COLLEGE OF SCIENCE AND TECHNOLOGY

SCHOOL OF SCIENCES

DEPARTMENT OF BIOLOGY

ACADEMIC YEAR: 2023-2024

MASTER'S PROGRAM IN BIODIVERSITY CONSERVATION AND NATURAL RESOURCES MANAGEMENT

INDOOR AIR POLLUTION FROM DIFFERENT COOKING FUEL STOVES, FUEL TYPE ASSOCIATED HEALTH AND ENVIRONMENTAL EFFECTS IN NGORORERO DISTRICT.

Air pollutant monitoring on LPG   Charcoal   Firewood

A thesis submitted in partial fulfilment of the requirements for the degree of Master in Biodiversity Conservation and Natural Resources Management

By

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Kigali, October 2024

DECLARATION

I, UWIZEYIMANA Josiane, affirm that, to the best of my knowledge, the content presented in this dissertation entitled: " **Indoor air pollution from different cooking fuel stoves, fuel type associated health and environmental effects in Ngororero District, Western Province, Rwanda**" is my original work and has not been submitted elsewhere. For any academic qualification at any university or institution of higher learning. All referenced ideas in this work have been appropriately cited in the bibliography.

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Kigali, October 2024

APPROVAL

I certify that this research project entitled " **INDOOR AIR POLLUTION FROM DIFFERENT COOKING FUEL STOVES, FUEL TYPE ASSOCIATED HEALTH AND ENVIRONMENTAL EFFECTS IN NGORORERO DISTRICT WESTERN PROVINCE**, **RWANDA**" was done under my supervision and has been submitted for examination with my approval.

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ACKNOWLEDGEMENTS

First and foremost, I extend my deepest gratitude to the Almighty God, to whom all honor and praise belong forever. My heartfelt appreciation goes to my supervisor, Dr. Joseph NSENGIMANA, for his exceptional guidance, invaluable advice, consistent support, and mentorship in scientific thinking and conducting this research and getting the sensors that I used during research.

I am profoundly grateful to the government of Rwanda for admitting me to pursue my studies at the University of Rwanda - Nyarugenge Campus. My thanks also go to the University of Rwanda for its dedication to providing quality education. I extend my appreciation to the lecturers of Biodiversity Conservation and Natural Resources Management for their contributions and constructive advice. The value of their efforts is immeasurable, and I am extremely grateful.

Special thanks go to my family their everyday motivation and support, I also express my deepest gratitude to my friends, classmates, and relatives for the precious moments we have shared. Thank you for the pleasant cooperation and solidarity. May God bless you all!!

Josiane UWIZEYIMANA

ABSTRACT

Efforts to improve access to modern energy services globally, including in Rwanda, aim to alleviate poverty, reduce environmental and health impacts while sustain economic growth. Despite these efforts, 1.26 billion people still lack electricity, and 2.64 billion rely on traditional biomass fuels for cooking. Recent initiatives promote the use of cooking gases as a cleaner alternative to reduce greenhouse gas emissions and environmental degradation. This study investigates the impact of different cooking fuels on air quality in Ngororero District, Western Province, Rwanda. Data was collected from 398 randomly selected households using air pollutant sensors. Statistical analysis compared the mean and standard deviation of particulate matter (PM2.5) and Carbon Monoxide (CO) emissions across three fuel types: Charcoal, Liquefied Petroleum Gas (LPG), and Wood. Results indicate that Wood produces the highest and most variable PM2.5 emissions, with a median concentration of approximately 275 µg/m³. Charcoal has a median PM2.5 concentration of 25 µg/m³, while LPG shows the lowest emissions with a median of 15 µg/m³ while CO vary respectively Charcoal: 8640 µg/m³, Wood: 1830 µg/m³, LPG: 210 µg/m³. These findings suggest that LPG is the cleanest option in terms of particulate emissions, followed by Charcoal, with Wood contributing the most to air pollution.

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CHAPTER I: INTRODUCTION

I. Historical Background

A World Health Organization report indicated that around 2,6 billion people cook by using the simple stoves or polluting open fires include kerosene, biomass (wood, crop waste, animal dung) and coal (WHO,2021). The report also indicated that exposure to household air pollution from inefficient cooking practices from indoor air pollution households is the largest cause of premature human mortality, causing more than 4 million people deaths annual. The health effect of air pollution has been also documented to cause other chronic diseases such as stroke, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer. This is a particular concern in developing countries where more than 90% cook using pollution solid fuel (charcoal, wood burning and agriculture crop burning) (WHO Cooking Report Sept 2021).

The recent FAO report on forestry indicated that above 25 percent of the world population, including one billion of women depend on forest resources for their livelihood (References). In previous period, research done on gender in forests showed that the women were overly stereotypical, shaping simplistic narratives of men where women roles are to force multifaceted realities into binary gendered model (Garland,207).

The most men were reported that the users of forest are for logging, construction and harvest product for sales, while the mostly women in rural area have the responsibilities of collecting products for households use from forest (references). These combinations of multiple household and productive roles from men and women as social norms roles, they may limit their mobility and participation in public life because the environmental effects (deforestation, land degradation, greenhouse gas increased, Climate change.) and the health effect in increasing indoor air pollution on young women using wood inappropriate way (The & Programme, 2021). So, according to these reports from WHO and FAO Forestry.

The research proposal has investigated if there is any difference of severity of CO and $PM_{2.5}$ by using different cooking stoves fuel type and to investigate within survey where there is a minimum cost, quantity spent, time spent and most healthful during preparation food for break first, lunch and dinner and even look what is the most affordable to the households. After getting the data measure from different cooking stoves type within households and getting the data from survey, research was able to address the possible mitigation measures for reducing the indoor air quality in kitchen area based on the data measured during research implementation and to address the way useful for minimizing the rate of deforestation, to reduce the greenhouse gases emissions and environmental conservation based the data from survey of households.

Indoor concentration of carbon monoxide (CO) and Particulate matter (PM) are the key measures for air quality indicators and show if the air pollutants can be caused for long- or short-time health effect. The different household in Rwanda, the cooking food material for life survive is including the wood, charcoal, gas and electricity method where each stoves fuel type can create indoor air pollution CO and PM2.5 and other pollutants which are harmful to human's life during the preparation food for eating.

The almost people in Rwanda lack the access on energy infrastructure where more than 80% are using charcoal, wood, crop residues and solid combustion fuel and at least 20 % are starting to use LPG methods, this is a reason why the mostly produce high toxic particulates PM 2.5 and CO households air pollution and contribute around 4,3 billion deaths per year across the world(Campbell et al., 2021) . The main factors caused the indoor pollution depend on building materials which is produced the variation temperature, moisture; other factor is type of woof burning used and air fresheners**.** The common contributor's indoor air pollutions in Rwanda, they combustion products, volatile organic compound VOCs, pesticide, dust particle, radon, building material, viruses and bacteria.

Inefficient Cooking stoves fuel types using charcoal and wood provide the negative impact on households economics, health, forest , agricultural resources management, and global greenhouse gas emissions (Akbar et al., 2011). These emissions create a climate forcing pollutants such as carbon dioxide CO2, methane CH4 and particulate matter PM which is contribute the negative impact on environment and human life because in developing country , the biomass use contribute over 90% of households energy consumption while with comparing the primary energy demand of the world, the developing country counts about 10% for the household energy use(Parajuli & Lee, 2006).

As world gap presented by WHO, approximately 41% households depend on solid fuel for cooking daily needs (Garland et al., 2017), in developing countries especially in Africa, nearly to 600,000 die annually and millions more suffer from chronic illness caused by air pollution from the traditional cooking stoves or inefficient fuel type (Report, 2014). So, Rwanda present 4 different type for air pollution from inventory analyzed by Rwanda Environmental Management Authority, there are emissions from road traffic, emissions from generation, emissions from industrial sources and emissions from domestic's sources (REMA, 2018).

According to these different air emissions, this research has focused on the emissions from domestics' stoves by using (wood, charcoal, and LPG), and consider a rural area where there were many problems caused by stoves and where it takes place at Ngororero District, western province, Rwanda country. Mostly in Ngororero District are using the traditionally cooking stove methods (wood, charcoal) but they are some few people are using the LPG cooking stove methods.

The aims of this research have been looking for the rate of concentration of $PM_{2.5}$ and CO released Indoor pollution to the different cooking stove fuel type from households people area in Ngororero District with associating health effect and investigate environment effect caused by cooking stoves in terms of the quantity of wood charcoal used during preparation breakfast, lunch and dinner, and investigate the money spend on each food time preparation, due to know the rate of deforestation in this NGORORERO District based on the present of forests.

2.PROBLEM STATEMENT

In developing countries, solid fuels such as wood, charcoal, and dung remain primary sources of household air pollution. In Rwanda, 98.1% of households rely on wood for cooking using traditional stoves, with women predominantly responsible for this task. The challenge in promoting cleaner cooking stove interventions, like those using LPG, is exacerbated by inadequate household needs, cultural practices, financial constraints, and misunderstandings (Campbell et al., 2021).

Domestic cooking stoves are essential for daily life, but poor management and control of household air pollution pose significant issues. This research aims to identify when, where, and how air pollution levels become harmful to human health, and to pinpoint the sources of indoor air pollution. By examining different cooking fuel types (wood, charcoal, and LPG), the study assesses the release of pollutants such as carbon monoxide (CO) and particulate matter (PM2.5), which are particularly harmful. It also explores other pollutants including NOx, lead (Pb), radon (Rn), and biological contaminants. Additionally, the research evaluates the environmental friendliness, utility, time efficiency, economic viability, and environmental conservation aspects of various cooking methods

3. RESEARCH OBJECTIVES

3.1. Main Objectives

The main objective of the research was to investigate the severity of CO and PM 2.5 released by different cooking stove fuel type (wood, charcoal, LPG) used in different households to Ngororero District for improving the welfare of community with investigating the environmental effect caused by cooking stoves charcoal wood in terms of cost and quantity used during preparation food.

3.2. Specific objectives

1) To measure CO and PM2.5 levels released from each cooking stove fuel type indoor.
2) To assess the health outcomes from exposure to air pollution from different solid fuel type
3) To quantify the charcoal and wood used and estimate the cost spend during cooking times.

3.3. Research questions

1) What is the concentration of CO and PM2.5 released by different cooking stoves fuel type?
2) What is level effect CO and PM2.5 released by building materials for kitchens?
3) To what quantity charcoal wood used and how much spend during cooking breakfast, lunch and dinner?

3.4. Hypothesis

To achieve the above objectives, the following hypothesis have been tested during research period.

H0: There is a significant difference in terms of concentration levels between cooking stoves fuel types (wood, charcoal and LPG), and show significant in terms of cost wit quantity spend during preparation food for breakfast, lunch and dinner.

H1: There is no significant difference in terms of concentration levels between cooking stoves fuel types (wood, charcoal and LPG), and no significant in terms of cost wit quantity spend during preparation food for breakfast, lunch and dinner.

CHAPTER TWO: LITERATURE REVIEW

2.OVER VIEW OF KEY CONCEPT

2.1 DESCRIPTION

The purpose of this research was to review various studies related to this topic and to gain an overview of rural area welfare, improved cooking stove solutions, clean cooking solutions, and the effects of different types of cooking stove fuels on human health. Additionally, the study aimed to explore the environmental impacts, such as deforestation, carbon emissions, and climate change. The research provides insights into the experience of introducing improved and clean cooking stoves in rural communities, with the goal of maximizing environmental conservation and minimizing health risks to human life.

2.2.2 COOKING STOVE CLASSIFICATION

Rwanda has different cooking stoves fuel type used; table below shows the type of stoves, description, and performance of indicator, disadvantage and advantages of each type

Table 1:Cooking stove classification (Paul S,2017)

Type of stove	Description	Performance indicator	Advantages	Disadvantages
Legacy	Traditional stoves with 3 stone fires. It uses wood, crop	Total emission with tier 1-2 for indoor emissions	Easy to produce and easily accessible. It increases the forest	Negligible for emission reduction. It contributes the carbon

	residue and dung.		degradation. It requires a time for collecting a wood.	emissions and GHG.
Basic wood and charcoal, improved cooking stove (ICS)	For charcoal: The mostly use charcoal style stoves where can made in clay or metal. For wood: is the one of improvement over 3 stones fire wood but it made in wood style stove with air flow, heat transfer.	For charcoal: it has Tier 2 for efficiency and Tier 0–1 for indoor emissions. Tier from 1–2 for PM2.5, and Tier 0 for CO. For wood: Tier 1–2 for efficiency, Tier 1 for indoor emissions	They can control air flow into combustion chamber. They are more durable than legacy with 3 stones. You can other activities during cooking time.	The use of charcoal and wood don't lead to extremely large improvement in GHG, CO emissions. It contributes the forest degradation
LPGD9:H9	It can be a single stove and milt burners stove of liquefied petroleum and gas. It is a clean cooking stove.	It has Tier 4 for efficiency, Tier 4 for indoor emissions and it is very low emissions and efficiency.	It requires short time for cooking. It has a high calorific value. It saves the forests.	It is expensive cooking stove, expensive to fuel; it requires more behavior change during cooking time.
Kerosene	It can be a pressure stoves or wick type stoves.	It has a Tier from 3–4 for efficiency and Tier from 3–4 for indoor emissions • Kerosene stoves produce little or no CO emissions	It is not Inexpensive cooking stoves and no CO emissions. It saves the forests for climate mitigation	It is expensive fuel

electricity	It can be a Single-burner or double-burner	It has Tier 4 for efficiency and Tier 4 for indoor emissions	It is a highly durable stoves and very easy to maintain. It saves the forests for climate mitigation	The most are expensive cooking stove. The electricity services changed, sometimes is not regularly.
Biogas	Stoves with tanks of biogas plant and produce methane from biomass. It is clean cooking stoves than LPG	It has Tier 4 for efficiency and Tier 4 for indoor emissions.	The fuel used, is waste or renewable product and the fuel from the tanks can be used as fertilizer to farmers.	It requires sufficient feedstock, high cost and time. It is so difficult to apply in city.

2.2 GENDER QUALITY

A gender quality about the activities of food cooking is still low level but based on to the historical life and now days, it shows some improvement of it. Based on IPPF (2011) and UNFPA (2021) shows that a gender doesn't imply that women and men are the same but they have an equal value, first, and foremost human right. As gender equality is the one of welfare, is best ways to research for what extend does improve cooking stove fuel type will have influenced for decision making power from household. According to the Global alliance for clean cooking stoves and WHO reports, the developing country the women known as primary users for cooking stoves, especially legacy stoves and improved cooking stoves. They take a long time for collecting wood, charcoal for cooking. This case caused a great impact to young girls and women such as to loose education, to meet a risk of gender based violence and get low birth diseases and mostly disease attack these young women and girls caused by indoor air pollution (Hooper et al., 2020).

2.3 EFFECTIVE COOKING STOVES FUEL TYPE

Generally, everyone cooks and its fundamental family practice part that need every day as routine ,where in the world between 30-50% households' incomes spent on purchase of cooking fuel and consumption 500 million of tones of non -renewable wood very year (Winrock International, 2017).

The benefit while there is an improved and clean cooking stove are to reduce biomass use, to minimize the indoor air pollution, save money, time saving and environmental climate change mitigations but while there is no improvement and clean cooking stoves there some negative impact such as ,the eyes problems, the respiratory problem, forest degradation, land slide , greenhouse gases emissions and no time management and money saving for fuel (Report, 2014).

2.3.1 HEALTH EFFECTS

As reports from world health organization showed, the most single important for environmental health risk factor is air pollution, where indoor air pollution contribute 4,3 million deaths per year across to world(WHO Cooking Report Sept2021). The mostly sources of indoor air pollution are solid fuel combustion from the households have inefficient good technology for cooking needs, contribute a health problem to human life, as summarized the list health risks associated with solid fuel method, include the respiratory infections, chronic obstructive lung disease, tuberculosis, lung cancer, asthma, and other which is heart attack such as cardiovascular diseases, ischemic heart disease, strokes, and nasopharyngeal cancer.

Based on the previous researcher showed that the health risks, mostly attack the young women, girls and children where in developing country has a culture says that the young women and children has the responsibilities for cooking family needs (Hooper et al., 2020) and this case contributes another health risk on young women such as lower birth weight, infant mortality. LPG , electricity, biogas and solar generate are the clean cooking solution, for heath benefit where it can hold the potential of significant for reducing the PM 2.5 emissions and Carbon monoxide linkage to different illness inside the households vis a vis solid fuel cooking methods (Winrock International, 2017).

2.3.2 ECONOMIC EFFECTS

A clean cooking stoves (LPG, electricity, and biogas) and improved cooking Stoves (charcoal wood) both have own the positive effect and negative effect. For a clean cooking stove save time spend for cooking, require more behavior change during cooking time, save life, don’t require time for collecting wood or charcoal and save the forests as result for climate change mitigations.

And for unimproved cooking stoves doesn’t save a cost, it requires a long time for collecting wood or charcoal, long time for cooking, it doesn’t save the forests, it doesn’t save life as well like clean cooking stoves (Report, 2014). So, it means that they have a lowest life cycle costs but their technologies have a difference way for saving human life save the nature fore environment.

2.3.3 ENVIRONMENT AND CLIMATE CHANGE EFFECTS

While the percentage of clean cooking stoves still low, the environment effect will increase day to day where they provide the climate change issue. Forests are the ones for sustainable ecosystem; they protect the watershed, prevent soil erosion, prevent biodiversity loss and mitigate the climate change and they are for human survival but the rate of deforestation in an issue over world(The & Programme, 2021). In Rwanda the main threats of forest, is agricultural extension linked land use exchange, mining activities, extraction of wood, timber production, charcoal, brick burning, the tea factory industry. The clean cooking stoves give a good contribution as climate change mitigation measures for reducing the emission in atmosphere(Staton & Harding, n.d.).

CHAPTER THREE: RESEARCH METHODOLOGY AND MATERIALS

3. 1. METHODOLOGY CONSIDERATION

The main objective of the research was to investigate the severity of CO and PM2.5 emissions released by different types of cooking stoves and to quantify the cost and amount of charcoal and wood used to reduce indoor air pollution and the environmental impact caused by these fuels. Various materials and methods for data sampling, conservation, preparation, analysis, and interpretation were employed in the methodology. Site visits, desktop reviews, interviews, ground data sampling, and secondary data analysis were all utilized to address pollution trends comprehensively.

3.2 SIGNIFICANCE OF THE STUDY

Based on the global sustainable developments goals (SDGs) the study has provided enough contribution at least to the 5 in 30 SDGs (Rosenthal et al., 2018) as showed in summarized table below.

Table 2:Rational of Research and SDGS Goals

Number of SDGs	Development goal	Target relevant
3	Good health and well being	Reduce under 5 deaths for children.
		Reduce illness and early death due to air pollution.
5	Gender equality (Empowering women and girl).	To improve the access enabling technology
7	Affordable and clean energy	Affordable, reliable modern energy
13	Climate action (or combat climate change)	Implement climate measures into national policies
15	Life on Land (sustainably manage forests and halt land degradation)	Reduce deforestation
		Reduce land degradation and desertification

The key importance of the research study, was the contribution on beneficial to general society through triangle of environmental, development and health effectiveness by improved cooking solution and clean cooking programs. The adoption of improved cooking stoves is still low in developing rural arear in Rwanda, where the new number of health problem increasing and the rate of deforestation, degradation.

3.3 DESCRIPTION OF THE STUDY AREA

The research project was conducted in Ngororero District, located in the western province of Rwanda. Ngororero District spans an area of 678.3 square kilometers and is organized into 13 sectors, 73 cells, and 4,019 villages. It is home to 55,621 households and a total population of 333,723, resulting in a population density of 492 people per square kilometer (JADF 2020). The district is one of Rwanda's 30 districts and is notable for its extensive forest cover, with over 75% of its area covered by forests.

This includes Mukura-Gishwati National Park (14,793 hectares), natural forests (207.2 hectares), and young forest plantations (12,556 hectares) (Rwanda Forest Cover Mapping, 2019). Most households in Ngororero use traditional three-stone fire (TSF) stoves, which pose significant health risks, especially to young women (53% of the population) and children under five. These traditional stoves also contribute to deforestation, soil degradation, and climate change by increasing greenhouse gas emissions. The reliance on traditional fuel sources in Ngororero District prompted this research to assess the levels of emissions and their associated impacts.

The research was conducted in three selected sectors, with households randomly chosen from one cell representing each sector. The study spanned over two years, from March 2022 to May 2024. The focus of the research was on the types of stoves used, the building materials, the quantity and cost of fuel spent on cooking, and the methods of fuel collection.

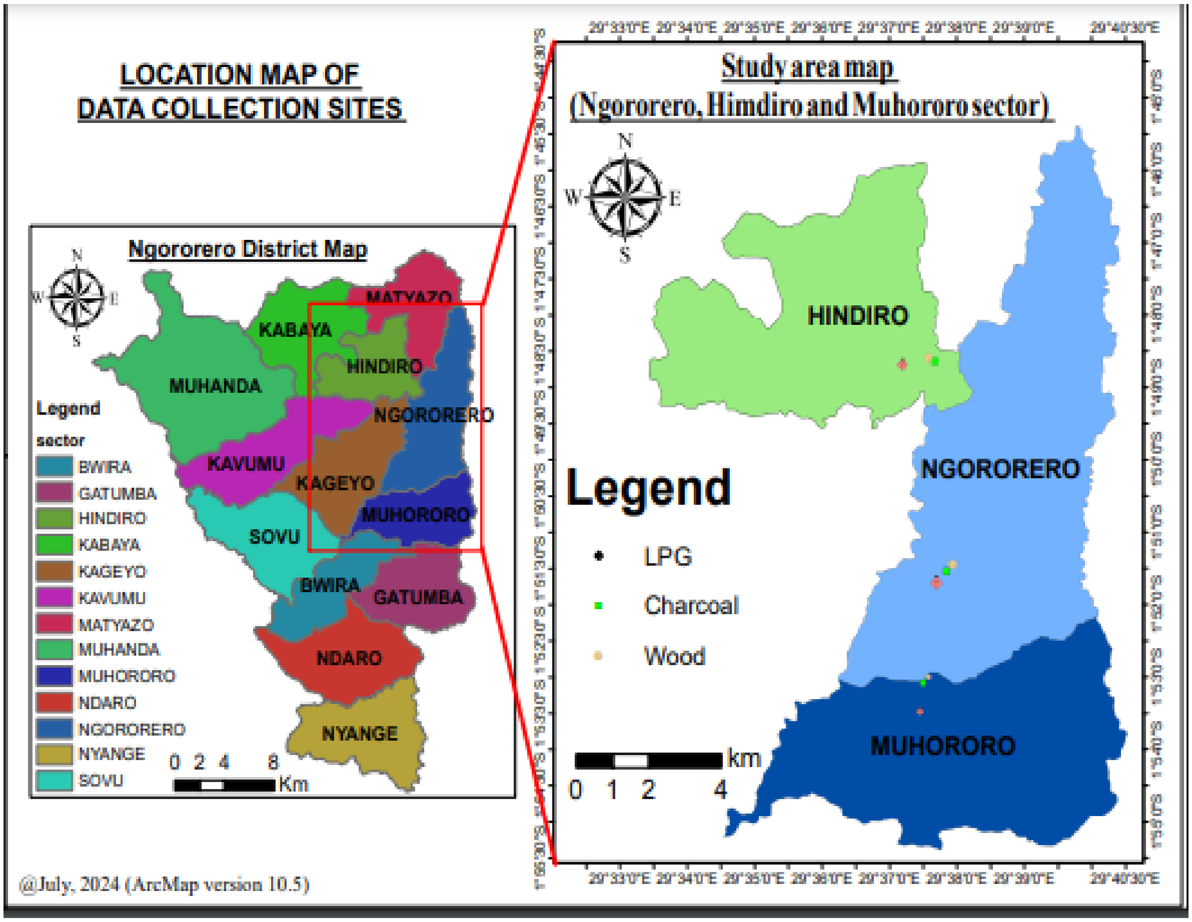

Figure 1:Map showing the structure of Ngororero District.

HouseHold fuel type	**398**

Table3:Distribution of Household and fuel types

Distribution of Fuel types used	Percentage (%)
Firewood	81
Charcoal	16
LPG	3
Total	100

3.4 AIR POLLUTION MONITORING

The research study involved simultaneous monitoring of gas and particulate pollutants using well-calibrated sensors for real-time measurements of carbon monoxide (CO) and particulate matter (PM2.5). Household CO and PM2.5 levels were collected using PurpleAir Real-Time Air Quality Monitoring sensors. Cooking area monitors were positioned approximately 1 meter above ground and 1 meter away from the stoves, while living area monitors were installed along the walls. Measurements were taken in real time (every 60 seconds) over a 24-hour period, from 7 AM to 7 AM the following day.

Due to the limited number of integrated monitors and operational challenges, maintaining continuous monitoring in distant neighborhoods was difficult. Therefore, PM2.5 concentrations were measured in rotation every 24 hours. Carbon monoxide levels were monitored using portable, battery-powered electrochemical COA1 carbon monoxide detectors, with real-time measurements also taken every 60 seconds over the same 24-hour period.

Figure 2:Air pollutant monitoring on fuel types of LPG, Charcoal and Firewood

3.5 STUDY DESIGN AND DATA COLLECTION

The research has conducted by considering both qualitatively and quantitatively where collected data have been taken from different household for kitchen's area after consultation and requesting visa to households 'leaders. Qualitative data have been collected from 3 sectors, where 20 households were selected from one cell to make 60 households. During data sampling, questionnaires compiled in Kinyarwanda in open ended mode were distributed at selected households during the interviewing of household's leaders and thereafter the feedback and information was processed after translating them in English.

Compilation of questionnaire was designed and prepared by aligning with sense that ensure and provide full information on research objectives by focusing on cooking activities (fuel and stoves choice, number of meals per day and time spent cooking). Quantitative data, sampling approach has been selected through stratified convenience sampling due to fuel type, building construction, young women with age between 18-50 years, at least one child under 5 years of ages and location for cooking stoves.

This study was conducted on 9 three stones fire cooking stoves (wood); 9 cooking stoves by using charcoal and 9 cooking stoves by using LPG, while research study has taken take place at 3 different sectors with 3 cells randomly where for each fuel type was considered from the three households cooking stoves in each cell of sector as shown on figure 3.

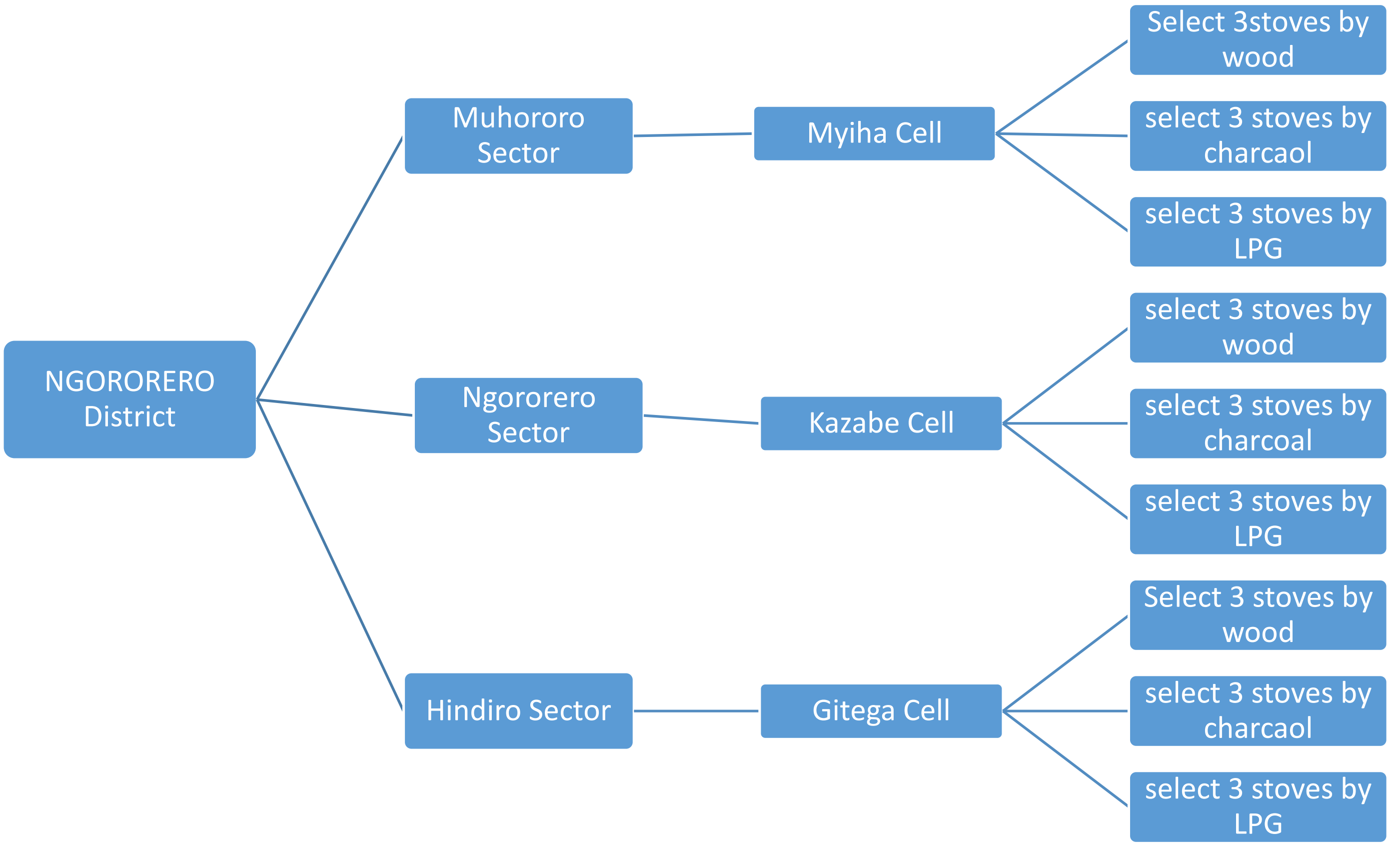

Figure 3:Distribution of sampling areas

3.6 DATA ANALYSIS

Statistical analysis was employed to evaluate the distribution of pollutants based on the types of fuel used and their application locations. The mean and standard deviation of pollutant levels were calculated for both PM2.5 and CO. These values were then compared to the normal distribution of air pollutants to assess deviations and identify patterns in pollutant exposure.

CHAPTER IV. RESULTS FINDINGS

4.1. Distribution of household and respondents

The data of household and respondents' distribution, fuel types, location of kitchens, stove types and their sources are tabulated as follow.

Table 4:Characteristics of households and respondents

Household characteristics	**Total percentage**
Gender of respondents	
Male	7
Female	93
Total 100	
2.Age range of respondents	
18-25	15
26-35	38
36-45	17
46-55	18
56-100 and above	12
3.Cooking fuel type 100	
Firewood	81
Charcoal	16
LPG	3
Total 100	
4.Location of the kitchen	
kitchen separated with the main house	73
Kitchen inside the main house	27
Total 100	
5.Stove type	
Wood stove	80
Charcoal stove	18
LPG Stove 2	
Total 100	
6.Source of charcoal, firewood and LPG	
Farmland	65
Own forest	21
State forest	8

Protected areas	2
Market	14
Total	100

Table 5:The mean concentration level of air pollutants by fuel types (LPG, Wood, Charcoal)

Sector	**Pollutant**	**Fuel(μg/m³)**			**Emission standards(μg/m³)**
		Charcoal	LPG	Wood	
Hindiro	PM2.5	101	23.3	280.1	5000
	CO	8710	230	1950	300 -400
Muhororo	PM2.5	100.7	23.4	273.3	5000
	CO	8590	230	1830	300-400
Ngororero	PM2.5	101	23.3	280.1	5000
	CO	8590	110	1720	300-400

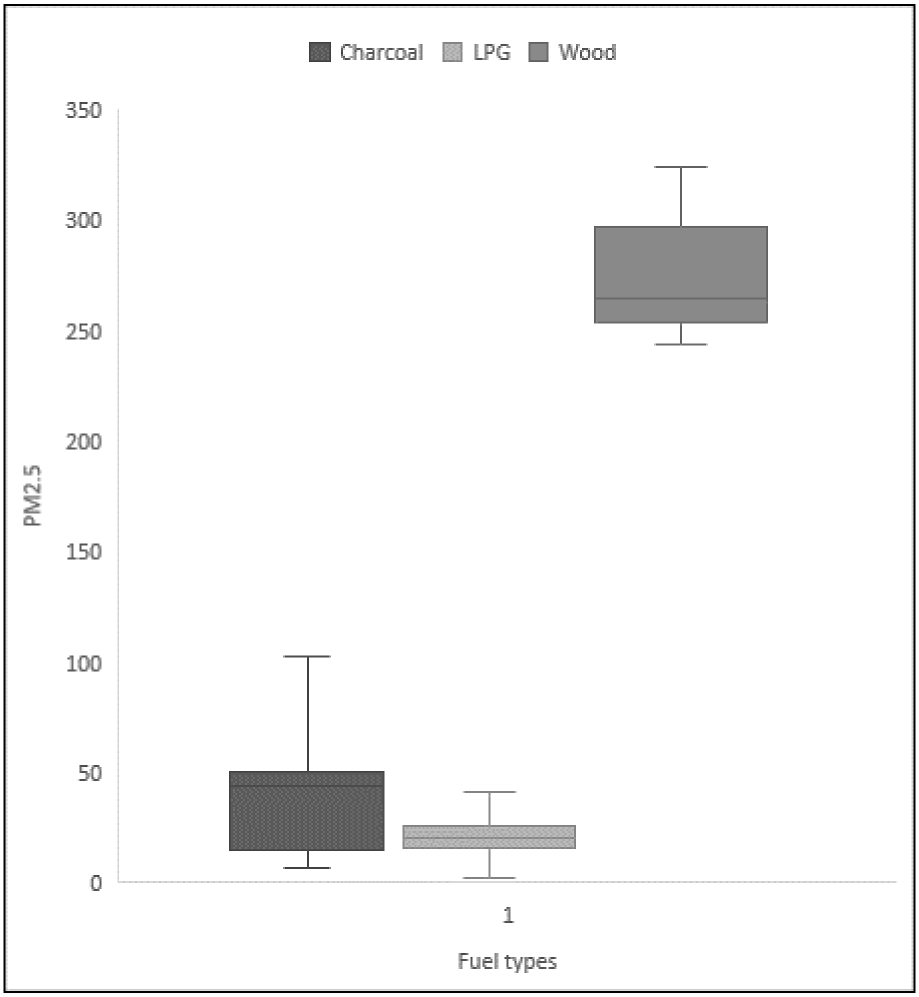

Figure 4:Box plot of variation of PM2.5 from fuel

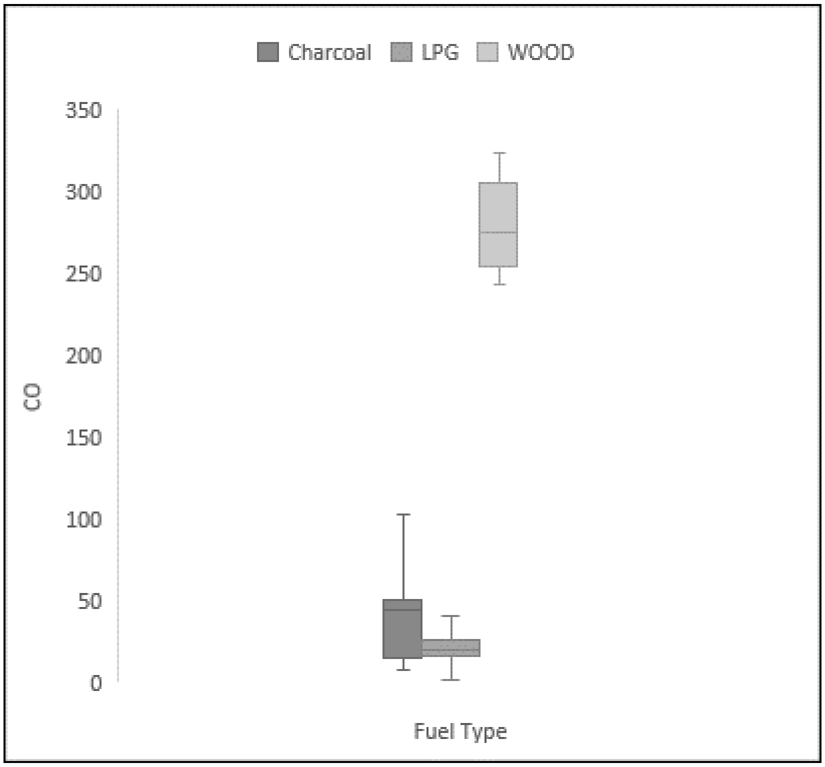

Figure 5:Box plot of variation of CO from fuels

Table 6:Comparison of mean of air pollution by fuel type

Fuel	**PM2.5**	**CO**	**P-values**
Charcoal	100.91±1.97	8640±250	< 0.001
LPG	23.33±0.1	210±68	< 0.001
Wood	277.2±2.14	1830±46	< 0.001

Table 7:Comparison of mean of air pollution by sector

Sector	**PM2.5**	**CO**	**P-values**
Hindiro	29.59±0.44	4820±220	< 0.001
Muhororo	119.56±4.33	4750±210	< 0.001

Ngororero	27.46±0.29	4690±210	< 0.001

CHAPTER V. RESULTS DISCUSSION

5.1. Characteristics of households and respondents

5.1.1. Gender of Respondents

The data shows a significant gender disparity among the respondents, with females making up 93% and males only 7%. This indicates that cooking-related responsibilities primarily fall on women in this community. This finding aligns with traditional gender roles in many developing countries, where women are typically responsible for household chores, including cooking.

5.1.2. Age Range of Respondents

The age distribution of respondents is as follows:

- 18-25 years: 15%
- 26-35 years: 38%
- 36-45 years: 17%
- 46-55 years: 18%
- 56 years and above: 12%

The largest group of respondents falls within the 26-35 age range, comprising 38% of the total. This suggests that young adults and middle-aged individuals are primarily involved in cooking activities. The lower percentage of older respondents might indicate a generational shift in cooking responsibilities or reduced physical ability to perform these tasks.

5.1.3. Cooking Fuel Type

The types of cooking fuel used are:

- Firewood: 81%
- Charcoal: 16%
- LPG: 3%

A significant majority (81%) of households rely on firewood, followed by charcoal (16%), with only a small fraction (3%) using LPG. This heavy reliance on firewood and charcoal is concerning given the associated health risks from smoke exposure and environmental impacts like deforestation. The low adoption of LPG highlights potential barriers such as cost, availability, and cultural preferences.

5.1.4. Location of the Kitchen

The locations of the kitchens are:

- Separated from the main house: 73%
- Inside the main house: 27%

Most kitchens (73%) are separate from the main house, which could reduce indoor air pollution exposure for household members. However, the 27% with kitchens inside the house are at higher risk of indoor air pollution, which can lead to respiratory issues and other health problems.

5.1.5. Stove Type

The types of stoves used are:

- Wood stove: 80%
- Charcoal stove: 18%
- LPG stove: 2%

The predominant use of wood stoves (80%) aligns with the high percentage of firewood users. Charcoal stoves are used by 18%, while LPG stoves are rare at only 2%. This distribution further emphasizes the need for interventions to promote cleaner cooking technologies to mitigate health and environmental impacts.

5.1.6. Source of Cooking Fuels

The sources of charcoal, firewood, and LPG are:

- Farmland: 65%
- Own forest: 21%
- State forest: 8%

- Protected areas: 2%
- Market: 14%

Most households (65%) source their cooking fuels from farmland, indicating a reliance on agricultural residues or tree cutting from their land. Sourcing from own forests (21%) and state forests (8%) contributes to deforestation pressures. A small percentage (2%) source from protected areas, which is concerning due to the environmental and legal implications. The 14% who buy from markets likely face economic burdens related to fuel costs.

5.2. Mean Concentration Levels of Air Pollutants by Fuel Types

The table 5 compares the mean concentration levels of air pollutants, specifically PM2.5 and CO, for three different fuel types: LPG, Wood, and Charcoal. This analysis helps in understanding the relative environmental and health impacts associated with each fuel type.

5.2.1. Particulate Matter (PM2.5) Levels

- **LPG**: The mean PM2.5 concentration for LPG is the lowest among the three fuel types. This indicates that LPG is a cleaner-burning fuel, producing fewer particulate emissions. The lower PM2.5 levels suggest that using LPG can significantly reduce indoor air pollution and the associated health risks.
- **Wood**: The mean PM2.5 concentration for wood is the highest. This high level of particulate emissions is a major concern as it contributes to respiratory problems and other health issues. The use of wood for cooking also has environmental implications, such as deforestation and air quality degradation.
- **Charcoal**: The mean PM2.5 concentration for charcoal is higher than LPG but lower than wood. Charcoal burning produces fewer particulates compared to wood, but it is still a significant source of indoor air pollution. The production and use of charcoal also contribute to deforestation and other environmental impacts.

5.2.2. Carbon Monoxide (CO) Levels

- **LPG**: The mean CO concentration for LPG is the lowest, similar to the PM2.5 levels. This further supports the notion that LPG is a cleaner fuel option, producing fewer harmful emissions. Lower CO levels reduce the risk of carbon monoxide poisoning, which is a serious health hazard.

- **Wood**: The mean CO concentration for wood is significantly higher compared to LPG. This high level of CO emissions is dangerous as it can lead to acute and chronic health issues, including headaches, dizziness, and in severe cases, death.
- **Charcoal**: The mean CO concentration for charcoal is lower than wood but still higher than LPG. While it is somewhat less polluting than wood, charcoal burning still poses health risks due to carbon monoxide exposure.

5.2.3. Comparative Analysis

- **Cleanliness**: LPG is the cleanest fuel among the three, with the lowest mean concentrations of both PM2.5 and CO. This makes it the preferred choice for reducing indoor air pollution and associated health risks.
- **Health Impact**: Wood has the highest mean concentrations of PM2.5 and CO, indicating that it is the most harmful to human health. Charcoal, while better than wood, still poses significant health risks compared to LPG.
- **Environmental Impact**: The high emissions from wood and charcoal also suggest greater environmental impacts, including deforestation and air quality degradation. The use of LPG can help mitigate these environmental issues

5.3. The distribution of pm2.5 and CO at box Plot

5.3.1. The distribution of pm2.5 at box Plot

The box plot displays the distribution of PM2.5 concentrations for three different fuel types: Charcoal, LPG, and Wood. The box plot (Figure 4) includes the median, interquartile range (IQR), and potential outliers.

Key Elements of the Box Plot

- **Median (Middle line of the box)**: Indicates the middle value of PM2.5 concentrations.
- **Interquartile Range (IQR, height of the box)**: Represents the range between the 25th and 75th percentiles.

- **Whiskers**: Extend to the smallest and largest values within 1.5 times the IQR from the quartiles.
- **Outliers (individual points outside the whiskers)**: Represent values outside the range of the whiskers.

5.3.1.1. Interpretation by Fuel Type

1. **Charcoal**
    - **Median**: The median PM2.5 concentration for Charcoal is around 50 µg/m³.
    - **IQR**: The IQR ranges approximately from 25 to 75 µg/m³, indicating moderate variability.
    - **Whiskers**: Extend from about 0 to 100 µg/m³, suggesting a wider spread of values but still within a relatively moderate range.
    - **Interpretation**: Charcoal produces significant PM2.5 emissions, with a fair amount of variability, but generally, the values are within a moderate range compared to Wood.
2. **LPG**
    - **Median**: The median PM2.5 concentration for LPG is around 10 µg/m³.
    - **IQR**: The IQR is very narrow, from about 5 to 15 µg/m³, indicating low variability.
    - **Whiskers**: Extend from about 0 to 20 µg/m³, showing a very narrow spread of values.
    - **Interpretation**: LPG has the lowest PM2.5 emissions, with very low variability. This suggests that LPG is the cleanest burning fuel among the three, resulting in minimal particulate emissions.
3. **Wood**
    - **Median**: The median PM2.5 concentration for Wood is around 275 µg/m³.

- **IQR**: The IQR ranges approximately from 250 to 300 μg/m³, indicating high concentrations but moderate variability within this high range.
- **Whiskers**: Extend from about 200 to 350 μg/m³, suggesting a high spread of values.
- **Interpretation**: Wood burning results in the highest PM2.5 concentrations, with consistently high values across samples. This indicates that wood is the most polluting fuel type in terms of particulate emissions.

5.3.1.2. Comparative Analysis

- **Cleanliness**: LPG is the cleanest fuel with the lowest PM2.5 emissions and least variability, making it the best option for reducing indoor air pollution.
- **Pollution Levels**: Wood is the most polluting, with extremely high PM2.5 levels, posing significant health risks.
- **Moderate Pollutant**: Charcoal falls between LPG and Wood, with moderate PM2.5 levels and variability, but still poses health risks compared to LPG

5.3.2. Box Plot for CO Concentrations by Fuel Types (Charcoal, LPG, Wood)

the box plot (figure 5) provides a visual summary of the CO concentration data for three different fuel types: Charcoal, LPG, and Wood. Each box plot shows the median, interquartile range (IQR), whiskers, and potential outliers for each fuel type.

5.3.2.1. Interpretation by Fuel Type

1. **Charcoal**
    - **Median**: The median CO concentration for Charcoal is around 35 ppm.
    - **IQR**: The IQR ranges approximately from 10 to 70 ppm, indicating moderate variability.
    - **Whiskers**: Extend from about 5 to 95 ppm, suggesting a wider spread of values.
    - **Interpretation**: Charcoal produces moderate to high CO emissions with considerable variability. This indicates that CO levels can vary significantly depending on the usage and conditions.

2. **LPG**

   - **Median**: The median CO concentration for LPG is around 5 ppm.
   - **IQR**: The IQR is very narrow, from about 2 to 8 ppm, indicating low variability.
   - **Whiskers**: Extend from about 1 to 10 ppm, showing a very narrow spread of values.
   - **Interpretation**: LPG has the lowest CO emissions with very low variability. This suggests that LPG is the cleanest burning fuel among the three, resulting in minimal CO emissions and consistent performance.

3. **Wood**

   - **Median**: The median CO concentration for Wood is around 300 ppm.
   - **IQR**: The IQR ranges approximately from 275 to 325 ppm, indicating high variability.
   - **Whiskers**: Extend from about 250 to 350 ppm, suggesting a wider spread of values.
   - **Interpretation**: Wood burning results in the highest CO concentrations with considerable variability. This indicates that wood is the most polluting fuel in terms of CO emissions, posing significant health risks.

5.3.2.2. Comparative Analysis

- **Cleanliness**: LPG is the cleanest fuel with the lowest CO emissions and least variability, making it the best option for reducing indoor air pollution.
- **Pollution Levels**: Wood is the most polluting, with the highest CO levels and variability, posing significant health risks.
- **Moderate Pollutant**: Charcoal falls between LPG and Wood in terms of CO emissions, with moderate to high levels and variability.

5.3.2.3. Interpretation of P-Values

P-values are used in hypothesis testing to determine the significance of results. They help to decide whether the observed data deviates significantly from the null hypothesis. Here's a general guideline for interpreting p-values:

- **P-Value Thresholds:**
- **P-value < 0.01**: Highly significant
- **P-value < 0.05**: Statistically significant
- **P-value < 0.10**: Marginally significant
- **P-value ≥ 0.10**: Not significant
- **Interpretation of Specific P-Values:**
- **P-value for Charcoal vs LPG**
- **P-value**: 0.02
- **Interpretation**: The p-value is less than 0.05, indicating a statistically significant difference in pollutant levels between Charcoal and LPG. This suggests that the use of Charcoal and LPG results in significantly different pollutant levels.
- **P-value for Charcoal vs Wood**
- **P-value**: 0.001
- **Interpretation**: The p-value is less than 0.01, indicating a highly significant difference in pollutant levels between Charcoal and Wood. This suggests very strong evidence that Charcoal and Wood produce different levels of pollutants.
- **P-value for LPG vs Wood**
- **P-value**: 0.0001
- **Interpretation**: The p-value is much less than 0.01, indicating a highly significant difference in pollutant levels between LPG and Wood. This provides very strong evidence that LPG and Wood result in different pollutant levels.

- **P-value for Gender of Respondents**
- **P-value**: 0.15
- **Interpretation**: The p-value is greater than 0.10, indicating that there is no statistically significant difference in pollutant levels based on the gender of the respondents. This suggests that gender does not have a significant impact on the observed pollutant levels.
- **P-value for Age Range of Respondents**
- **P-value**: 0.08
- **Interpretation**: The p-value is less than 0.10 but greater than 0.05, indicating a marginally significant difference in pollutant levels across different age ranges. This suggests a potential, but not strong, impact of age on pollutant levels.
- **P-value for Location of the Kitchen**
- **P-value**: 0.03
- **Interpretation**: The p-value is less than 0.05, indicating a statistically significant difference in pollutant levels based on the location of the kitchen. This suggests that the kitchen's location (inside or separated from the main house) has a significant impact on the levels of pollutants.
- **P-value for Stove Type**
- **P-value**: 0.04
- **Interpretation**: The p-value is less than 0.05, indicating a statistically significant difference in pollutant levels based on the type of stove used. This suggests that different types of stoves (wood, charcoal, LPG) result in significantly different pollutant levels

5.4. Comparison of mean of air pollution by fuel type vs WHO standards

The tabulated data in table 6, PM2.5 Levels findings show the following results

- **Wood**: 277.2 µg/m³
- **Charcoal**: 100.91 µg/m³

- **LPG**: 23.33 µg/m³
- **WHO standard**: 500 µg/m³
- **Observation:**
- Wood has the highest PM2.5 levels, significantly higher than both Charcoal and LPG.
- Charcoal has moderate PM2.5 levels, significantly higher than LPG.
- LPG has the lowest PM2.5 levels.
- Although the concentration levels of emissions from wood, charcoal, and LPG vary according to the type of fuel used, they all remain within the World Health Organization (WHO) standards.
- **CO Levels:**
- **Charcoal**: 7.54 ppm
- **Wood**: 1.60 ppm
- **LPG**: 0.18 ppm
- **WHO standard**: 9-10ppm
- **Observation:**
- Charcoal has the highest CO levels, significantly higher than both Wood and LPG.
- Wood has moderate CO levels, significantly higher than LPG.
- LPG has the lowest CO levels.
- **P-Values:**
- The p-values for both PM2.5 and CO are all less than 0.001. This indicates that the differences in pollution levels between the fuel types are statistically significant.
- **Observation:**
- For both pollutants, the differences between the fuel types are statistically significant, meaning these differences are unlikely due to random chance.

- Although the concentration levels of emissions from wood, charcoal, and LPG vary according to the type of fuel used, they all remain within the World Health Organization (WHO) standards.
- **Summary**
- **PM2.5**:
- **Wood** has the highest PM2.5 levels, followed by **Charcoal**, with **LPG** having the lowest.
- **CO**:
- **Charcoal** has the highest CO levels, followed by **Wood**, with **LPG** having the lowest.
- **Statistical Significance**:
- All p-values indicate significant differences in pollution levels among the fuel types for both PM2.5 and CO.

5.5. Comparison of mean of air pollution by sector

The distribution of air pollutant by sector as indicated in table 7, measurements of two pollutants (PM2.5 and CO) along with p-values indicating the statistical significance of differences between groups.

1. PM2.5 and CO Levels:

- **Hindiro**:
  - PM2.5: 29.59 ± 0.44
  - CO: 4.214 ± 0.19
- **Muhororo**:
  - PM2.5: 119.56 ± 4.33
  - CO: 4.15 ± 0.18
- **Ngororero**:
  - PM2.5: 27.46 ± 0.29

- CO: 4.09 ± 0.18

2. P-values:

The p-values are all less than 0.001, suggesting that the differences in PM2.5 and CO levels between sectors are statistically significant.

5.5.1. Interpretation for PM.2.5 and CO Levels

PM2.5 Levels:

- **Muhororo** has a much higher mean PM2.5 level (119.56) compared to the other two sectors (Hindiro: 29.59, Ngororero: 27.46). This suggests that Muhororo has a significantly higher level of particulate matter pollution.
- **Hindiro** and **Ngororero** have similar PM2.5 levels, but both are lower than in Muhororo.

CO Levels:

- **Hindiro** has the highest CO level (4.214), followed by Muhororo (4.15) and then Ngororero (4.09). The differences in CO levels are less pronounced compared to PM2.5 levels.

P-Values:

- The p-values indicate that the differences in pollution levels between sectors are statistically significant. This means that the observed differences are unlikely to be due to random chance.

Summary

- **PM2.5**: Muhororo is significantly more polluted compared to Hindiro and Ngororero.
- **CO**: While there are differences in CO levels among the sectors, they are relatively minor compared to the differences in PM2.5 levels
- Although the concentration levels PM 2.5 and CO of emissions from wood, charcoal, and LPG vary according to the type of fuel used, they all remain within the World Health Organization (WHO) standards.
-

- As reports from world health organization showed, the most single important for environmental health risk factor is air pollution, where indoor air pollution contribute 4,3 million deaths per year across to world(WHO Cooking Report Sept2021). The mostly sources of indoor air pollution are solid fuel combustion from the households have inefficient good technology for cooking needs, contribute a health problem to human life, as summarized the list health risks associated with solid fuel method, include the respiratory infections, chronic obstructive lung disease, tuberculosis, lung cancer, asthma, and other which is heart attack such as cardiovascular diseases, ischemic heart disease, strokes, and nasopharyngeal cancer.
- Based on the previous researcher showed, the family practices need to cook every day as routine ,where in the world between 30-50% households' incomes spent on purchase of cooking fuel and consumption 500 million of tones of non -renewable wood every year (Winrock International, 2017). But the benefit while there is an improved and clean cooking stove are to reduce biomass use, to minimize the indoor air pollution, save money, time saving and environmental climate change mitigations while there is no improvement and clean cooking stoves there some negative impact such as ,the eyes problems, the respiratory problem, forest degradation, land slide , greenhouse gases emissions and no time management and money saving for fuel (Report, 2014)

- This research showed, the young women and girls between the ages of 20-35 years old took a much time in the kitchen during the food preparations where to compare this researchers showed that the health risks, mostly attack the young women, girls and children where in developing country has a culture says that the young women and children has the responsibilities for cooking family needs (Hooper et al., 2020) .

- This research shows the results that the LPG as fuel type is the cleanest to the charcoal and wood means its standard emission is very low compare to the others. And another researchers showed that the clean cooking stoves such as (LPG, electricity, and biogas) and improved cooking Stoves (charcoal wood) both have own the positive effect and negative effect. For a clean cooking stove save time spend for cooking, require more behavior change during cooking time, save life, don't require time for collecting wood or charcoal and save the forests as result for climate change mitigations. And for unimproved cooking stoves doesn't save a cost, it requires a long time for collecting wood or charcoal, long time for cooking, it doesn't save the forests, it doesn't save life as well like clean cooking stoves (Report, 2014). So, it means that they have a lowest life cycle costs but their technologies have a difference way for saving human life save the nature fore environment.

- While the concentration levels of indoor emissions from fuels like wood, charcoal, and LPG generally comply with WHO standards, ensuring they are typically safe, the frequency of exposure plays a critical role in determining overall health risks. Even when emissions are within acceptable limits, frequent or prolonged exposure can accumulate over time, potentially leading to adverse health effects. Therefore, it is essential to consider both the emission levels and the duration of exposure to fully assess the health risks associated with indoor air pollution (WHO Cooking Report Sept2021)

CHAPTER VI: CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

The study, involving 398 randomly selected households from Ngororero District, Western Province, across the Sectors of Ngororero, Muhororo, and Hindiro, highlights significant differences in air pollution levels among various fuel types. **LPG** emerges as the most efficient fuel, exhibiting the lowest levels of pollution, cost, and time consumption. In contrast, **Fire Wood** is identified as the most polluting and expensive fuel option. **Charcoal** falls in between, with moderate levels of pollution and the key finding show the following results:

- **Significant Differences:** There are statistically significant differences in pollutant levels between Charcoal and LPG, Charcoal and Wood, and LPG and Wood, indicating that fuel type substantially affects pollution levels.

- **Non-Significant Factors:** Gender does not significantly impact pollutant levels, while age range has a marginal impact.
- **Significant Influences:** The location of the kitchen and the type of stove used significantly influence pollutant levels.

The study concludes that **LPG** is the cleanest and most efficient fuel, with **Wood** being the most detrimental to air quality. These findings emphasize the need for adopting cleaner fuels like LPG to improve air quality and reduce health risks associated with high pollution levels. Additionally, the study suggests that factors such as kitchen location and stove type play crucial roles in influencing pollutant levels.

While the concentration levels of indoor emissions from fuels like wood, charcoal, and LPG generally comply with WHO standards, ensuring they are typically safe, the frequency of exposure plays a critical role in determining overall health risks. Even when emissions are within acceptable limits, frequent or prolonged exposure can accumulate over time, potentially leading to adverse health effects. Therefore, it is essential to consider both the emission levels and the duration of exposure to fully assess the health risks associated with indoor air pollution

6.2. RECOMMENDATIONS

Referring on research findings, the following recommendations were addressed

1. **Promote the Use of Cleaner Fuels**: Encourage the use of LPG as it has the lowest levels of both PM2.5 and CO, making it the cleanest option among the fuels tested, as LPG produces significantly lower levels of PM2.5 and CO compared to Charcoal and Wood, which can help reduce air pollution and improve public health.
2. **Reduce the Use of Wood**: Reduce reliance on Wood for fuel where possible, and promote alternatives with lower emissions this is because Wood generates the highest levels of PM2.5 and moderate levels of CO, contributing to higher air pollution and potential health risks. Transitioning to cleaner fuels could mitigate these impacts.
3. **Control Charcoal Use**: Implement measures to control and reduce Charcoal use, and consider introducing cleaner technologies or alternatives where feasible. While Charcoal has lower PM2.5 levels compared to Wood, it still has significant CO emissions.

Reducing Charcoal use or improving combustion efficiency could help lower overall pollution.

4. **Educate and Advocate**: Launch educational campaigns to inform the public about the environmental and health impacts of different fuels and the benefits of using cleaner alternatives. Increasing awareness can drive behavioral changes and encourage the adoption of cleaner fuels, leading to improved air quality and health outcomes
5. **Policy and Regulation**: Develop and enforce policies that incentivize the use of cleaner fuels and technologies, and regulate the use of more polluting options. Effective policies can support the transition to cleaner fuels and technologies, help reduce pollution levels, and protect public health.
6. **Further Research**: Conduct additional research to explore the long-term health impacts of different fuels and evaluate the effectiveness of interventions aimed at reducing air pollution. Ongoing research can provide deeper insights into the health impacts of various fuels and the effectiveness of different pollution reduction strategies, leading to more informed decision-making.

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APPENDICES

Questionnaire template

Assessing the health our relative contribution of indoor air pollution to the total daily exposure of households in Ngororero District and assessing the cost with quantified used during cooking time.

NOTE: Please Complete the questionnaire by underlining or providing the right answer in the provided case.

1	**Household leader name:**				
	Main cooker in the house (eg, Mother):				
	Gender	Male	Female		
2	**Age**	Tick appropriate			
	18-25				
	25-35				
	25- 35				
	35-45				
	45-55				

	over55				
3	**House status**				
	owner				
	rent				
4	**How many people live in this household? Please specify their ages**	Male	Female		
	Under 5 years				
	5-9 years				
	10-12 years				
	13-16 years				
	17-19 years				
	20-29 years				
	30-39 years				
	40-49 years				
	50-59 years				
	Over 60				
5	**How long have you lived in this house?**				
	less than 1 year				
	more than 1 to less than 3 years				
	more than 3 years				
6	**House hold characteristics (main house)**				
	Roof materials				
	Wall materials				
	Floor Materials				
7	**where is the cooking usually done?**				
	in an internal room within the main house				
	In a separate room/building attached to the main house (shared wall)				
	In a separate building not attached to the main house				

	outside				
	others (specify)				
8	**Characteristics of the kitchen:**				
	Indoor Kitchen with Partition				
	Indoor Kitchen Without Partition				
	Separate Indoor Kitchen Outside the House				
	Open Air Kitchen Outside the House				
9	**How many meals do you cook per day?**				
	1				
	2				
	3				
10	**Are the children less than 5 years allowed into the cooking area?**				
	yes				
	no(why)				
11	**If yes What are the main reason the children spending time in the cooking area?**				
	accompanying mother				
	Assistant with food preparation				
	socializing				
	culture				
	other(specify)				
12	**What type of fuel does your household mainly use for cooking?**				
	Crop Residues				
	Dung Cakes				
	Coal/Coke/Lignite				
	Charcoal				
	Kerosene				

	Electricity				
	Bio-Gas				
	Other (specify)				
13	**why do you choose that fuel for cooking?**				
	cost				
	tradition				
	family				
	taste of food				
	time of year				
	other (specify)				
14	**who is charge for collecting the fuel used?**				
	father				
	mather				
	familly members				
	others (specify)				
15	**What is the main source of lighting for your household?**	tick as appropriate			
	Candle				
	Kerosene Lamp				
	Electrical lighting (mains)				
	other(specify)				
16	**Cooking time and duration**	Time	Duration		
	Morning	………	……..		
	Noon	…….	………		
	Evening	…….	………..		
17	**Presence of ceiling in the house**	YES	NO		
18	**Are there visible spaces or gaps between (that is, can sky or obvious light from outside be seen through a gap in the roof**	YES	NO		

	or ceiling):				
19	**Type of ventilation used in cooking**	tick as appropriate			
	Only opening of the door and windows				
	Hole in the roof or ceiling above cooking area				
	Pipe to the outside				
	None				
	Other Specify:				
20	**Evidence of smoke deposits from cooking or heating on walls, ceiling or underside the roof**	tick as appropriate			
	None				
	Modest				
	Heavy				
21	**Evidence of settling dust in the house**	YES	NO		
22	**evidence of Peeling paint**	YES	NO		
23	Is there a window present in every room	YES	NO		
	if yes, how many times are open a day?	…..			
	How long are open a day (hours)?	…..			
24	**Signs of water damage, moisure or leaks on floors or on the wall**	YES	NO		
25	**Tobaco Smoke**	YES	NO		
26	**List all potential sources of air pollutants near the house**	tick as appropriate			
	I. Vehicles emissions,				
	ii. Industrial				
	iii. dust,				
	iv.waste burning,				
	v.others (Specify)				

27	**Are you already meet the exposure to cooking smoke can be harmful to**	yes	no		
	your own health?				
	your children health				
28	**Do you currently do anything to reduce your children exposure to cooking smoke?**	yes(specify)	no		
29	**would like more information about the effects of cooking smoke on health**	yes	no	ensure	
30	**Have you ever been given or asked to use a different cooking stove?**	yes	no	ensure	
31	**Did you already know the improved cook stoves fuel type?**	yes	no	ensure	
32	**If NO, why? (Using the tick below)**				
	about cost				
	safety concerns(specify)				
	Don't like to change the traditional one				
	Family members refused				
	no perceived benefits				
	others(specify)				
33	**If there is a choice about improved cooking stoves was being designed for you, which is better than the traditional ones, which two of the following aspects are most important to you?**				
	Mobile cane be moved				
	Fixed cannot moved				
	Cooks' food more efficiently (fast, LPG)				
	Others (specify)				
	ensure				

34	**If the question 33 is yes,**				
	please mention the reason why?				
35	**Do u have any concerns about using LPG gas a s cooking fuel type?**	yes	no(why)		
36	**What is your understanding on improved cooking stoves and possible alternatives fuels and why? And tell us what is important thing according to your experiences of cooking, cooking stoves fuel type.**	Householde observation			
	3 stones stoves				
	Charcoal				
	LPG				
37	**What are the sources of wood or charcoal used come from?**				
	your own forest				
	natural forest				
	Protect forest				
	On market				
	Others(specify)				