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Environment for Development Research Brief

Evaluating Electric Stoves as a Solution for Household Air Pollution

A Study in the World's Most Polluted Region

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Key Points

- Household air pollution is a major contributor to the disease burden in India
- Electric induction stoves are relatively cheap to own and operate and can serve as an alternative to the use of solid fuels for cooking
- Our study shows that electricity availability substantially reduces kitchen PM2.5 during morning and evening cooking hours
- In spite of the erratic and unreliable electricity supply, early adopters of induction stoves do use them for cooking
- Improving the reliability of electricity and promoting electric cooking appear to be very promising solutions to the problem of household and ambient air pollution in India and other developing countries

Air pollution is the largest killer among all environmental problems worldwide. Ambient (outdoor) air pollution in India alone accounts for more than a million deaths annually (about 10% of all deaths), and the largest single source of ambient air pollution in India is household emissions from cooking with solid fuels, such as fuelwood, dung cake or crop residue. Household air pollution (HAP) is a major contributor to the disease burden in India.

Despite decades of efforts, improved solid fuel stoves (designed to produce less smoke) have largely failed to reduce household air pollution due to limitations of the technology, low adoption rates by households, and infrequent use of the stoves even when adopted. Liquefied Petroleum Gas (LPG), although widely available even in rural India, is expensive given prevailing low incomes. Solid fuels are, therefore, still commonly used for cooking in most rural homes, with attendant air pollution. Within this context, electric cooking technologies (such as electric induction stoves) are particularly important to investigate. In the long run, carbon-free electricity will be the only scalable and sustainable clean energy source.

We examined the extent to which electric induction stoves substitute for traditional solid-fuel stoves and thereby reduce air pollution in village clusters in northern India that are subject to unreliable power supply. We collected minute-by-minute data over a one-year period on electricity availability, induction stove use, and pollution levels measured as fine particulate matter (PM2.5) in a sample of households, as well as data from detailed household surveys on cooking practices and other variables. We found that electricity availability increases induction stove use and reduces air pollution very substantially during morning and evening cooking hours. These findings strongly suggest that electric cooking should get much greater policy attention as a way of tackling the household air pollution crisis in India and other developing countries. However, not all communities have reliable access to electricity.

Given that electric induction stoves have become available recently and are relatively cheap to own and operate, policymakers in India are beginning to consider the large-scale adoption and use of these stoves as a possible solution to household air pollution. However, it is not yet clear if induction stoves are suited to Indian culinary habits and will be adopted widely. Moreover, even if usage is high, it is unclear if the electric stoves will substitute for polluting solid fuels rather than substituting only for LPG.

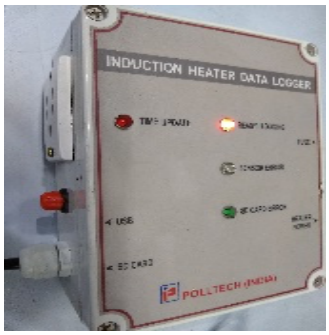
To answer these vitally important questions, we directly measured air pollution in 8 village clusters of the Sultanpur district of the state of Uttar Pradesh in northern India. This is one of the poorest parts of the country and has the worst air quality in the world. In addition, highly variable

electricity availability in this region made it possible to measure the impact of electricity supply on household air pollution.
In partnership with a social enterprise, Dharma Life, we selected 50 households in 8 village clusters that had bought (un-subsidized) induction stoves and reported that they used them to cook meals. We call these "early adopters" because they were among the first in their area to buy these stoves. For comparison, we also selected 16 nearby households in these village clusters that did not possess an induction stove. We measured PM2.5 in all the households' kitchens using optical particle sensors. These instruments were also used to measure ambient pollution in each village cluster. In households owning induction stoves, stove usage was recorded using ammeters (an instrument used to measure the current in a circuit). Finally, availability of electricity in each of the ten power lines that reached the sample households was recorded using voltage monitors. Data collection for all equipment was at the one-minute frequency and was carried out from 1 September 2018 to 20 September 2019.

We find extremely high ambient pollution with even higher levels in kitchens during morning and evening cooking times. While the annual average outdoor concentration of PM2.5 in the study village clusters is close to 100μg/m^3, concentrations in kitchens often rise to more than 1000μg/m^3 during cooking hours. The average concentration of PM2.5 for non-induction households is clearly higher most of the time than that for the households that own induction stoves because the former cook exclusively with polluting solid fuels.

As far as induction stove usage is concerned, it is quite remarkable that households cook meals on induction stoves despite the extremely unreliable power supply. Our survey results show that induction stoves are even used to cook *rotis* (flatbread), contrary to the frequent assertion that *rotis* cannot be cooked on an induction stove due to the absence of a flame.

We find that electricity availability reduces kitchen PM2.5 during morning and evening cooking hours substantially, with larger effects in the morning. The reductions resulting from electricity availability in kitchen PM2.5 are estimated to be about 60μg/m^3 in the morning and about 34μg/m^3 in the evening. Further, by using only the portion of the variation in induction use that is explained by electricity availability, we find that the effect of induction stove use on kitchen PM2.5 during the morning and evening cooking hours is large and statistically significant. The size of the estimated reductions, ranging from 200 to 600 μg/m^3 is more than sufficient to remove the effect of the peaks in kitchen pollution during cooking hours.



Ammeter with clock and data logger

Electricity supply monitors


Optical particle sensor with clock and data logger

Kitchen sensor over c*hulha* (solid-fuel stove)

Electric Cooking: A Promising Solution to the Household Air Pollution Crisis in India

Our study shows extremely high ambient pollution levels and the seriousness of the household air pollution issue in Sultanpur. We find that in spite of the erratic and unreliable electricity supply, early adopters of induction stoves do use them for cooking. Most importantly, we see that the availability of electricity reduces air pollution during cooking hours significantly. Thus, improving the reliability of electricity and promoting electric cooking appear to be very promising solutions to the problem of household and ambient air pollution in India and other developing countries.

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