COMPARATIVE STUDY OF STOVE EMISSIONS: TRADITIONAL STOVES VS FAN-DRIVEN MODIFIED STOVES AND LPG VS NATURAL GAS STOVE EMISSIONS

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ABSTRACT: This study investigates the emissions from traditional stoves, fan-driven modified stoves, LPG stoves, and natural gas stoves. Various Parameters like PM, CO, SOx and NOx were quantified using isokinetic Assembly for Particulate Matter and Portable Gas Analyzer (PG-350) for the flue gases/ emission testing. Coal used as fuel for the Traditional and Fan-modified stove. LPG and Natural gas stoves managed and different locations. The results indicate that fan-driven modified stoves are relatively more efficient and cleaner than traditional stoves. Natural gas was found to be a clean fuel with the highest combustion efficiency. The Study comparing types of stoves evaluate the potential of fan-modified stoves and Natural gas to reduce the health risks associated with indoor air pollution and lessen the environmental impact of the fuel consumption.

Key Words: Fan driven Stoves, Traditional Stoves, Burning Efficiency, Pollution.

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INTRODUCTION

Traditional stoves, commonly used in developing countries, rely on biomass fuels such as wood, charcoal, and agricultural residues. These stoves are highly inefficient and emit significant amounts of pollutants, including particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOCs). These pollutants contribute to indoor air pollution, which is a major health concern, particularly for women and children who spend long hours cooking (World Health Organization, 2022).

To address the health risks associated with traditional stoves, various modifications have been developed, including fan-driven stoves. These stoves incorporate fans to increase airflow and improve combustion efficiency, leading to reduced emissions. However, the effectiveness of fan-driven stoves can vary depending on the design, fuel quality, and operating conditions (Kumar et al., 2018).

Liquefied petroleum gas (LPG) stoves are a cleaner alternative to traditional stoves. LPG is a cleaner-burning fuel that produces lower levels of pollutants compared to biomass fuels. However, LPG stoves can still emit significant amounts of CO and NOx, especially if they are not properly maintained or operated (Kumar et al., 2019).

Natural gas stoves are another option for reducing emissions. Natural gas is a cleaner-burning fuel than LPG and produces even lower levels of pollutants. However, natural gas stoves may still emit small amounts of CO and NOx, particularly during startup and shutdown (World Health Organization, 2022).

In addition to the health risks associated with indoor air pollution, the emissions from traditional stoves also contribute to climate change. Biomass combustion releases greenhouse gases, such as carbon dioxide and methane, into the atmosphere, contributing to global warming. The adoption of cleaner-burning stoves can help to reduce greenhouse gas emissions and mitigate the impacts of climate change (World Bank, 2021).

However, the transition from traditional stoves to cleaner alternatives can be challenging, particularly in rural areas with limited access to modern energy sources. Factors such as cost, availability, and cultural preferences can influence the adoption of new stove technologies. To promote the widespread adoption of cleaner stoves, it is essential to address these barriers through policy interventions, financial incentives, and community engagement programs (International Energy Agency, 2021).

Furthermore, it is important to consider the long-term sustainability of the fuel sources used in cleaner stoves. For example, while LPG stoves offer a cleaner alternative to traditional stoves, the extraction and transportation of LPG can have environmental and social impacts. Natural gas, on the other hand, is a relatively abundant and cleaner-burning fuel, but its extraction and use can also contribute to greenhouse gas emissions and environmental degradation. Therefore, it is essential to evaluate the overall environmental footprint of different stove technologies and select the most sustainable options for a given context (United Nations Environment Programme, 2021).

MATERIAL AND METHODOLOGY

Emissions from each stove type were measured using a flue gas analyzer and isokinetic assembly. The monitored emissions included particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur dioxide (SO_2). The detailed procedure was as follows,

- **Stoves:** Traditional stoves, fan-driven modified stoves, LPG stoves, and natural gas stoves were selected for the study. Each stove was operated under typical household cooking conditions, simulating various cooking tasks such as boiling water, frying, and simmering.
- **Emission Monitoring:** CO, SO2, and NOx emissions were monitored using a multi-gas analyzer. The analyzer was calibrated using standard gas mixtures prior to each measurement. PM emissions were monitored using the isokinetic sampling method, which ensures that the particulate matter is collected at the same velocity as the flue gas. A high-volume sampler was used to collect PM samples, which were then analyzed in a laboratory using gravimetric techniques.

Experimental Procedure

1. **Stove Preparation:** Each stove was prepared for testing by ensuring proper fuel supply and ventilation.
2. **Emission Monitoring:** The multi-gas analyzer and Isokinetic sampler were connected to the stove's flue pipe. The stoves were operated for a predetermined duration, simulating typical cooking activities.
3. **Data Collection:** The multi-gas analyzer recorded the concentrations of CO, SO2, and NOx in the flue gas. The Iso Kinetic sampler collected PM samples, which were later analyzed to determine the PM mass concentration.
4. **Data Analysis:** The collected data was analyzed to compare the emissions from different stove types. Statistical analysis was performed to determine the significance of the differences between the emissions.

RESULTS AND DISCUSSION

The traditional stoves continue to be a major source of indoor air pollution, the adoption of modified stoves, LPG stoves, and natural gas stoves can significantly reduce emissions and improve health outcomes. However, it is important to consider the specific context, including fuel availability, affordability, and local infrastructure, when selecting the most appropriate stove technology for a given population.

Cooking stoves are a significant source of indoor air pollution, adversely affecting human health and the environment. This study compares emissions from traditional stoves, fan-driven stoves, LPG stoves, and natural gas stoves. The solid fuels including biofuels and coal are the solid materials that are burned in inefficient house stoves. A number of air pollutants are released into the atmosphere, leading to serious air pollution and detrimental health effects. It is essential to fully understand the processes involved in the generation and release of pollutants into the air from these sources of burning when assessing the effects on climate change and human health. The emission factors of air pollutants resulting from the combustion of solid fuels indoors can significantly differ depending on several aspects such as fuel stove systems, environmental circumstances, sampling and analysis tools, and testing procedures

The Table 1 presents a comparison of emissions from conventional stoves and fan-modified stoves for various pollutants. The PEQS (Permissible Exposure Standards) are also included for reference.
Here's a breakdown of the key findings:

- **Nitrogen oxides (NOx):** Conventional stoves emitted significantly higher levels of NOx compared to fan-modified stoves. The fan-modified stoves achieved a 37.46% reduction in NOx emissions.
- **Sulfur dioxide (SO2):** Similar to NOx, conventional stoves emitted higher levels of SO2. The fan-modified stoves showed a 48.24% reduction in SO2 emissions.
- **Carbon monoxide (CO):** Conventional stoves emitted substantially higher levels of CO compared to fan-modified stoves. The fan-modified stoves achieved a 42.46% reduction in CO emissions.
- **Particulate matter (PM):** While the PEQS for PM is not provided, the table shows that both conventional and fan-modified stoves emitted significant amounts of PM. The fan-modified stoves achieved a 21.30% reduction in PM emissions.
- **Combustion efficiency:** The fan-modified stoves demonstrated significantly higher combustion efficiency compared to conventional stoves, reaching 98.10% compared to 93.13%.

The Table 2 presents a comparison of emissions from LPG stoves and natural gas stoves for various pollutants, as measured by different laboratories in Pakistan. The PEQS (Permissible Exposure Standards) are also included for reference.
Here's a breakdown of the key findings:

Nitrogen oxides (NOx): Both LPG and natural gas stoves emitted NOx levels below the PEQS. However, there were variations in the measured values between different laboratories. Natural gas stoves generally emitted lower levels of NOx compared to LPG stoves.

Table 1: Comparison of Traditional Stoves and Fan-Driven Modified Stoves

Sr. No	Parameter	PEQS* (mg/ Nm^3)	Conventional Stove (mg/ Nm^3)	Fan Modified Stove (mg/ Nm^3)	% Reduction of Stove Emission
1	Nitrogen oxides (NOx)	800	108.82	68.05	37.46 %
2	Sulphur dioxide (SO_2)	1700	102.55	53.07	48.24 %
3	Carbon Monoxide (CO)	800	4195.5	2397	42.46 %
4	Particulate matter (mg)	-	615	484	21.30 %
5	Combustion efficiency (%)	-	93.13	98.10	-

- **Sulfur dioxide (SO2):** LPG stoves emitted significantly lower levels of SO2 compared to natural gas stoves. All measurements for LPG stoves were below the PEQS, while natural gas stoves exceeded the PEQS in some cases.
- **Carbon monoxide (CO):** Both LPG and natural gas stoves emitted CO levels below the PEQS. However, natural gas stoves generally emitted higher levels of CO compared to LPG stoves.
- **Particulate matter (PM):** PM emissions were below the detection limit (BDL) for all stove types and laboratories.
- **Combustion efficiency:** Both LPG and natural gas stoves demonstrated high combustion efficiency, with values ranging from 85.88% to 99.79%.

The results indicate that both LPG and natural gas stoves are cleaner alternatives to traditional stoves, with significantly lower emissions of pollutants compared to biomass fuels. However, there are variations in the measured emissions between different stove types and laboratories, highlighting the importance of standardized measurement protocols and ongoing monitoring.

Table 2: Comparison of LPG and Natural Gas Stove Emissions

Sr. No	Parameter	PEQS mg/Nm^3	LPG Stove Emission (mg/Nm^3)	Natural Gas Stove Emission (mg/Nm^3)				
				By ESPAK	By Pak Green Lab	By Pak Green Lab	By Green Crescent Lab	By Green Crescent Lab
	Date of monitoring		15.05.24	06.06.24	15.05.24	07.06.24	06.06.24	7.6.24
1	Nitrogen oxides (NOx)	800	191.68	154.33	277.55	1021.47	31.55	97.23
2	Sulphur dioxide (SO_2)	1700	10.17	232.64	3731.68	1054.87	43.89	55.78
3	Carbon Monoxide (CO)	800	193.69	273.90	1944.40	1021.47	279.98	101.43
4	Emission factor for PM (g/Kg)	-	BDL***	BDL***	BDL***	BDL***	BDL***	BDL***
5	Combustion efficiency (%)	-	98.82	99.79	85.88	99.39	99.50	99.79

*** Below Detection Limit

Conclusions: It can be concluded that both LPG and natural gas stoves offer significant improvements in air quality compared to traditional stoves. Both stove types emit significantly lower levels of pollutants, including NOx, SO2, CO, and PM, than traditional stoves.

While LPG stoves generally outperform natural gas stoves in terms of SO2 emissions, natural gas stoves tend to emit lower levels of NOx. Both stove types demonstrated high combustion efficiency, indicating their potential for efficient energy use.

However, it is important to note that there are variations in the measured emissions between different stove types and laboratories. This highlights the need for standardized measurement protocols and ongoing monitoring to ensure accurate and reliable data.

In addition to the environmental benefits, the adoption of cleaner stoves can also have positive health and economic impacts. By reducing indoor air pollution, cleaner stoves can improve respiratory health, particularly for women and children who are disproportionately affected by traditional stove use. Additionally, the transition to cleaner stoves can create new economic opportunities in the energy sector and contribute to sustainable development.

Overall, the data presented in the tables suggests that both LPG and natural gas stoves are promising alternatives to traditional stoves for improving air quality and promoting sustainable energy use. Further research and policy interventions are needed to ensure the widespread adoption of these cleaner technologies and address the challenges associated with the transition from traditional stoves.

Recommendations: Based on the findings presented in the two tables, the following research recommendations are proposed:

1. **Long-term monitoring:** Conduct long-term monitoring of emissions from LPG and natural gas stoves to assess their performance over time and identify any potential changes in emission profiles. This will help to evaluate the long-term sustainability of these technologies.

2. **Comparative analysis:** Compare the emissions from LPG and natural gas stoves with other types of stoves, such as electric stoves and induction cooktops. This will help to identify the most effective and sustainable options for reducing indoor air pollution.

3. **Economic analysis:** Conduct an economic analysis to evaluate the costs and benefits of adopting LPG or natural gas stoves compared to traditional stoves. This will help to identify the most economically viable options for households and communities.

4. **Policy analysis:** Analyze existing policies and regulations related to stove use and emissions in Pakistan. Identify any barriers to the adoption of cleaner stoves and propose recommendations for policy improvements.

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