Evaluating Steer Manure and Sawdust Mixtures as an Alternative Cooking Fuel for Women in East Africa

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Civil and Environmental Engineering Capstone Team

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Project Background

Need

More than 2.7 billion people rely on burning biomass fuels for cooking [1].

Women spend between 2 to 9 hr/day collecting fuel wood [2].

Burning wood produces hazardous chemicals and pollutants

- Particulate Matter ($PM_{2.5}$), fine particles that harmfully affect the respiratory system [3].

Goal

Develop a cleaner and easy to access alternative fuel with a high energy content and low PM emissions.

Project Background

Client

Women in a Maasai village and any other pastoral communities in East Africa.

- The availability of Steer Manure

Demonstration of Jiko stove

Figure 1: Cooking in developing countries. Photo taken by: Dianne McDonnell.

Figure 2: Traditional cooking method, three stone stove [4].

Research Hypothesis

$PM_{2.5}$ are fine particles in air with a diameter of 2.5 micrometers [5].

- Dry briquettes will have the highest concentrations of $PM_{2.5}$ compared to pyrolyzed briquettes.
- Pyrolyzed briquettes will boil water faster because they have a higher energy concentration.

Methodology

Prepared Site (Trotta's farm at NAU)

- Developed Fire Mitigation Plan
- Erected 10 x 10 tent

Acquired Sawdust at AP Sawmill (Flagstaff, AZ) and Steer Manure from Grantham Ranch (Williams, AZ)

Figure 3: Team Assembling Tent at Trotta's Farm (Photo by: Mohammad Alkandari)

Figure 4: Grantham Ranch (Photo by Dylan Chambal)

Table 1: Weight of Materials Used in Dry and Pyrolyzed Briquettes

Ratio (by weight)	Sawdust (g)	Steer Manure (g)	Water Added (mL)	6% Binder (g)
20% Sawdust , 80% Steer Manure	50	200	630	15
25% Sawdust , 75% Steer Manure	62.5	187.5	633	15
30% Sawdust , 70% Steer Manure	75	175	690	15
Pyrolyzed 30% Sawdust , 70% Steer Manure	75	175	690	15

Figure 5: Dry Briquettes Before Testing (photo by: Mohammad Alkandari)

Pyrolysis Briquettes

Pyrolysis is the heating of organic material in the absence of oxygen to decompose chemical compounds into combustible gases and charcoal [6].

- Torrefication (mild form of pyrolysis) was performed at 230 degrees Celsius for 1.5 hours.
- Purpose: Remove organic compounds to increase carbon content.
- Removal of Hemicellulose (24%), Cellulose (4%), and Ligin (16%) [7].

Burns primarily remaining carbon to carbon dioxide, resulting in less smoke compared to regular wood burning [6].

Figure 6: Briquette Chamber in Pyrolysis Oven (Photo by: Mohammad Alkandari)

Equipment

Particulate Profiler(MetOne Model 212)

- Measuring the numbers of $PM_{2.5}$ in numbers/m^3

Thermocouple (OM-DAQ-USB-2401 model)

- Measuring the water and the stove temperature in Celsius degree

Figure 7: Particulate Profiler (photo by: Xiaoying Tang)

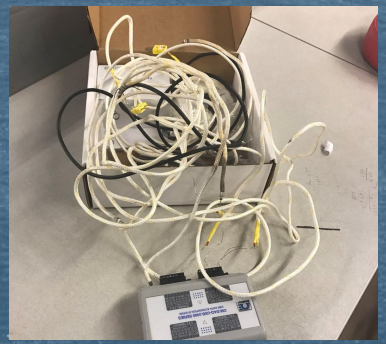

Figure 8: Thermocouple (photo by: Xiaoying Tang)

Thermocouple

Figure 9: Thermocouple Jiko Stove Set-up (photo by: Xiaoying Tang)

Data Analysis: Plots of Dry Briquettes

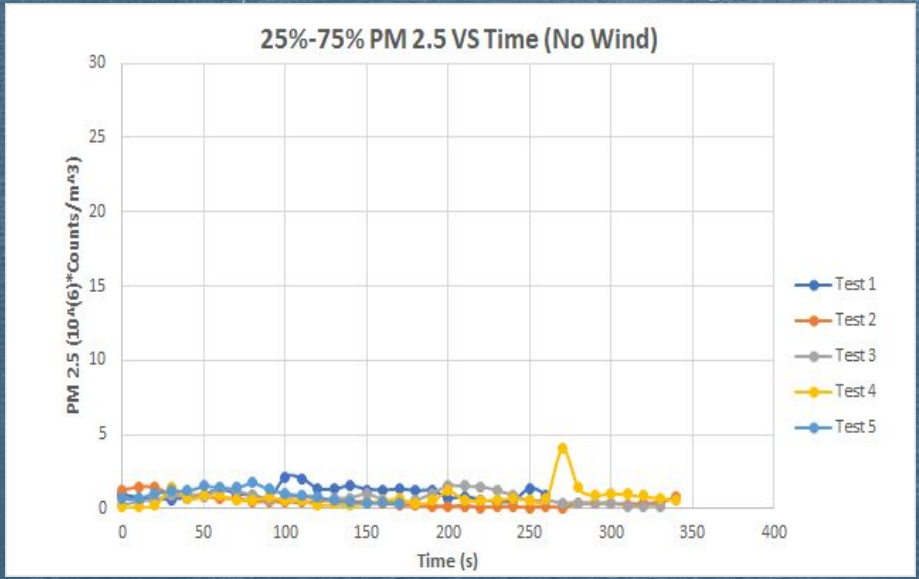

Figure 10: Emission of $PM_{2.5}$ for 25%-75% Ratio

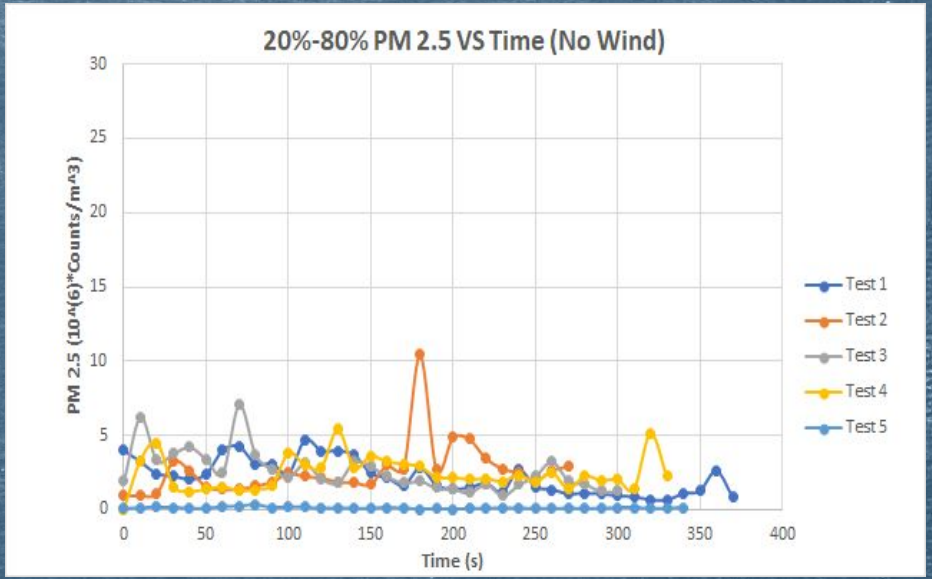

Figure 11: Emissions of $PM_{2.5}$ for 20%-80% Ratio

Data Analysis: Plot of Dry Briquettes and Pyrolyzed Briquettes

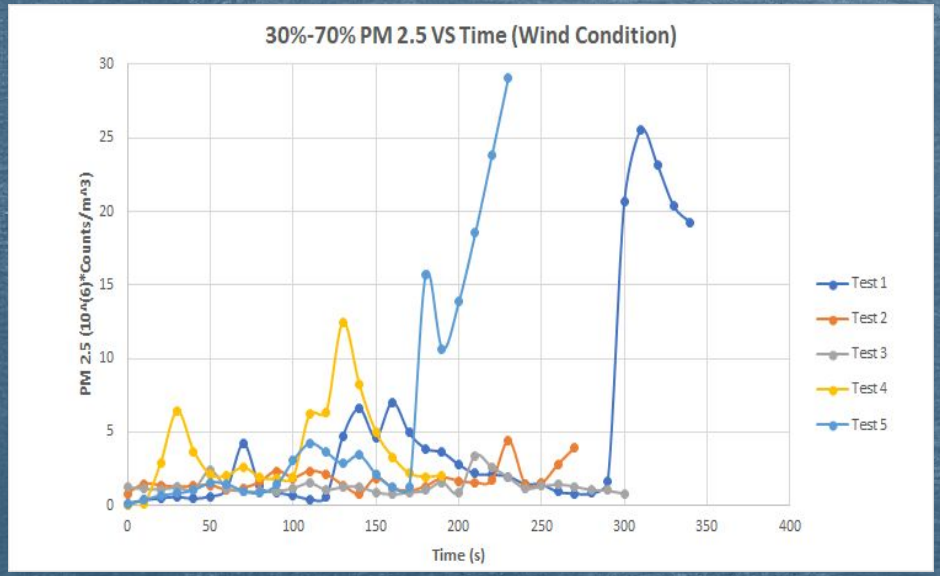

Figure 12: Emission of $PM_{2.5}$ for 30%-70% Ratio

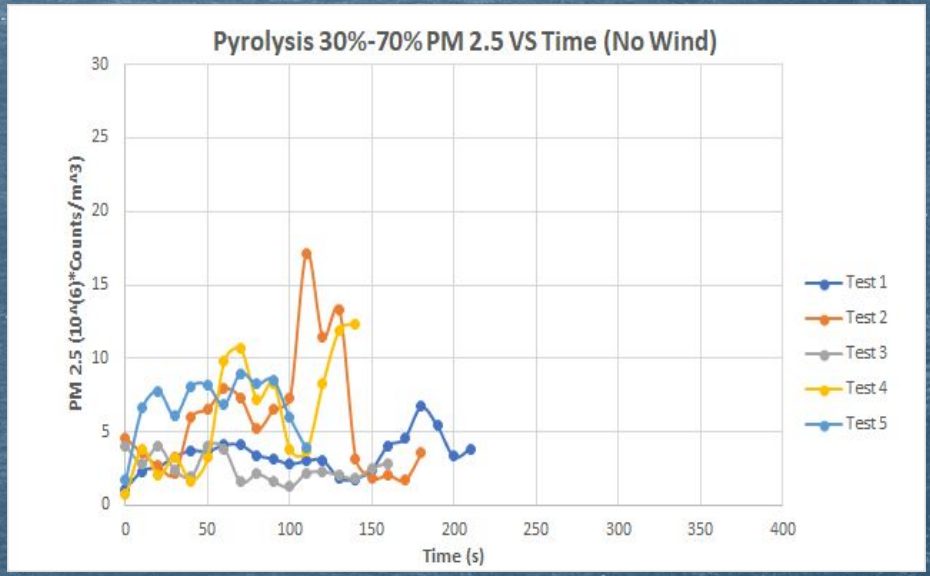

Figure 13: Emissions of $PM_{2.5}$ for Pyrolyzed 30%-70% Ratio

Data Analysis: Wind Interference

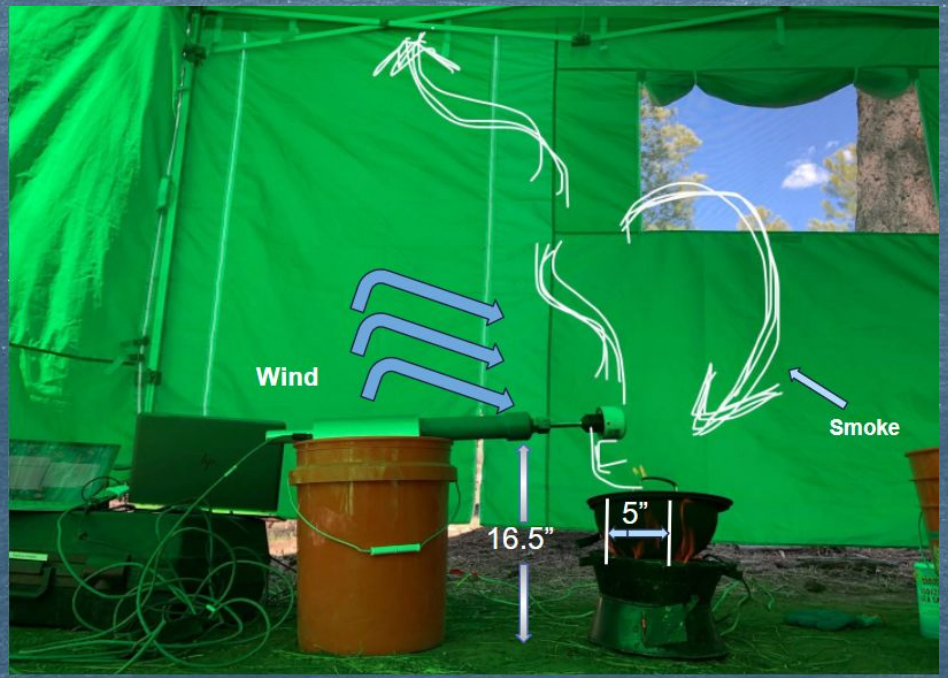

Figure 14: Influence of Wind Movement among Data Collecting (picture made by: Xiaoying Tang)

Data Analysis

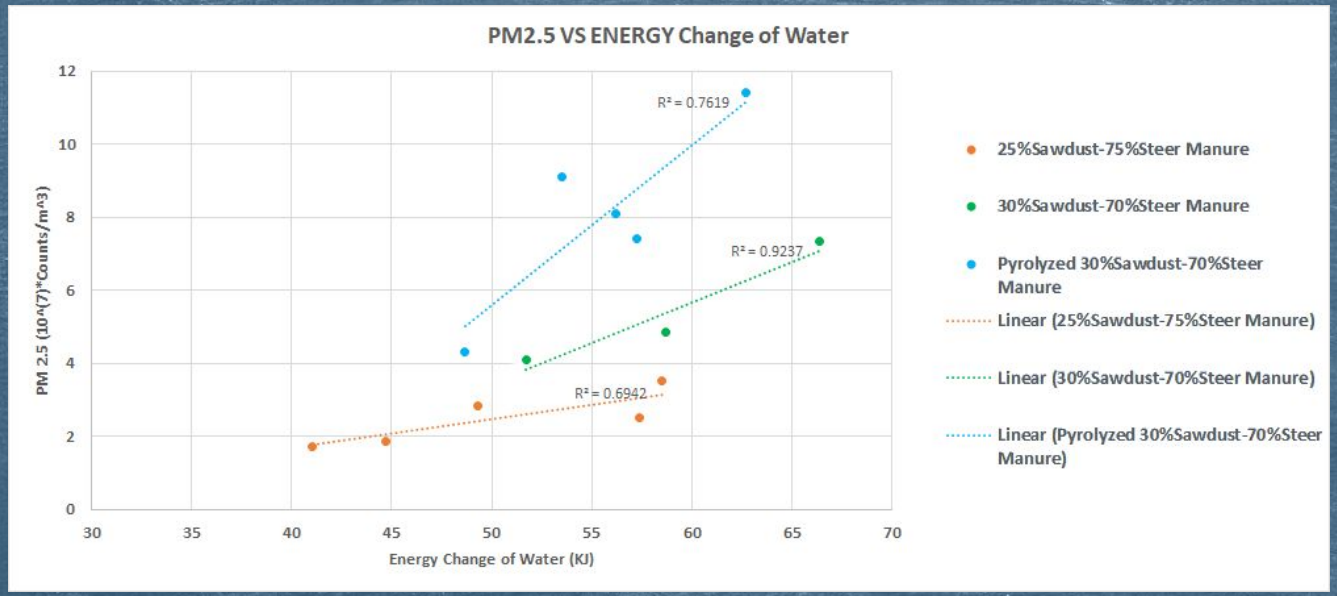

Figure 15: Production of $PM_{2.5}$ according to Energy Change of Water.

Change in Energy= $C_p M \Delta T$

ΔT = temperature change

M = mass of water

C_p = specific heat

$C_p^{water} = 4.2 \times 10^3$ J kg^{-1} $°C^{-1}$

Data Analysis

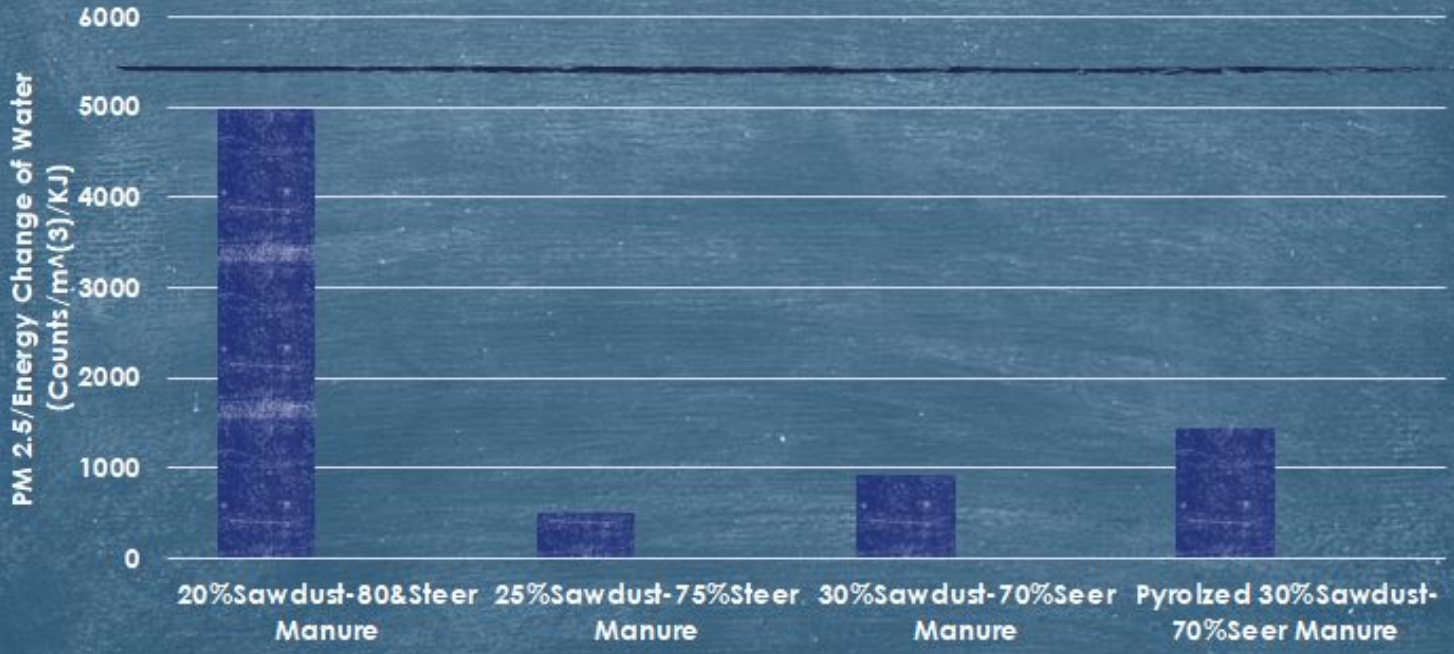

Figure 16: Bar Chart of Production of $PM_{2.5}$ per Energy Change of Water.

Ratio= Emission of $PM_{2.5}$/ Energy Change of Water

Table 2: Updated Schedule

Task	Projected Start Date	Projected End Date	Actual Start Date	Actual End Date
1.0 Preparing Site	1/15/18	1/23/18	1/15/18	1/23/18
2.0 Acquiring Material	1/24/18	1/31/18	1/24/18	2/16/18
3.0 Design Briquettes	2/03/18	2/20/18	2/17/18	3/11/18
4.0 Running Test	2/23/18	3/02/18	3/13/18	4/21/18
5.0 Analyze Data	3/13/18	3/28/18	4/5/18	4/23/18

	Unit Cost	Projected Total Hours	Actual Total Hours	Cost	Adjusted Cost
Senior Engineer	$150/hr	35	90	$13,500	$17,550
Lab Manager	$45/hr	40	115	$5,175	$6,728
Project Manager	$65/hr	40	100	$6,500	$8,450
Junior Engineer	$25/hr	75	150	$3,750	$4,875
Cassava Flour	$16.19/2lbs	N/A	N/A	$16.19	$16.19
10x10 Tent	$245	N/A	N/A	$245	$245
			Total Hours: 455		Total Cost: $37,864.19

Table 3: Costs of Engineering Services, Equipment, and Materials

Conclusion

Pyrolysis briquettes boils the water in a shortest time but have the highest amount of particulate matter.

75% steer manure - 25% sawdust briquettes have the least amount of particulate matter

Figure 17: Jiko Stove and a pot assembly

17 (Aldahlan)

Recommendations

Improve Testing Enclosure

- Prevent wind interference

Composted steer manure

- Increase organic matter to be burned off in pyrolysis

Pyrolysis testing for the other ratios

- Compare the ratios

Figure 18: Example enclosure to be used for future testing

Acknowledgment

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References

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