



**FACULTY OF ENGINEERING**

**DEPARTMENT OF WATER RESOURCES ENGINEERING**

**FINAL YEAR PROJECT REPORT**

**REDESIGN AND CONSTRUCTION OF AN SMAL SCALE BIOMASS AND WASE OIL  
HYBRID POWERED INCINERATOR TOILET**

**A CASE STUDY; BUWALI IDP CAMP**

**BY**

NAME	REGISTRATION NUMBER	Email address
KISODI ASADI	BU/UP/2018/3635	kisodiasadi389@gmail.com
BESIIMYE FATWA	BU/UP/2018/3613	besiimyefatwa@gmail.com

**A final project report submitted to the department of water resources engineering as partial fulfillment as a requirement for the award of Bachelor of Science in water resources engineering at Busitema University.**

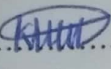
## Abstract

In response to the reinvent the toilet height challenge, a mobile incinerator toilet has been designed to address the inaccessibility of disabled people in Buwali camp and urban slums to available toilet with their consequences .AS an emergence sanitation mean to avoid open defecation, the designed incinerator toilet is simple, cheap, can be assembled and disassembled, environmentally friendly and efficient for treatment of human faeces. The designed incinerator toile is made up of biomass chamber with a combustion chamber area of 2100mm, seat metallic box, incinerator pot/shelf that carried the fecal matter during incineration, 310mm height chimney, strong pipe used for steam and gas channeling from the incineration pot back to the combustion chamber that increased combustion efficiency, steam reduced emissions of nitrogen oxides significantly with low carbon monoxide when using waste oil and biomass as a heat source. The pressure gauge was installed for pressure regulation to avoid bursting of the incinerator pot during the incineration process, the primary combustion zone operated at an air-fuel ration slightly higher than the stoichiometric air-fuel ratio. The method of heat transfer was convection and conduction, the insulation of the biomass chamber with clay reduced heat loss to the environment. The simulation of heat transfer predicted the heat transfer rate by convection through the design prototype up to maximum temperature of 723 when biomass was used and 833k when waste oil was used. The prototype was tested at Busitema University Engineering Workshop and laboratory tests were conducted from National Water and Sewerage Corporation, Tororo Laboratory. The heat reduced the mass of fecal waste by 92.0% when using the biomass chamber for treatment while it reduced by 94.6% when using waste oil and both burners eliminated pathogens concentration with a high efficiency. With an initial investment 1,335,000 UGX, a Net Present Value of 7,320,016.788 UGX can be realized by this project with savings of 243236UGX per year

## DECLARATION


I Kisodi Azadi, Besigye Fatwa declare that this project report is my own doing and has never been submitted to any university or institution of high learning for an academic

KISODI ASADI

Signature.....

Date.....16<sup>th</sup>/01/2023.....

BESIIMYE FATWA

Signature.....

Date.....16<sup>th</sup>/01/2023.....

## APPROVAL

The undersigned confirms that this project report has been under my supervision and is ready for submission to the department of Water Engineering for an award of bachelor's degree in Water Resources Engineering.

### SUPERVISOR

Dr. JOSEPH DDUMBA LWANYAGA

Signature.....

Date.....

MR. MASERUKA BENDICTO SSAJJABI

Signature..... *M. Maseruka*

Date... *16<sup>th</sup> - Dec - 2022*

## ACKNOWLEDGEMENT

We would like to extend my sincere thanks to the almighty GOD who has gifted us with life and has enabled us reach this academic level. Great thanks to our beloved families and FAWE(U) FOR THE emotional, spiritual and financial support not forgetting our course mates especially Kaaya Digamous and Mahender Francis for their endless encouragement, support prayers and advise given to us in the course of this project.

Great appreciation goes our supervisors Mr. Maseru Benedicta and Dr. Joseph Dumba Lwanga for their advice as well guidance during the preparation of this project report not forgetting Mr. Olowe Daniel, Mr. Kimora George, and Mr. Obit for their honest critic and comments during the course of the project.

# TABLE OF CONTENTS

## Contents

Abstract .....	ii
DECLARATION .....	iii
APPROVAL .....	iv
ACKNOWLEDGEMENT .....	v
TABLE OF CONTENTS .....	vi
List of Tables .....	xi
ACRYMONS .....	xii
1.0 CHAPTER ONE .....	13
1.1 1.1 Background .....	13
<b>1.2 Problem statement</b> .....	15
1.3 Justification .....	15
<b>1.4 Objectives of the study</b> .....	15
<b>1.4.1 Main objective of study</b> .....	15
<b>1.4.2 specific objectives</b> .....	16
<b>1.5 Significance</b> .....	16
<b>1.6 Scope of the study</b> .....	16
<b>1.6.1 Conceptual scope</b> .....	16
<b>1.6.2 Geographical scope</b> .....	16
2.0 CHAPTER TWO: LITERATURE REVIEW .....	17
2.1 Preamble .....	17
2.2 General characterization of faeces .....	17
<b>2.3 Volume of excreta</b> .....	18
<b>2.4 Disease causing pathogens in excreta</b> .....	19
2.5 Factors that affect pathogen die off .....	20
2.6 General characterization of urine .....	21
2.7 Human faeces as solid fuel .....	21
<b>2.8 Composition</b> .....	21
<b>2.9 Heating Value</b> .....	21
2.10 Treatment .....	22
<b>2.11 Flush toilets</b> .....	22

2.12	Compost toilets: .....	22
2.13	Pit latrines: .....	23
2.14	ECO SAN toilets:.....	23
2.15	Incineration toilets: .....	24
2.16	Burner system .....	24
<b>2.17</b>	<b>Principles of combustion (Biomass fuel system).....</b>	<b>25</b>
<b>2.18</b>	<b>Complete Combustion .....</b>	<b>25</b>
<b>2.19</b>	<b>Incomplete combustion.....</b>	<b>25</b>
<b>2.20</b>	<b>Perfect Stoichiometric Combustion.....</b>	<b>25</b>
2.8	Waste oil burning system.....	28
2.9	lower heating value and high heating value of waste/used oil.....	28
2.30	Simulation heat transfer in the design system.....	28
2.31	CFD analysis tool.....	28
2.32	Steps of CFD analysis.....	29
2.33	Applications of CFD simulation and modeling .....	29
2.34	SOLIDWORKS software.....	30
2.35	Applications of SolidWorks Software .....	31
3.0	CHAPTER THREE .....	32
3.1	Methods and Materials.....	32
3.2	Specific objective one: To design the system components.....	32
3.4	Methods for data collection.....	32
<b>3.5</b>	<b>Desk study.....</b>	<b>32</b>
<b>3.6</b>	<b>Design software .....</b>	<b>33</b>
3.7	Conceptual drawings.....	33
3.8	Design considerations .....	33
3.9	Mass and volume of the fecal waste .....	34
<b>3.10</b>	<b>Design of the incinerator components.....</b>	<b>34</b>
<b>3.11</b>	<b>Energy demand for the reactor pot .....</b>	<b>34</b>
3.12	Design of the biomass and waste oil fuel system.....	35
3.13	Toilet seating mechanism.....	38
3.16	Specific objective three; To fabricate and test the performance of the system.....	39
3.17	Material selection for components.....	40
3.18	To test system performance .....	40
3.19	System energy use efficiency test .....	40
<u>3.20</u>	System waste treatment efficiency.....	40

3.21	To carry out the economic analysis.....	40
3.22	The Net Present Value (NPV).....	40
3.23	Profitability index (P. I) .....	41
3.24	Payback time .....	42
4	CHAPTER FOUR.....	44
4.1	RESULTS AND DISCUSSIONS .....	44
4.2	Daily quantity of urine and feces .....	44
4.3	. Energy required for sanitation of faecal matter by biomass.....	45
4.4	Sizing the reactor pot .....	47
4.5	Design of the combustion chamber;.....	47
4.6	Stoichiometric combustion products.....	48
4.7	combustion with excess air .....	49
4.8	when using waste oil .....	52
4.9	Volumes of flue gases/ combustion products.....	53
4.10	Steam effects on waste oil combustion and NO <sub>2</sub> Emission.....	54
4.11	Air flow rate, AFR;.....	54
4.12	Calculations for the combustion chamber dimensions.....	54
4.13	Effect of steam on NO <sub>x</sub> emission .....	57
4.14	Toilet Seating Mechanism .....	57
4.15	Specific objective two: To Simulate the heat transfer in the design prototype.....	61
4.16	Specific objective three: system construction and testing.....	67
4.17	Materials selection .....	69
4.18	The height of the toilet in accordance to the standard toilet .....	70
4.19	Operational principle of the system prototype .....	70
4.20	System prototype .....	71
4.21	Temperature changes when using biomass as fuel .....	72
4.22	Temperature changes when using waste oil as fuel. ....	74
4.23	Reduction in the waste in the incineration chamber .....	77
4.24	System energy use efficiency test .....	78
4.25	Oven consumption and energy production efficiency .....	78
4.26	System Efficiency of the biomass .....	79
4.27	Reduction in the waste in the incineration chamber when using waste oil.....	79
4.28	ECONOMIC ANALYSIS.....	80
4.29	Savings to be made by using the incinerating toilet.....	82
4.30	Salvage value .....	84



4.31	Net Present Value (NPV).....	84
4.32	Profitability index (P.I).....	85
4.33	Payback period.....	86
5	CHAPTER FIVE .....	87
5.1	Conclusion .....	87
5.2	Recommendations.....	87
5.3	REFERENCES .....	89
5.4	APPEDIX.....	92

Table of figures

Figure 1 .....	<b>Error! Bookmark not defined.</b>
Figure 2 .....	19
Figure 3 .....	<b>Error! Bookmark not defined.</b>
Figure 4 .....	532
figure 5.....	53
Figure6.....	55
Figure7.....	55
Figur8.....	57
Figure9.....	57
Figure10.....	58
Figure11.....	58
Figure12.....	58
Figure13.....	61

## List of Tables

Table1 .....	<b>Error! Bookmark not defined.</b>
Table2 .....	18
Table3 .....	19
Table4 .....	220
Table5 .....	37
Table6.....	24
1	
Table7.....	31
Table8.....	35
Table9.....	59
Table10.....	62
Table11.....	64
Table12.....	66
Table13.....	66
Table14.....	67
Table15 .....	68
Table16.....	69
Table17.....	70
Table18.....	72
Table19.....	73

## ACRYMONS

IDP: Internally Displaced People

LHV: Lower Heating Value

HHV: High heating Value

HV: Heating Value

SDG: Sustainable Development Goal

UN: United Nations

UNHCR: United Nations High Commission for Refugees

WHO: World Health Organization

## 1.0 CHAPTER ONE

### 2. 11.1 Background

Open defecation facilitates the transmission of pathogens that cause diarrheal diseases, which is the second leading contributor to the global burden of disease (Belay et al., 2022). It also exposed hundreds of millions of girls and women around the world to increased sexual exploitation. 494 million people practice open defecation and most of these people 92% lived in rural areas (WHO&UNICEF, 2021). Diarrhea is currently the second most important cause of child morbidity and mortality after malaria (Az pogo et al., 2019), causing 1.7 million morbidities and 760,000 deaths every year globally (Belay et al., 2022). In Africa, it is also one of the main causes of death under five-year children.

In 2010, The United Nations General Assembly adopted a historical resolution recognizing “the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights and since 2015, the General Assembly and the Human Rights Council have recognized both the right to safe drinking water and the right to sanitation as closely related but distinct human rights (United Nations 2015).

Uganda is the largest refugee hosting country in Africa hosting over 1.5 million refugees (UNHCR Refugee Statistic, 2021). These are from South Sudan, Burundi, Rwanda and Democratic Republic of Congo (DRC) and they are settled in different camps with in the country. On addition there are Ugandans displaced by natural disasters like floods and landslides with in the country. These are also settled in camps like the Buwali IDP camp in Buddha, and some were relocated to Air landing settlement.

Diarrhea is the major cause of child mortality and morbidity in the Africa with Uganda having the highest rate in East Africa of 22%. Diarrheal disease deaths in Uganda are 12,103 or 5.83% of total deaths as of 2020 (WHO 2020) making Uganda to be ranked 40<sup>th</sup> worldwide. These deaths could be prevented if only we paid extra attention to hygiene and sanitation (Oona et al., 2020). A cumulative total of 241 cases and 2 deaths have been recorded on 6<sup>th</sup>/set/2019. Among these, Buddha registered 66 cases and 1 death due to displacement of around eight hundred displaced persons in this district (Ayame et al., 2019).

### 5.3 REFERENCES

Abney, S., Bright, K., McKinney, J., Ijaz, M., & Gerba, C. (2021). Toilet hygiene—review and research needs. *Journal of Applied Microbiology*, 131(6), 2705-2714. Doi: 10.1111/jam.15121

A. Parkera., C. (2015). The Characterization of Feces and Urine: A Review of the Literature to Inform Advanced Treatment Technology. Retrieved 14 October 2022, from <https://www.tandfonline.com/doi/full/10.1080/10643389.2014.1000761>

(Banamwana, Musoke, Tumwesigye, Ntakirutimana & Dukuziyaturemye, 2020).

Banamwana, C., Musoke, D., Tumwesigye, N., Ntakirutimana, T., & Dukuziyaturemye, P. (2020). Application of human excreta on the farms as an effective option to the uptake and replication of ecological sanitation (Ecosan) in Burera District, Rwanda. *Rwanda Journal of Engineering, Science, Technology and Environment*, 3(1). doi: 10.4314/rjeste.v3i1.1

(Phil Caruso, 2016)

Phil Caruso. (2016). Sustainable Toilets: A Pleasant Solution to a Foul Problem - Technology and Operations Management. Retrieved 19 October 2022, from <https://digital.hbs.edu/platform-rocketom/submission/sustainable-toilets-a-pleasant-solution-to-a-foul-problem/>

Nagy, J., & Zseni, A. (2016). Swot analysis of dry toilets. *WIT Transactions On Ecology and The Environment*. doi: 10.2495/eid160231

Anand, C. K., & Apul, D. S. (2014). Composting toilets as a sustainable alternative to urban sanitation - A review. *Waste Management*, 34(2), 329–343. <https://doi.org/10.1016/j.wasman.2013.10.006>

CONSTRUCTION MANUAL FOR THE FIREWOOD SAVING ROCKET BAKING OVENS  
With the Support of the German Technical Cooperation. (2008). November.

Graham, J. P., & Polizzotto, M. L. (2013). Pit latrines and their impacts on groundwater quality: A systematic review. *Environmental Health Perspectives*, 121(5), 521–530. <https://doi.org/10.1289/ehp.1206028>

Jackson, B. (2005). A Review of EcoSan Experience in Eastern and Southern Africa. *Sanitation and Hygiene Series*, 16 pages.

- Lenton, R., & Wright, A. (2019). Interim Report of Task Force 7 on Water and Sanitation. Water, December 2004, 131.
- Mara, D. (2017). The elimination of open defecation and its adverse health effects: A moral imperative for governments and development professionals. In *Journal of Water Sanitation and Hygiene for Development* (Vol. 7, Issue 1, pp. 1–12). IWA Publishing. <https://doi.org/10.2166/washdev.2017.027>
- Omona, S., Malinga, G. M., Opoke, R., Openy, G., & Opiro, R. (2020). Prevalence of diarrhoea and associated risk factors among children under five years old in Pader District, northern Uganda. *BMC Infectious Diseases*, 20(1). <https://doi.org/10.1186/s12879-020-4770-0>
- Tearfund, & WaterAid. (n.d.). The Human Waste The Human Waste The Human Waste The Human Waste A call for urgent action to combat the millions of deaths caused by poor sanitation A report from Tearfund and WaterAid. [www.tearfund.org](http://www.tearfund.org)
- USEPA. (1999). Water Efficiency Technology Fact Sheet - Incinerating Toilets, EPA 832-F-99-072. <https://www.epa.gov/sites/production/files/2015-06/documents/incinera.pdf>
- C. Rosea. (2015). The Characterization of Feces and Urine: A Review of the Literature to Inform Advanced Treatment Technology. Retrieved 14 October 2022, from <https://www.tandfonline.com/doi/full/10.1080/10643389.2014.1000761>
- D.kIPKORIR. (2021). classification of fuel properties and standard specification. Retrieved 16 October 2022, from <https://hoahoc.info/properties-of-waste-distilled-engine-oil-and-biodiesel-ternary-blends.html>
- Belay, D., Asratie, M., Aragaw, F., Tsega, N., Endalew, M., & Gashaw, M. (2022). Open defecation practice and its determinants among households in sub-Saharan Africa: pooled prevalence and multilevel analysis of 33 sub-Saharan Africa countries demographic and health survey. *Tropical Medicine and Health*, 50(1). <https://doi.org/10.1186/s41182-022-00416-5>
- Azupogo, F., Abdul-Rahaman, F., Gyanteh, B., & Atosona, A. (2019). Hygiene and Sanitation Practices and the Risk of Morbidity among Children 6–23 Months of Age in Kumbungu District, Ghana. *Advances in Public Health*, 2019, 1-12.

<https://doi.org/10.1155/2019/4313759>

Charles B. Niwagaba. (2009). Treatment Technologies for Human Faeces and Urine. Retrieved 16 October 2022, from [https://pub.epsilon.slu.se/2177/1/niwagaba\\_c\\_091123.pdf](https://pub.epsilon.slu.se/2177/1/niwagaba_c_091123.pdf)

Pooja G. Nidoni. (2017). EFFECTIVE UTILIZATION OF BY PRODUCTS DURING INCINERATION. Retrieved 16 October 2022, from <https://www.irjet.net/archives/V4/i12/IRJET-V4I1270.pdf>

Mubatsi, J., Wafula, S., Etajak, S., Ssekamatte, T., Isunju, J., & Kimbugwe, C. et al. (2021). Latrine characteristics and maintenance practices associated with pit latrine lifetime in an informal settlement in Kampala, Uganda. *Journal Of Water, Sanitation And Hygiene For Development*, 11(4), 657-667. doi: 10.2166/washdev.2021.032

Sam Kubba. (2017). Water Efficiency and Sanitary Waste. Retrieved 19 October 2022, from <https://www.amazon.com/Chapter-Water-Efficiency-Sanitary-Waste-ebook/dp/B00DGS9KV8>