacity of the bio-digester. Disposing of non-biodegradable materials also results in blockage problems (Wamuchiru & Moulaert, 2017). According to the European Biofuel Technology Platform (2016), biogas-based engines are not well-developed enough to properly deal with technical issues resulting from the use of technology.

THEORETICAL REVIEW

Innovation Diffusion Theory

Roger's innovation diffusion theory guided the research. The five elements considered influential to the rate at which an innovation is adopted under this theory provided a framework for the researcher to investigate the factors that influence the use of biogas technology in managing human excrement.

An idea must be novel to be considered innovative. The characteristics of innovation will determine how quickly the technology is adopted. The benefits and disadvantages of technology, complexity, adaptability, observability, and compatibility all have a significant impact on the rate at which it will be adopted. The benefits of biogas technology over other available technologies, such as sewerage systems, pit latrines, pour-flush toilets, and ecological sanitation, influence its rate of adoption (Uhunamure *et al.,* 2021).

An innovation that is well aligned with a given society's norms and values will face little resistance and thus be adopted quickly. Communication is essential in technology adoption. Through information sharing, people become aware of the existence of innovation. Communication can influence people's perceptions and attitudes (Albronda *et al.,* 2021).

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

Human behaviour and technology adoption are profoundly influenced by social influence (Graf-Vlachy *et al.,* 2018). Socio-economic statistics, culture, religion, social support, education, and age are some of the social factors that influence the adoption of technology. The social structure acts as a barrier to the dissemination of innovation.

Knowledge Gap

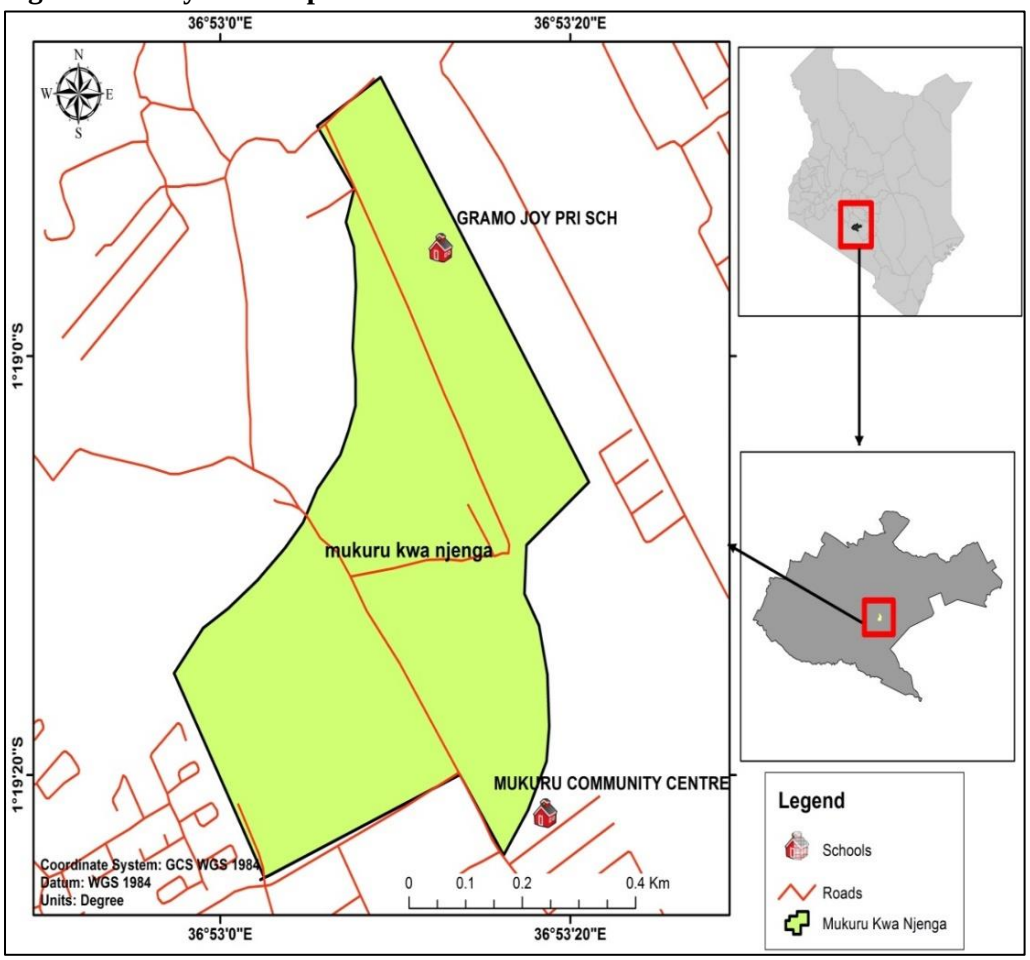
Although much study has been done on the application of biogas technology, most researchers have focused on the conversion of animal dung into energy, such as Wamuyu (2014), Wachera (2009), Momanyi et al.,2019, Wawa (2012), and Mwakaje (2012). However, the use of human excrement as an energy source and its potential to remedy existing sanitation problems has received little attention. Although studies have shown that biogas technology has the potential to treat human excrement and improve sanitation while also providing energy, there is little literature on the technology's suitability and challenges in solving sanitation issues in informal settlements where sewerage systems are rare.

MATERIALS AND METHODS

Study Area

The study was carried out in the Mukuru Kwa Njenga slum, which is one of the major informal settlements within Nairobi City County in Kenya. According to the Kenya National Bureau of Statistics 2019, the area has a population of 242,941 individuals, comprising 97,890 households. It is situated near one of Nairobi's major waterways. Due to the steep slope within the Nairobi River, the area is prone to flooding during heavy rain seasons (Wanjiru *et al.,* 2017). It lies within longitudes of 1019’20” S, 1^{0}19’0” S, and latitudes of 36^{0}53’0” E, 36^{0}53’20” E.

Figure 1: Study area map



Source: Researcher, 2024

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

Sampling Procedure and Processing

The study was focused on residents of Mukuru Kwa Njenga slums. The respondents mainly involved residential households headed from all villages within Mukuru Kwa Njenga slums. They included both users and non-users of biogas technology. Households that depend on sanitation facilities connected to bio-digesters as the main human excrement disposal method and are also reported to have used biogas energy were classified as users. Those who depend on other human excrement disposal methods and are reported to have not used biogas energy were classified as non-users. A sample of 100 households, determined by the use of the Nassiuma formula (2000), was interviewed.

$$n = \frac{NCv^2}{Cv^2+N-1)e^2}$$

Where n- sample size; Cv- coefficient of variation (0.5); e- Tolerance level (0.05 at 95% confidence level)

Therefore $n = \frac{97{,}890(0.5)^2}{0.5^2+(97{,}890-1)0.05^2} =$ 100 households

The required number of respondents was chosen via a systematic random sample. The sample population was drawn from all eight zones namely; Moto Moto, Wape wape, Riara, Sisal, Mililmani, Zone 48, Vietnam and Mukuru Community Center. The interviewed households were the ones present during survey and those who were willing to participate. Technology users comprised households who depends on bio-digesters connected sanitation facilities as their primary sanitation facilities and who reported to have used gas produced from human excrement. Questionnaires were used to collect data.

The Statistical Package for Social Sciences (SPSS) was used to analyse quantitative data collected through questionnaires. Multiple linear regression was performed to evaluate demographic factors that have a significant impact on technology use. Below is the regression model that was used.

$$Y= \beta_0+ \beta_1X_1+ \beta_2X_2+ \beta_3X_3+\beta_4X_4+ \beta_5X_5+ \varepsilon$$

Where: β_0= Constant, β1 = independent variable coefficient, X_1= Gender, X_2= Age, X3 = household size, X4 = educational level, X5 = income level, ε= error term

The median was used as a measure of central tendency, and the chi-square was used to test for relationships between different variables. Since Likert scale questionnaires produce ordinal responses, the median was used as a measure of central tendency instead of means, which are often of less value unless data are normally distributed (Sullivan, 2013). Non-parametric tests, including chi-square, are considered appropriate in this study instead of parametric tests since the Likert scale falls within the ordinal level of measurements. The findings were summarized in frequencies and percentages and then represented in the form of tables and charts.

RESULTS AND DISCUSSION

Socio-Demographic Factors

These are factors that describe the characteristics of a population. According to the results in *Table 1*, among the users, 68% were female, while 32% were male. Since most of the women are engaged in cooking and taking care of their siblings, including their sanitation needs, most of them find it necessary to use sanitation facilities connected to biodigesters to satisfy their needs. This is because they are clean and safe to be used by all age groups, including children. Due to gender-related differences, women and girls are affected by sanitation issues. Access to clean and safe sanitation services is critical to their sexual and reproductive health. The need for proper sanitation becomes even more critical during menstruation, pregnancy, and postnatal stages (Vellema *et al.,* 2014). Additionally, some of them find it necessary to use the biogas for cooking. Some of the women in the Mukuru Kwa Njenga slums engaged in selling ready-made foods, such as cereals, use biogas energy.

Fifty-two (52%) of the people aged between 21 and 30 years and 32 percent of those aged between

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

31 and 40 years were found to use the technology. This can be explained in terms of the willingness of the majority of the young generation to embrace new technology. Results in *Table 1* further show the relationship between education level and use of technology, with a high percentage of respondents who had attained a Kenya certificate of secondary education (62%) being users. Understanding the need for proper sanitation, which includes the safer disposal of human excreta, encourages residents who are educated to embrace the technology. Furthermore, education has an impact on cultural belief.

Table 1: Demographic factors influencing the management of human excrement through biogas technology

Characteristic		Users		Non-users	
		Frequency	%	Frequency	%
Gender	Male	16	32	26	52
	Female	34	68	24	48
	Total	50	100	50	100
Age	21-30 years	26	52	23	46
	31-40 years	16	32	8	16
	41-50 years	5	10	15	30
	51-60 years	2	4	3	6
	61-70 years	1	2	1	2
	Total	50	100	50	100
Household size	Less than 3	13	26	24	48
	3-6	28	56	19	38
	7-10	9	18	6	12
	More than 10	0	0	1	2
	Total	50	100	50	100
Education level	Non-formal	1	2	4	8
	Primary level	7	14	22	44
	Secondary level	32	64	21	42
	Tertiary level	10	20	3	6
	Total	50	100	50	100
Income level (KSH)	Less than 21000	31	62	26	52
	21000-30000	11	22	19	38
	31000-4000	7	14	4	8
	More than 40000	1	2	1	2
	Total	50	100	50	100

Socio-economic Factors that Have a Significant Influence on Biogas Technology Adoption

The researchers employed multiple linear regression to identify parameters that have a substantial impact on the usage of biogas technology in the management of human waste. Multiple linear regression is used to determine the relationship between one dependent variable and multiple predictors or independent variables. The use of technology was chosen as the dependent variable, whereas gender, age, family size, education level, and income level were chosen as the independent factors. *Tables 2, 3,* and *4* show the results.

Table 2: Model summary

Mode	R	R Square	Adjusted R Square	Std Error Estimate
1	.532[a]	.283	.245	.437

a. Predictor (constant), income level, household size, age, gender, education level

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

Table 3: Variance analysis

Model		Sum of Squares	DF	Mean Square	F	Sig.
1	Regression	7.084	5	1.417	7.434	0.000[b]
	Residual	17.916	94	.191		
	Total	25.000	99			

a. Dependent Variable: User
b. Predictors: (Constant), income level, household size, age, gender, education level

According to the results in *Table 4* the F statistic was 7.4 F at a 5% significant level (p=0.00). This means that the model used is suitable for predicting the effects of factors affecting the use of biogas technology.

Table 4: Demographic factors influencing the use of biogas technology in the management of human excrement

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std Error	Beta		
1	(constant)	2.687	.262		10.245	.000
	Gender	.315	.089	.315	3.547	.001
	Age	.081	.043	.167	1.899	.061
	Household size	-070	.061	-.101	-1.143	.256
	Education level	.264	.060	.392	4.365	.000
	Income level	-.004	.059	-.007	-0.76	.940

Dependent variable: user

Table 4 shows the factors that significantly influence the use of biogas technology in the management of human excrement. Only gender (B = 0.315; p = 0.01) and education level (B = 0.392; p = 0.001) were found to be significant. The findings thus supported the hypothesis that sociodemographic factors such as gender and education level have a significant effect on the use of biogas technology in the management of human excrement. The other factors, household size, age, and income level, have no significant effect on technology use. The impact of poor sanitation on the sexual and reproductive health of women explains why, in comparison to men, women are more conscious of their choice of sanitation facilities. These results differ from Mumbi's 2017 research on human waste biogas technology, which shows that gender does not influence the use of technology. However, it concurs with Uhunamure *et al.,* 2019 findings, which indicate that there is a positive correlation between gender and biogas technology adoption. Men and women do not necessarily benefit equally from the adoption of technology; hence, they do not adopt it at the same rate. Because men and women have different reproductive responsibilities, their technological needs are also different. (Ikonyi, 2018).

The findings support Momanyi's (2019) conclusion that low biogas uptake among less educated respondents is related to their inability to internalize and grasp technical terms commonly used in training. According to Erick *et al.* (2018), education aids in the improvement of beliefs and habits, resulting in a favourable mental attitude toward the acceptance of new technologies. They also mentioned that education improves a person's ability to learn information, allowing them to be more aware of emerging technology. According to Uhunamure *et al. (*2019), there is an increased possibility of roughly 2% for heads of households with formal education to use technology. This is because educated people are more aware of the negative consequences of poor management of human excrement and thus more likely to try new technologies that can help them have a clean and conducive environment (Erick *et al.,* 2018).

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

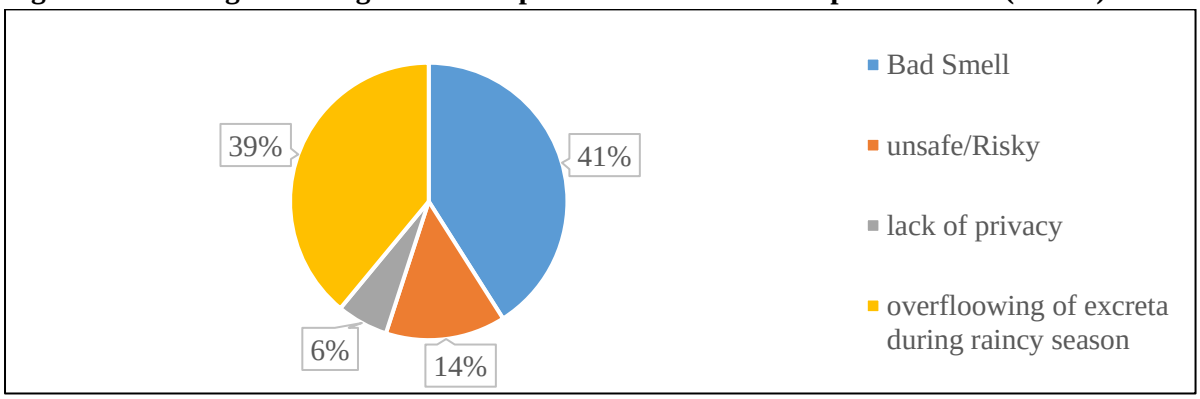
Biogas Technology as an Alternative to Human Excrement Disposal Problems

The degree to which an innovation is seen as superior to other ideas or innovations can be used to characterize its relative benefit, as per Roger's diffusion theory. This section looks at how the adoption rate of biogas technology is affected and whether it can address sanitation issues caused by the usage of unsustainable methods for disposing of human excrement. Apart from generating clean energy for cooking purposes, biogas technology is regarded as a sustainable solution for treating human excrement.

Challenges of Using Traditional Human Excrement Disposal Methods

The respondents were asked to state the main challenges of using traditional waste disposal methods. Forty-one percent (41%) reported that a bad smell is the main challenge of this kind of sanitation facility (*Figure 2*). Some explain that the bad smell from pit latrines is so awful that one prefers to defecate in the open. The results support Libby's (2018) findings, which show that smells and insects are the main disadvantages of using basic pit latrines. Thirty-nine percent (39%) of the respondents reported that the overflowing of excreta during the rainy season was the main challenge. Usually, most pit latrines and pour-flush toilets are not connected to sewer lines. The use of exhausters is limited by overcrowded house structures and a lack of passable roads. Some depend on the physical removal of human excrement, which is expensive and not safe. This has led to an increased number of neglected pit latrines, which overflow during the rainy season. This causes contamination of underground and surface water and, hence, the outbreak of water-borne diseases. Bad smells attract flies, which are transmitters of germs. This further leads to regular outbreaks of waterborne diseases in the area.

Figure 2: Challenges of using traditional pit latrines as a waste disposal method (N=100)



Relative Advantages of Managing Human Excrement through Biogas Technology

To assess if managing human excrement through biogas technology has an advantage over traditional methods of human disposal, the respondents were required to give their views on a scale of 1–5. 1-strongly agree, 2-agree, 3-neither agree nor disagree, 4-disagree, and 5-strongly disagree. Both technology users and non-users were interviewed. N=100.

The Use of Biogas Technology and the Elimination of Bad Odors from Sanitation Facilities

One of the major barriers to achieving sustainable sanitation is the bad odour from human excrement, which is associated with aesthetic, moral, social, and disease-related concerns. Despite all these concerns, smell has been overlooked in sanitation promotion (Rheinlander *et al.*, 2013). Bad odour attracts flies, which are responsible for the transmission of disease-causing microorganisms.

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

Table 5: The use of biogas technology and the elimination of bad odours from sanitation facilities

Prevents foul smell	Users		Non-users		Total		M	χ^2	P Value
	N	%	N	%	N	%			
SA	16	32	5	10	21	21	3.0	17.983	.001
A	20	40	8	16	28	28			
ND	4	8	9	18	13	13			
D	7	14	21	42	28	28			
SD	3	6	7	14	10	10			
Total	50	100	50	100	100	100			

SA-strongly agree, A-agree, ND-neither agree nor disagree, D-disagree, SD- strongly-disagree, median, χ2 – Chi-square

Results in *Table 5* indicate that most of the respondents were neutral about the effect of using biogas technology on reducing foul smells from sanitation facilities (median, 3). From the results, however, it is noted that 72% of the technology users agreed that the utilization of technology prevents foul smells from the sanitation facilities, with only 26% of non-users agreeing. During field studies, it was noted that most of the technology users consist of households living within the bio-centres. Due to accessibility, they were the ones who benefited most from the technology.

The containment of human excrement in the dome prevents foul smells from sanitation facilities, thus eliminating the issue of flies. The respondents reported that they now feel more comfortable when using the sanitation facilities connected to biodigesters. One of the respondents further explained how she used to remove her jacket when entering the toilet to avoid a bad odour. During the field study, it was evident that around areas where bio-digesters were used, there was no foul smell coming from latrines.

Statistical analysis ($\chi 2 = 17983$, P =.001) shows that there is a significant relationship between managing human excrement through biogas technology and preventing foul smells from sanitation facilities.

Impact of the Use of Biogas Technology on Overflowing Faecal Matter

The overflowing of faecal matter during heavy rainfall is one of the sanitation challenges in informal settlements. To assess if managing human excrement through biogas has any impact on faecal matter flows, the respondents were asked to give their views based on their experience before and after bio-digesters were installed in the area. They were to give their response based on the overflowing of faecal matter within the sanitation facilities and also the sewerage blockage leading to the overflow of the raw sewer.

Table 6: The relationship between the use of biogas technology and the prevention of faecal matter flows

Prevents overflowing of faecal matter	Users		Non-users		Total		M	χ^2	P Value
	N	%	N	%	N	%			
SA	24	48	5	10	29	29	2	26.937	.000
A	17	34	15	30	32	32			
ND	6	12	10	20	16	16			
D	2	4	14	28	16	16			
SD	1	2	6	12	7	7			
Total	50	100	50	100	100	100			

SA-strongly agree, A-agree, ND-neither agree nor disagree, D-disagree, SD- strongly-disagree, median, χ2 – Chi-square

The data in *Table 6* reveals that most of the respondents agreed that the utilization of biogas technology in the management of human excrement prevents the overflow of faecal matter

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

during the rainy season (median 2.0). Eighty-two percent (82%) of the technology users agreed that the technology has the potential to prevent the overflowing of faecal matter during the rainy season. According to the Umande Trust representative, the dome, which is a concrete tank constructed underground, has helped to solve several sanitation challenges (Plate 4.1). Being waterproof means that there is no contamination of the environment with faecal matter.

The lack of a physical barrier between human excreta and groundwater or soil where pit latrines are used poses a threat to public health. Environmental conditions, especially hydrological and soil conditions, determine the extent to which microbes are transported and contaminate the surrounding environment. The lack of a well-structured drainage system in Mukuru Kwa Njenga slums causes wastewater contaminated with faecal matter to remain stagnant (Michael, 2017). Additionally, open drains act as a pathway to the spread of water-borne diseases and infections. This makes the use of pit latrines unsustainable. The overflowing of faecal matter in pit latrines during heavy rainfall makes them unusable, forcing some residents, especially children, to defecate in the open. In most cases, raw sewer from pour-plash toilets finds its way into the nearby Nairobi River. This poses health hazards to the entire community. The use of biogas technology has proven to solve these challenges, thus speeding its adoption rate in the study area.

Statistical analysis shows a reliable relationship between technology use and the prevention of the flow of faecal matter during heavy rainfall ($\chi 2$ = 26.937, P =.000).

Sources of Information on Biogas Technology

According to Roger's diffusion theory, diffusion is a kind of communication. The two main communication channels include interpersonal communication and mass media. Interpersonal communication is more effective in changing people's attitudes than mass media. This is because diffusion involves interpersonal communication since it is a very social process (Sahin, 2006).

Table 7: Sources of information on biogas technology

Source of information	Users		Non-users	
	Frequency	%	Frequency	%
Organized training sessions	9	18	3	8
Biogas awareness campaigns	7	14	2	5
Neighbours/friends	18	36	13	33
Socio media i.e.	15	30	12	31
Media houses i.e. TVs, radios	1	2	9	23
Total	50	100	39	100

Results in T*able 7* indicate that interpersonal communication has played a great role in information dissemination concerning the management of human excrement through biogas technology. Most biogas technology users (36%) and non-users (33%) have obtained biogas-related information from neighbours or friends. This finding concurs with Irfan's 2013 finding, which shows that peer pressure makes people adopt biogas technology. Furthermore, socio-media platforms play a key role in information dissemination. In the region, Facebook was identified as the most commonly used social media platform. NGOs have played a key role in educating the community on the socio-economic and health benefits of using biogas technology through socio-media and organized training.

Technical Factors that Influence the Use of Biogas Technology in the Management of Human Excrement

To assess the challenges of using biogas technology in the management of human excrement. The respondents (both technology users and non-users) were requested to give their views on a scale of 1–5: 1: strongly agree; A:

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

agree; N: neither agree nor disagree; D: disagree; SD: strongly disagree. (N=100).

Technology Failure and Biogas Technology Adoption Rate

The inability of the technology to accomplish its intended purpose may slow down its adoption rate. For instance, the main aim of managing human excrement through biogas technology is to deal with human excrement disposal challenges while at the same time producing clean energy. It is meant to improve sanitation and improve people's socioeconomic well-being.

Table 8: Influence of biogas technology failure on its utilization

Technology failure	User		Non-users		Total		M	χ^2	P Value
	N	%	N	%	N	%			
SA	18	36	20	40	38	38	2	10.301	.036
A	28	56	16	32	44	44			
ND	0	0	4	8	4	4			
D	4	8	9	18	13	13			
SD	0	0	1	2	1	1			
Total	50	100	50	100	100	100			

SA-strongly agree, A-agree, ND-neither agree nor disagree, D-disagree, SD- strongly disagree, M-median, χ2-Chi-square

According to the results in *Table 8*, most of the respondents agreed that technology failure hinders the utilization of human excrement through biogas technology (median 2). Technical failures affect the production of biogas. From time to time, technology failure hinders the full utilization of biogas. To ensure efficient operation of the system for maximum biogas production, a number of factors must be considered, including the type of materials entering the dome. Additionally, the type of cleaning agent also affects biogas production. According to the Ogunwade *et al*. (2018) report on the effects of cleaning and disinfectant agents on biogas production in anaerobic digestion, increased concentrations of harpic and a commonly used cleaning agent inhibit the growth of microbes and thus have a negative impact on biogas production in a digester. The deposition of some materials, such as papers and sanitary towels, by users causes the blockage of the pipes and thus inefficiency in biogas production. Unblocking the system requires skilled manpower, which is often expensive, thus increasing the maintenance cost. Statistical analysis shows that technology failure has no significant effect on the utilization of biogas technology in the management of human excrement ($\chi2 = 10.301$, P =.036).

Availability of Technical Skills and Biogas Adoption Rate

Results in *Table 9* indicate that a lack of technical skills hinders the full utilization of human excrement biogas technology (median 2). This finding corresponds to one by Mumbi (2014), who found that more often than not, technology failure is a result of the inability of respondents to operate renewable energy technologies. It also concurs with findings by Ranjendran (2013), Solmaz and Mohammed (2012), and Momanyi (2019), which indicate that a lack of skilled labour and technical skills hinders the dissemination and adoption of biogas technology. According to Hazra *et al.* (2014), the lack of enough technical services is a result of poor training and a lack of interest from respondents. According to Momanyi (2019), it is difficult to embrace the technology without proper technical expertise, which is required in designing, constructing, and maintaining bio-digesters. According to Wawa (2012), the failure of many biodigesters is due to minor repairs that require professional assistance. Nethengwe *et al. (*2019 note that most of the households that have adopted biogas technology are frustrated by unsolved problems around their digesters caused by a lack of technical support and assistance. According to Mutai *et al.* (2016), the loss of biogas from latrines is a result of the use of

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

unskilled personnel in the construction of biodigesters.

Table 9: Influence of technical skills on biogas technology utilization

Lack of technical skills	User		Non-users		Total		M	χ2	P Value
	N	%	N	%	N	%			
SA	13	26	10	20	23	23	2	7.158	.128
A	17	34	14	28	31	31			
ND	5	10	1	2	6	6			
D	11	22	22	44	33	33			
SD	4	8	3	6	7	7			
Total	50	100	50	100	100	100			

SA-strongly agree, A-agree, ND-neither agree nor disagree, D-disagree, SD- strongly disagree, M-median, χ2 -Chi-square

Table 9 shows that there is no statistical significance between a lack of technical skills and the use of biogas technology in the management of human excrement (χ2= 7.518, P =.128). The hypothesis that technical factors have a significant effect on biogas technology is thus not supported by the findings.

Social-Economic and Cultural Factors

Social influence and peers have a stronger influence on individual adoption of an innovation. Social influence in which one behaviour in adoption is influenced by members of a social group determines the technology adoption rate (Talukder, 2012). Culture determines how people behave including how they deal with human excrement. It determines people's attitudes toward a given innovation. The economic status determines the ability of an individual/community to raise the initial installation cost (Arthur *et al.*, 2011).

Table 10: Influence of installation cost on biogas technology utilization

High installation cost	User		Non-users		Total		M	X^2	P Value
	N	%	N	%	N	%			
SA	10	20	26	56	36	36	2	23.262	.000
A	15	30	20	40	35	35			
ND	4	8	1	2	5	5			
D	19	38	3	6	22	22			
SD	2	4	0	0	2	2			
Total	50	100	50	100	100	100			

SA-strongly agree, A-agree, ND-neither agree nor disagree, D-disagree, SD- strongly disagree, M-median, χ2-Chi-square

Results in *Table 10* indicate that the high initial installation cost (Median, 2) is a challenge when it comes to the installation of bio-digesters. Ninety-six percent (96%) of the technology users agreed that the high initial capital required to install a single bio-digester is a challenge to most community-based organizations wishing to install a bio-digester. This explains the lower number of biodigesters in the area. During an in-depth interview with an Umande Trust representative, it was noted that most of the group organizations managing the facilities were unable to raise the initial capital required. Most of them depend on donors such as Oxfam, UN-Habitat, and others. The chi-square test result indicates there is a significant relationship between the high installation cost and the utilization of biogas technology (χ2 = 23.262, P =.000). These findings concur with results by Mwakaje (2012) and Erick *et al. (*2018), which show that the high installation cost of bio-digesters hinders the adoption of biogas technology. According to Nethengwe *et al. (*2019, access to credit, loans, and subsidies is a

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

noteworthy factor in promoting the adoption of biogas technology.

Table 11: Influence of cultural beliefs on the use of biogas energy from human excrement

Cultural belief	User		Non-users		Total		M	χ^2	P Value
	N	%	N	%	N	%			
SA	5	10	20	40	25	25	2.5	23.665	.000
A	9	18	16	32	25	25			
ND	6	12	0	0	6	6			
D	18	36	11	22	29	30			
SD	12	24	3	6	15	14			
Total	50	100	50	100	100	100			

SA-strongly agree, A-agree, ND-neither agree nor disagree, D-disagree, SD- strongly disagree, M-median, χ2-Chi-square

Table 11 indicates that the respondents agreed that cultural beliefs (median 2.5) impede technology usage. The result shows there is a difference concerning cultural beliefs among technology users and non-users. Seventy-two percent (72%) of non-users agreed that cultural beliefs hinder the use of technology, with only 28% of technology users agreeing. During the field study, it was clear that most of the respondents did not like the idea of cooking using the gas from human excrement. To them, this is unhygienic, taking into consideration that the cooker and the toilets are more often under the same roof due to a lack of enough space in the area. This is due to the unavailability of open spaces due to the high population.

The Chi-square test shows that there is a significant relationship between cultural beliefs and the use of biogas generated from human excrement (χ^2 =23.665, P =.000). The findings concur with Francois *et al. (2023),* who found that fear due to people's perception of using biogas produced from human excrement is a major concern for users. The finding supported the hypothesis that cultural beliefs have a significant effect on people's perceptions of the use of biogas from human excrement.

CONCLUSION

Despite the socio-economic and environmental benefits of biogas technology, its application in dealing with human excrement disposal issues is influenced by various factors. According to the study, gender and education level have a significant influence on the use of biogas technology in managing human excrement. This is mainly due to gender-related differences, which influence their sanitation needs. The ability of biogas technology to prevent odour from sanitation facilities and overflowing of faecal matter during the rainy season has made most of the residents embrace it. Interpersonal communication has played a key role in the dissemination of information on the application of biogas technology. The respondents agreed that technology failure and a lack of technical skills have negatively influenced the full utilization of biogas technology. The high initial installation cost of bio-digesters and cultural beliefs also have a significant impact on the use of biogas technology. Dependence on donors for funding slows down the installation process. Training and awareness campaigns are necessary to equip the residents with the necessary skills for the proper maintenance and operation of bio-digesters. It will also help to change people's perceptions of the use of gas produced from human excreta for cooking purposes. Financial support by both government and non-governmental organizations will see the installation of enough bio-digesters.

REFERENCES

Albronda, B., De Langen, F., & Huizing, B. (2011). The influence of communication on the process of innovation adoption. *Innovative Management Journal*, *4*(1), 22-31. https://doi.org/10.34894/pbc1wb

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

Amoah, A., Kwablah, E., Korle, K. and Offei, D. (2020). Renewable energy consumption in Africa: the role of economic well-being and economic freedom. *Energy Sustainability and Society 10* **(**32). https://doi.org/10.1186/s13705-020-00264-3

General Assembly. (2015). Sustainable development goals. *SDGs Transform Our World, 2030*. New York City, United States of America. https://sdgs.un.org/2030agenda

Donacho, D. O., Tucho, G. T., Olani, D. D., Kabtiyimer, H. E., Hailu, A. B., & Wolde, A. D. (2023). Experimental evaluation of fresh human faeces biogas and compost potential: Evidence for circular economy from waste streams in Ethiopia. *Heliyon*, *9*(12). https://doi.org/10.1016/j.heliyon.2023.e22494

Colombo, V., Chenal, J., Orina, F., Meme, H., Koffi, J. D. A. A., Koné, B., & Utzinger, J. (2023). Environmental determinants of access to shared sanitation in informal settlements: a cross-sectional study in Abidjan and Nairobi. *Infectious Diseases of Poverty*, *12*(1), 1-19. https://doi.org/10.1186/s40249-023-01078-2

Erick, M. K., Kirubi, G., & Muriuki, S. (2018). Key Factors influencing adoption of biogas technology in Meru Country, Kenya. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *12*(3), 57-67. https://doi.org/10.9790/2402-1203015767

François, M., Lin, K. S., Vaincoeur, E., Rachmadona, N., & Khoo, K. S. (2023). Haitians' perceptions of biogas produced via human excreta: An approach to the democratization of energy systems. *Chemosphere*, *334*(138986). https://doiorg/10.1016/j.chemosphere.2023.138986

Graf-Vlachy, L., Buhtz, K., & König, A. (2018). Social influence in technology adoption: taking stock and moving forward. *Management Review Quarterly*, *68*(1), 37-76. https//doi/10:1007/s11301-0133-3

Hazra, S., Lewis, J., Das, I. & Singh, A. (2014). Adoption and use of improved stoves and biogas plants in rural India.www.sandeeonline.org

Irfan, M. (2013). The perception about the biogas technology adoption: a case study of District Faisalabad (Punjab, Pakistan). *Middle-East Journal of Scientific Research*, *17*(2), 256-259. https://doi.org/10.5829/idosl_mjsr.2013.17.02.11891

Jadhav, M. P., & Sudhakar, D. S. S. (2015). Analysis of burner for biogas by computational fluid dynamics and optimization of design by genetic algorithm. *International Journal for Research in Emerging Science and Technology*, *2*, 39- 44. https://www.researchgate.net/publication/2804888.63

Josue, N. O., Wilfrid, L. N., & Dieumerci, O. D. (2023). Theoretical Analysis of Biogas Production from Septic Tanks: The Case of the City of Kinshasa. *Natural Science*, *15*(4), 149- 166. https://doi.org/10.4236/ns.2023.154011

Kasala, S. E., Burra, M. M., & Mwankenja, T.S. (2016). Access to improved sanitation in informal settlements': The Case of Dar es Salaam City, Tanzania. *Current urban studies*, *4*, 23- 35. http://dx.doi.org/10.4236/cus.2016.41003

Kenya National Bureau of Statistics (2019). 2019 Kenya population and housing census: volume 11 distribution of population by administrative unit. Kenya National Bureau of Statistics. Nairobi, Kenya.https://www.knbs.or.ke/download/2019-kenya-population-and-housing-census

Libby, J. A. (2018). An Evaluation of Pit Latrines and User Perception of Excrement in Ngäbe Communities in Panama. University of South Florida. https: digitalcommons.usf.edu/etd/7329

Nassiuma, D. K. (2000). Survey sampling. *Theory and methods*, Nairobi University Press. Nairobi. *10*(1), 59- 63. http://hdl.handle.net/11295/63034

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

Nethengwe, T., & Kutcherov, V. (2019). Barriers to the wider implementation of biogas as a source of energy: A state-of-the-art review. *Energy Strategy Reviews*, *26*, 100414 https://doi.org/10.1016/j.esr.2019.100414

Nevzorova, T., & Kutcherov, V. (2019). Barriers to the wider implementation of biogas as a source of energy: A state-of-the-art review. *Energy Strategy Reviews*, *26*, 100414. https://doi.org/10.1016/j.esr.2019.100414

Momanyi, R. K., &Benards, A. H. O. A. O. (2016). Social-Economic Factors Influencing Biogas Technology Adoption among Households in Kilifi County-Kenya. *Journal of Energy Technologies and Policy*, 6, 20-33

Mumbi, M. R. (2017). *Adoption of human waste biogas technology by rural households in Kiganjo division, Kiambu County, Kenya* (doctoral dissertation, Kenyatta Unive rsity). http: //ir.library.ku.ac.ke/handle/12345 6789/19351

Mutai, P., Niwagaba, C., Tumuhairwe, J. B., Kulabako, R., Katukiza, A., Nyenje, P., & Kansiime, F. (2016). Key factors affecting performance of biogas latrines in urban informal areas: Case of Kampala and Nairobi, East Africa. *African Journal of Environmental Science and Technology*, *10*(7), 207- 220. https://doi.org/10.5897/AJEST 2016-2018

Mwakaje, A. G. (2012). *Dairy Farming and the Stagnated Biogas Use in Rungwe District, Tanzania: An Investigation of the Constraining Factors*. Institute of Resource Assessment. Dar es Salaam, Tanzania. http:// hdl.handle.net/123456789/9484

Ogunwande, G. A., Adeleye, A. I., Nureni, I. O., & Omidiora, O. (2018). The effects of cleaning/disinfecting agents on biogas production in the anaerobic digestion of cow dung slurry. *Environmental technology*, *39*(14), 1803- 1813.https://doi.org/10:8010/0 9593330.2017.1340346

Onojo, O.J., Chukwedebe, C. A., Okator, E.N., Ononiwu, G.C., Chukwuchekwa, N., Opara, R.O., & Dike, D.O. (2013). Estimation of the electric potential of human waste using hostel students' hostel soak-away pits. *American Journal of Engineering Research (AJER*), 2(9), 198-203.www.ajer.org

Rheinländer, T., Keraita, B., Konradsen, F., Samuelsen, H., & Dalsgaard, A. (2013). Smell: an overlooked factor in sanitation promotion. *Waterlines*, 106- 112.https://doi.o rg/10.3362/1756-3488.2013.012

Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *Turkish Online Journal of Educational Technology-TOJET*, *5*(2), 14-23. https://files.eric.ed.gov/fulltext/ED501453.pd f

Schuster-Wallace, C.J., Wild, C., & Metcalfec. (2015). Valuing Human Waste as an Energy Resource. A Research Brief Assessing the Global Wealth in Waste.United Nations University. Institute for Water, Environment and Health (ANU- INWEH). http://inweh.an u.eduy

Talukder, M. (2012). Factors affecting the adoption of technological innovation by individual employees: An Australian study. *Procedia-Social and Behavioral Sciences*, *40*, 52- 57. https://doi.org/10.1016/j.sbspro.2012. 03.160

Uhunamure, S. E., Nethengwe, N. S., & Tinarwo, D. (2019). Correlating the factors influencing household decisions on adoption and utilization of biogas technology in South Africa. *Renewable and Sustainable Energy Reviews*, *107*, 264- 273. https:/doi.org/10.10 16/j.rse.2019.03.006

UNICEF. (2023). Sanitation and Hygiene for All:'Make a Splash!'Partnership Progress Report 2022-2023. Vellman, Y., Mason, E., Graham, W., Benova, L., Chopra, M., Campbell, O. M., & Cumming, O. (2014).

Article DOI: https://doi.org/10.37284/eajenr.7.1.1918

From joint thinking to joint action: a call to action on improving water, sanitation, and hygiene for maternal and newborn health. *Plos medicine*, *11*(12), https://doi.org/10.1371/journal.pmed.1001771.

Wachera, R. (2009). *Assessing the challenges of adopting biogas technology in energy provision among dairy farmers in Nyeri County, Kenya* (Doctoral dissertation, KenyattaUniversity). http: //irlibrary.ku.ac.ke/bitstream/handle/123456789/1194.

Wamuchiru, E. &Moulaert, F. (2017). Thinking through the community Bio-centres approach in Water and Sewerage service provision in Nairobi Informal Settlements. *Journal of environmental planning and management*, 1(20), 2166- 2185. https://doi.org/10.1080/09640568.2017.1389699.

Wamuyu, M. S. (2014). *Analysis of biogas technology for household energy, sustainable livelihoods and climate change mitigation in Kiambu County, Kenya*. (Dotoral dissertation, Kenyatta University)

Wawa, A. (2012). The challenges of promoting and adopting biogas technology as an alternative energy resource in Semi-arid areas of Tanzania: the case of Kongwa and Bahi Districts of Dodoma region. (Doctoral dissertation, Open University of Tanzania). Available at repository.out.ac.tz/319.http://repository.out.ac.tz/id/eprint/319

World Health Organization. (2020). State of the World's sanitation: an urgent call to transform sanitation for better health, environments, economies, and societies. World Health Organization.https://www.who.int/publication/i/item/9789240014473

