PROJECT TITLE: **The Inexpensive IAP reduction system**

NAME : **Tanaka Chirara**

SCHOOL : **ZRP High School**

CITY : **Harare**

PROVINCE : **Harare Metropolitan**

COUNTRY : **Zimbabwe**

INTRODUCTION

- According to the World Health Organization (WHO), around 2.6 billion people cook and heat using polluting open fires or simple stoves fuelled by kerosene, biomass (wood, animal dung and crop waste) and coal (*Air Pollution Data Portal*, n.d.). This generates high levels of health-damaging Indoor Air Pollution (IAP), such as particulates, tar and carbon monoxide. Because women are primarily responsible for cooking and raising young children, both are disproportionately affected by IAP. For example, the World Health Report (2002) states that in developing countries among the poor, Acute Respiratory Infection (ARI) is one of the leading causes of childhood mortality (under 5) and is responsible for up to 33% of all ARI cases. IAP also adversely affects Zimbabwe because of the number of people who live in poor, rural regions. (*Rural Population (67% of Total Population…2020) - Zimbabwe | Data*, n.d.).

Traditional cooking over an open fire. (Source: Author)

- A second problem caused by open or traditional heaths is the inefficient use of fuel. Past efforts to reduce IAP have focused on efficient combustion but have not necessarily focused on thermal efficiency of the overall cooking and heating process. As a result, a significant portion of the fuel's energy is lost, leading to increased levels of deforestation. In parallel, people who are faced with the challenge of indoor air pollution are from low-income communities which makes it very difficult for them to afford expensive clean cooking stoves. Most of the existing solution focus only on reduction of Indoor Air Pollution, but fall short on distribution the solution to billions of people who need it.

INTRODUCTION cont.

- Because of the above issues, the engineering goal of this experiment is to create pattern designs of creating an affordable, simple, and efficient cooking system whose design is based on origami. Origami is the Japanese technique of creating complex 3-dimensional objects from flat sheets of paper. All that is needed to make a well known object such as a Crane, Cube or Lion is the pattern and a piece of paper. Likewise, the clean cooking system's components will be fabricated from flat metal sheets using simple folds and cuts, enabling them to be made worldwide without complex fabrication techniques. Additionally, if a component's pattern is known, it can produce it using locally available material and tools. This reduces or eliminates funding and production bottlenecks that have limited the impact of prior efforts when attempting to produce and distribute billions of units worldwide.

- Since many regions that suffer from indoor air pollution also have electricity shortages, the practicality of using the thermoelectric chips to generate electricity from the cooking stove's waste heat is evaluated. Its cost per watt hour is compared to alternatives such as simple solar panels with local storage (batteries or super capacitors.)

HYPOTHEISIS AND TESTING METHOD

Procedure followed to design and construct the cooking Stove

Design a prototype unit, based on interviews with Zimbabwe residents who are affected by IAP. Test the :

- Alternative Hypothesis: A easy to construct, low-cost cooking system will significantly reduce IAP.
- Test Null Hypothesis: A low-cost cooking system will not significantly reduce IAP.

Key Variables:

  - Independent: Cooking method- Traditional hearth, Clean cooking system, Amount of fuel burned
  - Dependent: Cooking particulate residue (weight), Carbon Monoxide concentration, Temperature of stove

- **Experimental Procedure:**
  - Burn constant amount of fuel using both cooking methods (Open fire vs IAP Reduction Unit)
  - Measure weight of particulate residue from the smoke collected by HEPA filter
  - Measure concentration of Carbon Monoxide (CO) and heat at set time intervals.

.

- Compare weight of fuel residue, CO concentrations and heat generated..
- An infrared temperature thermometer at the different parts of the unit with respect to time
- A simple chimney with filter paper is designed to measure the weight of carbon and particulates per unit time.
- A CO meter is used to measure the concentrations of CO present throughout the burning process
- Determine if there a significant difference in IAP and combustion efficiency between the traditional and IAP Reduction cooking system

DESIGN

Procedure followed to design and construct the cooking Stove

- Test the performance of designs based on the experience of Zimbabwe residents who cook inside of their dwellings without proper ventilation and suffer from IAP.
- One square meter of discarded sheet metal 1mm thick was used to create several different units.
- The metal sheet was marked using some chalk to create fold lines and cut lines.
- The marked shapes were cut using sheet metal snips. The shapes were joining by folding the edges of the two-dimensional shapes to form three-dimensional shapes.
- Note: Pop rivets were used for speed, but the shapes can all be assembled using folded tabs.

Design of Combustion Chamber: The combustion chamber is designed in a rectangular prism shape. In the combustion chamber fuel (wood pieces) are combusted. It was observed that inner chamber became red hot. To reduce the heat losses from inner chamber, a jacket of coarse sand and heat resistance refractory material was added (Fire Clay). As shown in the figure below.

Thermal design assumption of the cooking stove

No-	Material	Parameter	Units	Values	Reference
1	Fuel Wood twigs	Calorific value	MJ/kg		
2	Stainless steel	Thermal conductivity	W.m−1. K−1	16	Young, 1992
3	Air	Thermal conductivity	W.m−1. K−1	0.02	Lienhard IV, 2000
4.	Flame	Theoretical Maximum temperature	K	2123	Yusuf, 2011

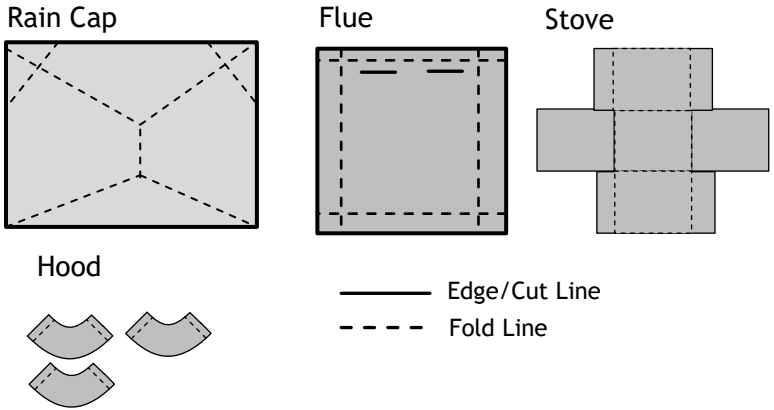
Photo taken by Panashe Garikai

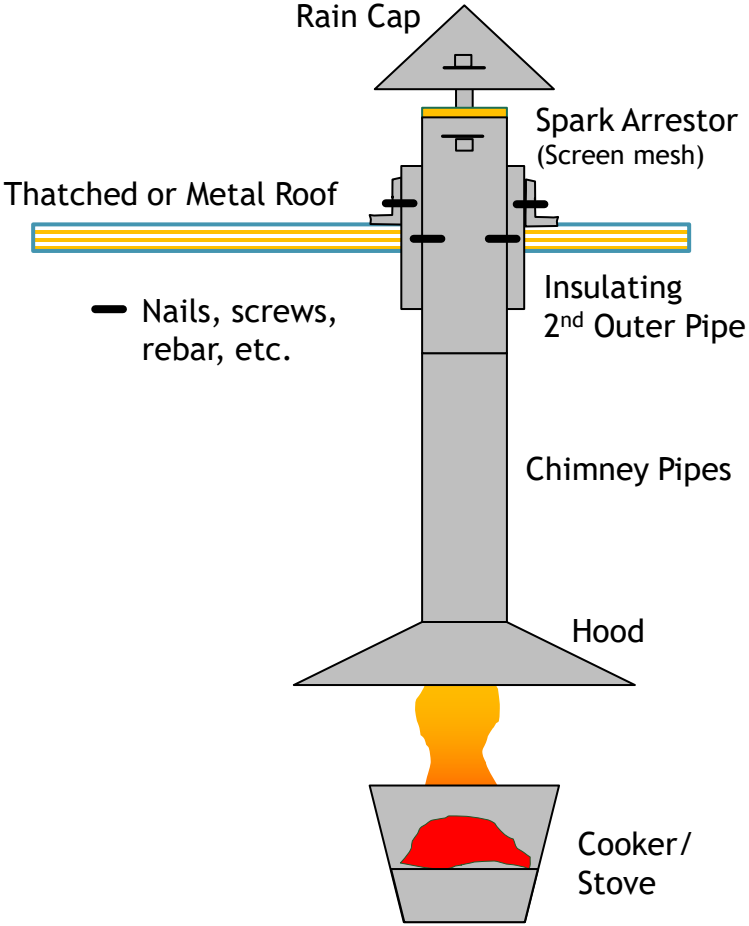
Photo taken by Panashe Garikai

DESIGN cont.

- Clean Cooking System has two components
  - Stove “Cooker” to burn fuel more efficiently and reduce emitted smoke.
  - Chimney and hood, to eliminate fumes from dwelling. The chimney is isolated from the roof by a 2nd outer pipe. Nails are used to isolate the chimney pipe from the insulating pipe and the roof.

Example Patterns (Not to scale)

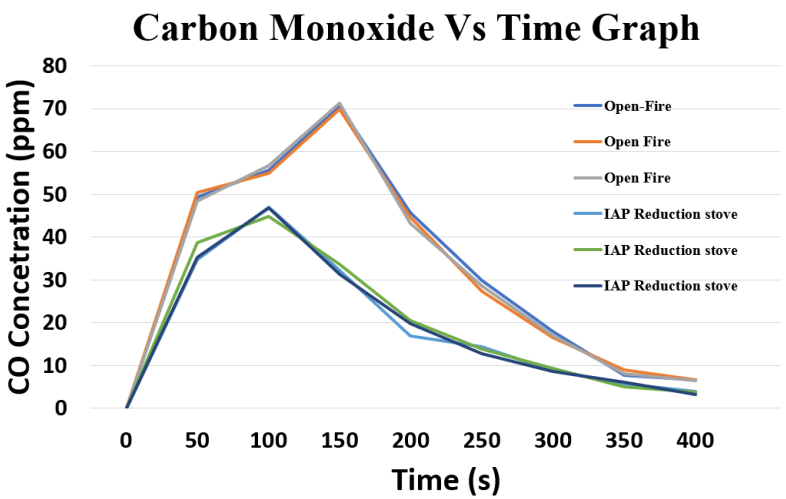




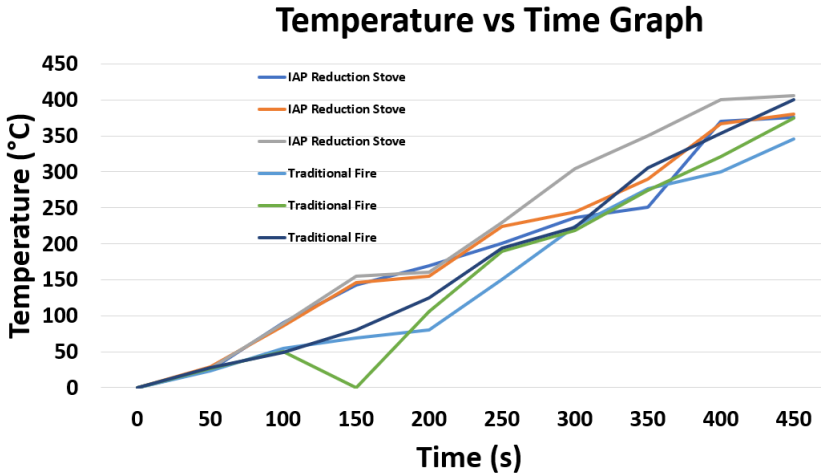
RESULTS

For the experimental results the IAP reduction cook stove was compared to an open traditional fire in terms of temperature carbon monoxide concentration and weight of particulates and tar released.

Graph 1.1 shows CO concentration vs time o f the 2 cooking methods

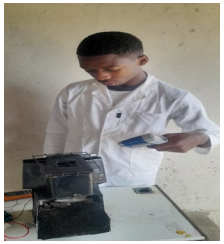


Graph 1.2 shows temperature vs time o f the 2 cooking methods

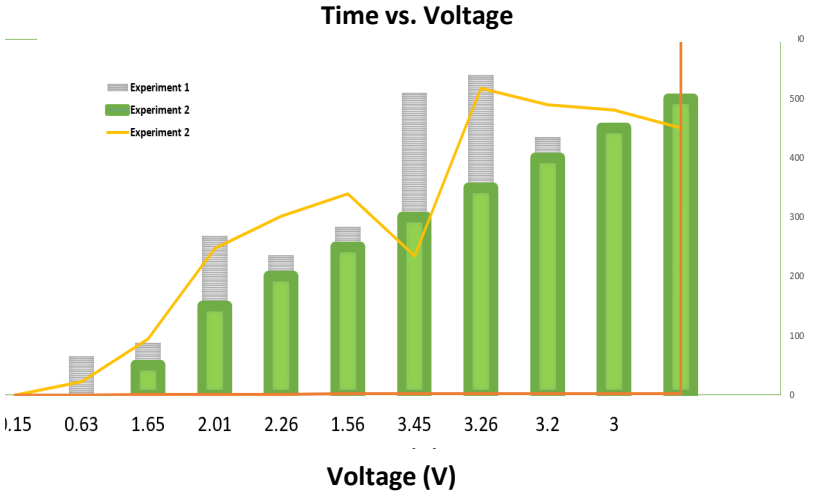


Traditional open fire

Clean Cooking Stove – Source: Author



Graph 1.3 shows CO concentration vs time o f the 2 cooking methods



Graph 1.4 shows CO concentration vs time o f the 2 cooking methods

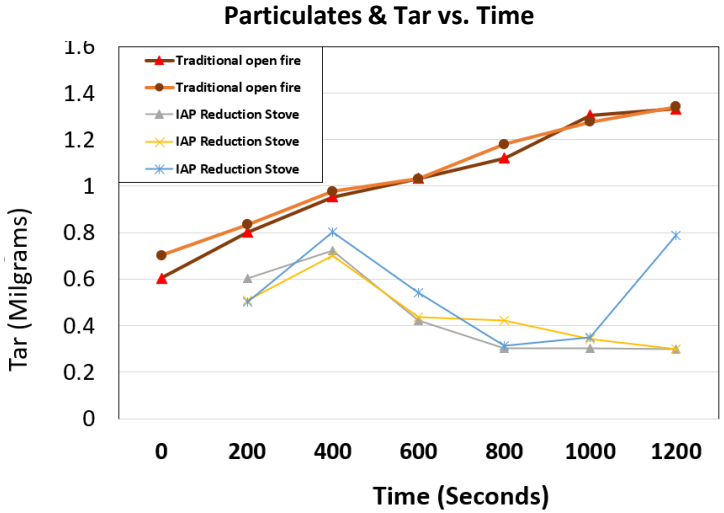
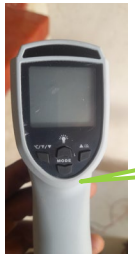


Photo taken by Panashe Garikai

Photos taken by Panashe Garikai

Thermoelectric Chip

Carbon Monoxide Meter



Infrared Thermometer

Some of the apparatus used in carrying out the experiment

DISCUSSION

- Equal amounts of homogenised fuel with the same moisture content were used to run all the test experiments. To ensure the fuel sample had the same moisture content they were enclosed in a black plastic bag through out the experiment.
- In the CO concentration vs Time graph a curve was produced which shows the distribution through the fuel burning process. According to the data the IAP Reduction Stove had a lower mean CO concentration produced per unit time which implies it had higher burning efficiency when compared to the traditional fire
- According to the particulate and tar vs time graph, the weight of particulates and tar in milligrams from the IAP Reduction Stove were less when compared to the weight of particulate and tar from a traditional open fire
- The decrease in the CO concentration and in weight of particulate and tar by IAP Reduction stove per unit time when compared to traditional open fires proves the null hypothesis of the experiment to be correct thus there is correlation between cooking methods and gases produced.
- According to the temperature vs Time graph, the IAP Reduction Stove reached the highest temperature per unit time when compared to traditional open fire which meant the designed sand heat insulation jacket of the IAP Reduction stove helped to improve the thermal efficiency of the unit per unit time.
- An attempt was made to capture the waste heat released to the environment by the IAP Reduction Stove during the burning process. The voltage vs time graph shows the amount of power generated by the TEG-12610 5 1 thermoelectric module that was attached to the IAP Reduction Stove as way to capture and utilise the waste heat released. While the thermoelectric module produced useful electricity, its cost was 10 times more per kilowatt hour than commercially available solar panels. Additionally, lengthy blackouts, limited time, resources, and budget made it impossible to perform additional experiments to thoroughly investigate thermoelectric chips.

CONCLUSION

- The results disproves the null hypothesis in the tested configuration. The clean cooking apparatus does reduce IAP. Therefore, the next step will to be improve the design of the IAP Reduction Stove so that it best suits the people who need it the most. The next step will be building a full-scale prototype with the hood and chimney to test the cut and fold patterns and the minimum gage steel that can be used.
- After building the prototype it is then installed in a unit dwelling with a steel roof or thatched roof to determine its usefulness and efficiency in the real world.
- I will also look for partners to create the units and a website where those who have installed a unit can upload their experiences and suggested improvements (and their improved layout patterns). This adopts the highly-successful approach of crowdsourcing, whereby products are continually improved by their users. This enables the basic approach to be refined for different climates, cultures and lifestyles. Examples of this include Waze, which collects traffic data for use by everyone, MacDonalds and Starbucks, who collect user ideas to improve their products, and the publicly maintained software UNIX operating system, (Berkeley Standard Distribution - BSD), and its descendent, Linux, which is installed on over 32.8 million systems and on 1.6 billion Android phones worldwide (99 Firms 2022).

BIBLIOGRAPHY OF REFERENCES

- *Air pollution data portal*. (n.d.). Retrieved 13 February 2022, from https://www.who.int/data/gho/data/themes/air-pollution
- WHO (2002). *The World Health Report 2002: Reducing Risks, Promoting Healthy Life*. World Health Organization.
- *Rural population (% of total population)—Zimbabwe | Data*. (n.d.). Retrieved 13 February 2022, from https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ZW
- U. O. Yusuf, "Experimental performance evaluation of charcoal stove. Department of mechanical engineering-University of Nigeria, 2011".
- H. D. Young, Physics, vol. 1, Addison-Wesly Publishing Company & Inc, 18th edition, 1992 Rohani (the year 2010) www.sciencedirect.com
- Heat transfer engineering, Naim Afgan, MGS Carvalho and Suzana Prstic (July 2003) www.researchgate.net
- Thermoelectric power generator by Joseph W.Harpster(March 2007) www.britannica.com
- Thermoelectric Energy Harvesting article by D Enescu www.intechopen.com
- *Adora, Mr. Nikunj; Mehta, Prof Shruti; Shah, Mr. Pratik (2015-03-01).* "Review of thermoelectricity to improve energy quality"*. 2 – Issue 3 (March-2015). JETIR. www.metadata.com*
- 99 Firms*, Linux Statistics (2022-18-2). https://99firms.com/blog/linux-statistics/#gref*