Adoption of smokeless Chulha (Stove) in rural of Meghalaya and its feasibility: A case study

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INTRODUCTION

In many parts of the world, particularly in rural areas of developing countries, traditional cooking methods involve cow dung, wood, etc., in open or rudimentary stoves with no proper ventilation. While these methods have been used for centuries to prepare meals, they come with a significant drawback: the production of smoke (Alex et al., 2018; Smith, 2000; Belachew et al., 2023). When these traditional chulhas are used, they emit large amounts of smoke that can have severe health and environmental impacts. The smoke emitted from traditional stoves contains harmful pollutants and particulate matter, including carbon monoxide, nitrogen oxides, volatile organic compounds (VOCs), and fine particulate matter (PM2.5 and PM 10) (Das et al., 2009; Shrestha and Shrestha, 2013). The abovementioned pollutants and particulate matter are well-known for multiple health hazards (Lachowicz et al., 2022; Sidibe et al., 2023). Prolonged exposure to this smoke can lead to various health problems, including respiratory diseases, eye irritation, lung cancer, and cardiovascular issues (Witinok-Huber et al., 2022; Hussain et al., 2022). It is particularly concerning for women and children who spend more time near the stove while cooking or carrying out domestic activities. Furthermore, the smoke produced by traditional stoves (Chulahs) contributes to environmental degradation. The inefficient combustion of biomass fuels leads to the release of greenhouse gases, including carbon dioxide...
and methane, contributing to climate change (Bhattacharya and Abdul Salam, 2002; Venkataraman et al., 2010). Additionally, using biomass fuels exacerbates deforestation and strains local ecosystems as communities rely on unsustainable fuel sources. With government efforts, environment-friendly energy sources LPG (Liquid petroleum gas) cylinders have reached villages, yet they continue to be expensive for a reasonable population. To address these problems, researchers, organizations, and governments have been working to develop and promote smokeless 

chulhas (Bhojvaid et al., 2014; Chandra et al., 2022). The primary objective is to improve combustion efficiency, minimize smoke production, and reduce the negative health and environmental impacts associated with traditional cooking methods (Chandra Nayak Manmatha et al.; Roul 2022; Dilshad et al., 2020; Panwar et al., 2006). Smokeless 

chulhas incorporate various design features and technologies to achieve these goals. One important aspect is the improvement of insulation to ensure that heat is retained within the cooking chamber, resulting in better combustion (Sheikh and Bhaduri, 2020). By retaining heat, less fuel is required, reducing both the cost and the environmental impact of cooking. Insulation also helps to ensure that the outer surfaces of the stove remain cool to the touch, reducing the risk of accidental burns. Another key feature of smokeless 

chulhas is better airflow control. These stoves are designed to optimize the mixture of air and fuel, allowing for more complete combustion. Air vents or chimneys are incorporated into the design to facilitate the escape of smoke and ensure that it is directed away from the cooking area. This reduces smoke inhalation and improves indoor air quality (Chandra et al., 2022). Efficient combustion chambers are another important component of smokeless 

chulhas. These chambers are designed to promote complete fuel combustion, resulting in higher energy efficiency and reduced emissions. The chambers often have a well-defined shape and size to ensure the fuel burns uniformly and efficiently. In addition to these design features, smokeless 

chulhas may incorporate other technologies to enhance their performance further. Some stoves use forced air systems, such as fans or bellows, to provide a steady oxygen supply to the combustion chamber, ensuring a more controlled and efficient burn. Others may use catalytic converters or gasification techniques to convert the fuel into a cleaner-burning gas, reducing the production of smoke and harmful pollutants. The benefits of smokeless 

chulhas are numerous. They significantly reduce the amount of smoke generated during cooking. By providing better combustion conditions and directing smoke away from the cooking area, these stoves contribute to improved indoor air quality and reduce the risk of respiratory illnesses and other health issues associated with prolonged exposure to smoke. Smokeless 

chulhas also offer fuel efficiency advantages. Through their improved combustion design, they maximize the use of available fuel, resulting in reduced fuel consumption and cost savings for people using it (Chandra et al., 2022, Das et al., 2022). This study aimed to investigate the smokeless 

chulha's working and compared the savings in terms of time and energy consumed while using the smokeless 

chulha vis-a-vis the traditional 

chulha. The various parameters considered during the comparative study were not limited to fuel consumption and time-saving, but also included investigation of various gases such as Carbon dioxide (CO₂), carbon monoxide (CO), Formaldehyde (HCHO), total volatile organic compounds (TVOCs), etc. and particulate matters (PM10 and PM2.5) that were released during the burning of wood while cooking.

**MATERIALS AND METHODS**

**Description of smokeless 

chulha (stove)**

Smokeless 

Chulha was procured from Shivkupa Enterprise, Pune, India. The model used for the present study was Swastik Shegdi (Fig. 1). The smokeless stove also burns firewood like a traditional 

chulha. However, the smokeless 

chulha employed a closed system that helped to burn wood more efficiently and produce more heat.

**Study area**

The smokeless 

Chulha was installed in Tuber Kmai (25°25’51.97"N and 92°17’17.90"E) village of Meghalya, India (Fig. 2). As per the latest record from Block Development Officer (Khliehriat district, Meghalya), 460 households were there, and the population is 3195. A total of 30 households were selected. And 50% of these houses used smokeless 

chulha provided by the East Janita Hills Deputy Commissioner.

**Methodology**

**Fuel consumption**

For traditional 

chulha, villagers used locally available fuel wood collected from the nearby forest area of East Jaintia Hills. Hence, the same firewoods were used to determine the fuel consumption quantity by smokeless 

chulha. The consumption of firewood (kg) was measured daily for the same type of food cooked on traditional 

chulha and smokeless 

chulha.

**Smoke analysis**

Carbon Dioxide (CO₂ in ppm), Formaldehyde (HCHO in mg/m³), Volatile Organic Compound (TVOC in mg/m³), and Carbon monoxide (CO in ppm) were measured using Real-Time electrochemical sensors of a Multi-functional Air Gas Detector (Labart, India). In addition, particulate matter (PM10 and PM2.5) in smoke was measured daily for the same type of food cooked on traditional 

chulha and smokeless 

chulha.
measured using WREA HLW-100 Labart, India.

Statistical analysis
All analyses were conducted in triplicates, and the results are expressed in terms of mean ± SD (standard deviation) calculated using XLSTAT 2014.

RESULTS AND DISCUSSION

Firewood consumption and cooking time
The present study showed that, on average traditional chulha utilized 3.2 kg of fire wood during the cooking, whereas the smokeless chulha utilized only 1.0 kg of fire wood for the same kind of food. It was observed that firewood consumption reduced up to 68.7% with smokeless chulha (Table 1). Similar reduction in fuel consumption was observed with other smokeless chulha as compared to traditional chulha in other studies too (Chandra et al., 2022). For example, up to 42.3 % decrease in fuel consumption was observed with the smokeless chulha (Udairaj smokeless chulha developed by Renewable Energy Department, (College of Technology and Engineering, Udaipur) installed in Churachandpur District, Manipur (Devi and Singh, 2018; Dilshad et al., 2020). Further, low emission of smoke was observed with smokeless chulha compared to traditional chulha. Smoke from the fire wood contains large amount of CO₂, CO, carcinogenic elements, particulate matters, etc and cause various health hazards such as eye irritation, allergy, respiration issues, headache, etc. With smokeless chulha, a person's smoke exposure time reduces significantly compared to traditional chulha. Hence smokeless chulha directly contributes towards the health of people.

Gas analyses
Table 1 indicates the amount of carbon dioxide and carbon monoxide released by the smokeless chulha and traditional chulha while cooking. It was observed that, on an average up to 1654 ppm of carbon dioxide was released by the traditional chulha, whereas on the other hand, smokeless chulha released only 514 ppm of carbon dioxide while cooking. It was detected that smokeless chulha reduced the carbon dioxide production by 68% compared to the traditional chulha used by the villagers. Similar, reduction patterns were observed with the Carbon monoxide gas. Smokeless chulha utilization drastically reduced the amount of carbon monoxide gas by 98% (Table 1). Both carbon monoxide (CO) and carbon dioxide (CO₂) have harmful effects on human health and the environ-
Carbon monoxide is a toxic gas that, when inhaled, binds to haemoglobin in the blood, reducing its oxygen-carrying capacity and potentially leading to tissue damage and even death. It can cause symptoms such as headaches, dizziness, and nausea, and prolonged exposure can result in neurological damage (Manisalidis et al., 2020). On the other hand, carbon dioxide contributes to climate change and global warming. Increased CO₂ levels in the atmosphere lead to rising temperatures, altered weather patterns, and adverse effects on ecosystems (Scott et al., 2019). Further, the amount of total volatile organic compounds during the firewood burning reduces to 0.78 mg/m³ in smokeless chulha from 6.79 mg/m³ (traditional chulha) (Table 1). It was examined that smokeless chulha reduces the total volatile organic compound by 88.5% compared to traditional chulha. TVOCs can have negative effects on human health and the environment. Prolonged exposure to high levels of TVOCs can cause irritation of the eyes, nose, and throat, as well as respiratory problems, headaches, and fatigue. Some TVOCs are known to be carcinogenic or can contribute to the formation of ground-level ozone, leading to air pollution and respiratory issues (Oh et al., 2020). Additionally, TVOCs contribute to smog formation and can harm ecosystems and vegetation (Wu et al., 2023). In addition, the percentage of formaldehyde was also significantly reduced with smokeless chulha. It was observed that traditional chulha was emitting an average of up to 0.88 mg/m³ of formaldehyde, whereas smokeless chulha its concentration reduces to 0.22 mg/m³ (Table 1). Inhalation of formaldehyde smoke can irritate the eyes, nose, and throat, causing symptoms such as coughing, wheezing, and difficulty breathing. Prolonged exposure to formaldehyde smoke has been linked to an increased risk of respiratory problems, including asthma, bronchitis, and even lung cancer (Lee et al., 2021; Naddafi et al., 2019).

Socio-economic and environmental impact of smokeless chulha
Smokeless chulhas are designed to be more fuel-efficient compared to traditional cooking methods. They burn fuel more efficiently and generate more heat, which means less fuel is required to cook meals. This reduction in fuel consumption can lead to significant cost savings over time, especially in areas where fuel costs represent a substantial portion of household expenses. With traditional chulha, on an average, a family spends approximately up to Rs. 15000/annually (183$/Year) on firewood (including collection and transportation). In addition, a single-family utilises up to 21 trees annually for traditional chulha. It was concluded that smokeless chulha saves up to around 68% of fire wood, which would save around 14.28 trees/family on average. Hence 68% reduction in firewood consumption means an annual savings of almost Rs 10200/family (123$). Also, considering an average tree density of 600 trees per hectare, 500 smokeless stoves would save 7140 trees from felling and 11.9 hectares of forest from being cleared. Trees play a crucial role in carbon sequestration by absorbing and storing carbon dioxide from the atmosphere. Preserving trees through smokeless chulha helps maintain this important ecosystem service, contributing to climate change mitigation efforts (Das et al., 2022; Patil et al., 2021). By reducing deforestation and associated emissions, smokeless chulhas indirectly help mitigate the impacts of climate change. Further, traditional cooking methods often require significant time and effort in fuel collection, preparation, and cooking (Khandelwal et al., 2022; Das et al. 2022). With smokeless chulhas, the cooking process becomes...
more efficient, requiring less time and effort. This can free up time for household members, particularly women and children, to engage in income-generating activities or pursue education and skills development, potentially leading to increased earning opportunities in the long run. Moreover, traditional cooking methods often produce harmful smoke emissions, leading to respiratory illnesses and other health issues. By using smokeless chulhas and minimizing indoor air pollution (Table 1), households can reduce their healthcare expenses. Fewer medical expenses mean more disposable income that can be allocated to other essential needs or saved for future investments.

The present smokeless chulhas showed significant reduction in cooking time and fuel consumption compared to other smokeless chulhas, for example Udairaj used by the villager of Manipur (Devi and Singh, 2018). Available literature indicates that studies pertaining to particulate matter and volatile organic compounds are lacking in smokeless chulhas installed at other places to replace traditional chulhas. The present study clearly indicates that the usage of smokeless chulhas can reduce particulate matter and volatile organic compounds drastically.

### Conclusion

In conclusion, smokeless chulha (Swastik Shegdi) had significant advantages over traditional chulha regarding health, environmental, and socioeconomic factors. Smokeless chulha showed a reduction in the emission of harmful pollutants such as particulate matter (75-87%), carbon monoxide(98%), and volatile organic compounds (88.5%). As a result, they contributed to improved indoor air quality, reducing the risk of respiratory diseases and other health issues associated with indoor air pollution. Further, smokeless chulha was more fuel-efficient, reducing the amount of biomass fuel by 68.7% needed for cooking. This may lead to a decrease in deforestation and pressure on natural resources. Moreover, using smokeless chulha can also save households time and cost, as less time and money are required for fuel collection or purchase. Adopting smokeless chulha represents a sustainable and healthier cooking solution, addressing both the health and environmental challenges associated with traditional chulha.

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### Conflict of interest

The authors declare that they have no conflict of interest.
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