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Pilot project in rural western Madhya Pradesh, India, to assess the feasibility of using LED and solar-powered lanterns to remove kerosene lamps and related hazards from homes

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ABSTRACT

Background: Globally, 300,000 deaths are estimated to occur annually and the incidence is far greater as a large majority of burns are small and go unreported. Ninety-five percent of the global burden of burns is found in low- and middle-income countries; however, there is relatively little in the literature regarding effective primary prevention in these areas. Flame is the most common cause of burn in Madhya Pradesh, the central state of India. The most common demographic among the burn unit inpatient of Choithram hospital Indore, is young women from 21 to 40 years of age, whose burns are primarily caused by kerosene lamps. A non electrical source of illumination is essential for every household in rural areas due to the infrequent and poor power supply. At the baseline, 23 kerosene lamp burns were reported by villagers in the past 5 years among the study population of this pilot project.
Method: A pilot project to investigate the strategies for reducing the incidence of domestic burns in rural villages around the city of Indore was performed, by replacing kerosene lamps with safer and more sustainable alternatives, including solar-powered and light-emitting diode (LED) lamps. A total of 1042 households were randomly chosen from 18 villages within the Malwa region of Madhya Pradesh (population of 28,825) to receive the alternative light source (670 LED and 372 solar lamps). We investigated the efficacy of this strategy of reducing the incidence of burns, measured the social acceptance by villagers, and quantified the cost implications and availability of LED lamps in rural communities with a high incidence of burns.
Results: Replacing kerosene lamps with LED and solar alternatives was deemed socially acceptable by 99.34% of the participants and reduced the cost of lighting for impoverished rural villagers by 85% over 1 year. We successfully demonstrated a significant decrease in the use of kerosene lamps ($p < 0.01$). More evidence is required to investigate the efficacy of this strategy in reducing burns.

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Conclusion: This pilot study highlights the viability of the approach of replacing kerosene lamps as an effective primary prevention strategy for reducing burns in rural areas. However, barriers remain to the wider adoption of these lamps, including accessibility and availability for the populations of rural India.

1. Background

Globally, more than 300,000 deaths are estimated to occur due to fire-related injuries as reported in 2011 [1]. Unfortunately, 95% of burns affect people of low- and middle-income countries [2], and among them India has been reported to have the maximum burden of fire-related mortality. India has no national burn registry until now; therefore, we do not have any nationwide data as yet.

Based on our hospital data (yet unpublished), there were 1420 burn admissions in 9 years from 1996 to 2004. Of these burn admissions, 80% were due to flame burns at home: kerosene lamp burns comprised 60% of the incidence of flame burns whereas the kerosene stove caused less than 10% of the cases. A kerosene stove was called a kitchen bomb and was the most dangerous equipment in kitchens in the past. We were surprised to observe the changing epidemiology and were encouraged to look for alternative safer options to kerosene lamps.

Approximately 70% of the Indian population (830 million people) lives in rural areas. Around half of these either live in villages not connected to the electrical grid or have only limited and unreliable availability for 2–3 h per day [3]. Rural dwellings typically have small windows resulting in limited natural light, resulting in a high dependency on artificial light sources for routine daily activities. Artificial lights are also important for safety reasons (to ensure that homes are free of scorpions, snakes, etc.).

Open kerosene lamps are the most commonly used artificial light source in rural India used in the majority of homes. These have significant risks associated with storage and spillage. The evidence suggests that females between the ages of 21 and 40 are at the highest risk of burn, with the most common cause in rural India being flame burns from kerosene lamps [4,5].

However, the incidence of flame injuries in urban Indian homes with rising incomes are more often related to liquid petroleum gas stoves and they do not face the power shortage to face the challenge of alternate methods of indoor lighting [6].

1.1. *Kerosene lamps*

Kerosene lamps are often homemade, using a bottle or a tin container with a wick and a loose-fitting lid (Fig. 1). This is generally kept on a shelf inside the house which is often unstable and topples during cooking, or if disturbed by a rodent or a cat. Due to the flammable nature of the environment and traditional clothing, and the lack of first-aid awareness, the burns sustained are often serious and are associated with significant mortality. In addition to the rudimentary and unsafe design, there is a concerning lack of awareness of the risks involved with kerosene lamps and safety issues regarding the storage of large volumes of flammable fuel.

1.2. *Alternatives to kerosene lamps*

There are limited alternatives currently available, some of which require an electrical supply, which is a limiting factor in rural environments. The two main options that do not require a permanent electrical supply are as follows:

1. Commercially available light-emitting diode (LED) lamps, which run from a rechargeable battery. High luminosity, durability, and low maintenance costs make them ideal for rural lighting [7]. The process of light emission does not generate heat, unlike incandescent lights, increasing energy efficiency and safety.
2. Rechargeable battery-operated fluorescent lanterns, charged from a photovoltaic panel using solar energy. Most parts of India have ready access to at least 8 hours of daylight for 10–11 months of the year, and each 8 hours charge results in 8 hours of usable light, making solar lamps a feasible method.

1.3. *Aims*

The aims of this pilot study were as follows: (1) to determine the efficacy of replacing kerosene lamps in reducing burns, (2) to measure the social acceptability of alternative lamps by villagers, (3) to quantify the cost implications of alternative

Fig. 1 – Typical example of the sort of improvised lamps; many of them constructed from household items such as disused cans and bottles, found in many rural homes.

lamps, and (4) to investigate the availability of the lamps in rural communities with a high incidence of burns.

2. Methods

2.1. Location

The study took place in Madhya Pradesh, which has a population of 72,597,565. It is the second largest state by area and sixth largest in terms of population in India. Seventy-five percent of the population is based in rural areas, spread across 51,806 villages with a total area of 308,252 km^2. The villages included in the study were selected by stratified random sampling in the Malwa region to give five sites representative of the region. The Malwa region is the vast western half of Madhya Pradesh where the terrain consists of primarily hills and plateau. This area was selected as the Choithram Hospital and Research Centre, Indore, which provides burn care to this population. Our own clinical data revealed that the majority of burns were from the Dhar district (70 km from Indore). Ten villages were selected from this district. The remaining villages were selected due to poor power supply, which were within 50 km of Indore, and had a large population using kerosene lamps and were from the low-income group.

2.2. Study design

With funds provided by the world health organization, 670 LED lamps, and 372 solar lamps were distributed around the Indore region. The villagers' kerosene lamps were removed at the same time. The villagers were interviewed using a questionnaire at the time of distribution (January 2012–June 2012) and at 6 months (August 2012–April 2013). A 1-month follow-up was conducted by the authors to assess the effectiveness of the lamps and to resolve any issues.

2.3. Questionnaire (see appendix)

A questionnaire was carried out at baseline and 6 months after the alternative lamps were distributed. The questionnaire focused on the incidence of burns, problems encountered with the lamps, whether people were continuing to use kerosene lamps, and thoughts on social acceptability (satisfaction, ease of use, safety, and willingness to purchase in the future).

2.4. Purchase of LED lamps and solar lamps

The project originally planned for the distribution of 1000 LED lamps and 375 solar lamps. A long market survey of available options was undertaken to understand the market and assess the best models of LED lamps for the project. The original budget for 1000 LED lamps in the project proposal included purchasing 500 cheap lamps as one of the two LED models (costing less than $3 per lamp). This proved to be unreliable with a very limited lifespan. Consequently, two more expensive models had to be purchased and the total number of LED lamps reduced from 1000 to 670. The first model was purchased from an Indian company, BPL©, at the cost of INR 720 ($12). Of these lamps, 35 were initially purchased to compare against the other model. The second model was purchased from a local company, Spare King, costing INR 262 ($5). Of this model, 400 lamps were initially purchased; an extra 235 were purchased due to their popularity. The 35 lamps from BPL© were combined and distributed with the 635 lamps from Spare King, obtaining a total of 670.

Solar lamps were purchased from 'D. light solar', an international company with offices in Delhi. This solar lamp (S10) came with a 6-month warranty and had a retail price of INR 549 per unit ($9), which was negotiated down to INR 461 ($7.60) for a bulk order of 372 lamps (the order needed to be in multiples of 12 due to the case size).

2.5. Distribution of LED lamps (Table 1)

Within villages, the lamps were only distributed to the most impoverished households, with one lamp given to each home. Demonstrations of how to operate the lamps were given and kerosene lamps were collected at the same time as distribution (Figs. 2 and 3).

2.6. Distribution of solar lamps (Table 2)

A total of 372 solar lamps were distributed in the regions and villages listed in Table 2. These villages were geographically far away from the LED distribution areas using the same criteria as for the LED lamps. One lamp was provided per household.

Initially, it was planned that the project would distribute as many lamps to the family as necessary, so that they had one for each room and completely discontinued the use of kerosene lamps. However, when the lamps were being distributed, everyone wanted to receive an extra lamp, claiming that everyone had more than one room at home. As a consequence, it was decided to only give one lamp to each family of the village to avoid the hoarding of lamps by some villagers. As a result of this, people who had two rooms in their

Fig. 2 – An example of some of the kerosene lamps collected from households in the surveyed villages. The pictures demonstrate the poor condition and improvised nature of many of the lamps.

Fig. 3 – Distribution of solar lamps to villagers in Gajinda Village, a small settlement of 250 homes that lies 41 km from the Choithram Hospital. The villagers were given demonstrations of how to use the lamps.

home had to use a kerosene lamp in one room and an LED lamp in the other. As a result, in 78 homes a kerosene lamp was continued along with the LED/solar lamps to light the extra rooms.

2.7. *Statistical analysis*

The questionnaires were collected by the authors and quantitative data were inserted into the Stat Direct Statistical Analysis Software 2.7.2 UK. The data from the 6-month follow-up questionnaire were evaluated against the data from the baseline survey using the McNemar test. A p value of <0.05 was deemed statistically significant.

Table 1 – Number of LED lamps distributed amongst the villages (population estimate based on number of homes and average number of family members).

Distribution of LED lamps	
Village (population)	LED lamps distributed
Bagdi (7000)	40
Sagdi (500)	40
Billoda (5000)	100
Mundla (500)	29
Khanpur (400)	16
Kunda (300)	58
Nalsa (6000)	18
Aunvelia (240)	33
Gyanpura (100)	13
Shyopur (100)	3
Budhania (2000)	100
Rangwasa Nayapura and Shivchowk (2500)	150
Palakhedi (300)	35
Todi (200)	35
Total distributed	670

Table 2 – Number of solar lamps distributed amongst the villages.

Distribution of solar lamps	
Village (population)	Solar lamps distributed
Gajinda (1500)	252
A leper colony near Jamudi Khurd (85)	42
Manpur (2000)	14
Jamudi Khurd (100)	48
Budhania (2000)	16
Total distributed	372

3. Results

3.1. *Baseline survey*

The initial survey revealed that the region has frequent power cuts and villagers routinely used a kerosene lamp for general illumination at night. In the regions selected, most homes used wood, kerosene stoves, or liquid petroleum gas (LPG) stoves to cook. Most regions experienced house fires related to kerosene lamps and some burn accidents that were fatal.

The villagers welcomed the alternative light sources. Many indicated that they did not know that an alternative option to kerosene lamps existed: only 83 individuals said they knew about the alternative options available in the market, but none had actually purchased one to try replacing the kerosene lamps in their homes. When asked about alternatives, the majority answered by mentioning a lantern or an inverter, which is commonly used in urban homes for sustaining lighting during a power cut.

3.2. *One month*

At the first follow-up visit, the solar and LED lamps were found to be equally appreciated by the target populations. In the Dhar district, which was the first region for the distribution and follow-up, people were very satisfied with the LED lamps. No one sold their lamp to the market and everyone used them regularly. The 1-month survey in the Dhar district revealed that the LED lamps were functioning well. Some people had not fully understood the charging requirements of the lamps and required further explanation. They were happy to use them and found the quality of illumination comparable or better than the kerosene lamps. The 1-month survey in the Gajinda village was performed and the solar lamps were also found to be very useful, easily chargeable, and portable.

3.3. *Six months*

3.3.1. *Incidence of burns (Fig. 4)*

At the baseline, 23 burns were reported by villagers in the last 5 years of their memory. At 6 months post introduction of the alternative light sources, there was only one burn incident: a reported suicide by a female adult. This incidence was unrelated to the lamp and therefore not included in the analysis.

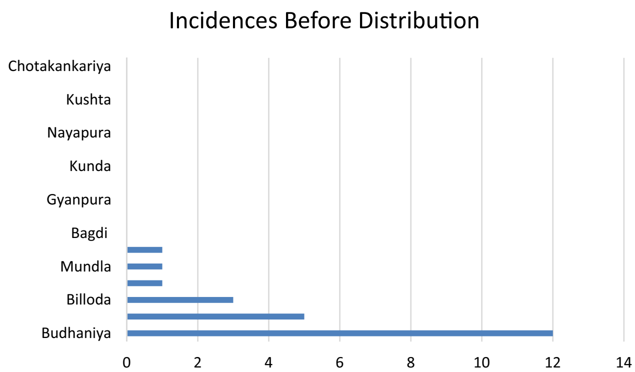

Fig. 4 – Burn incidence in the target population before distribution of the alternate light sources.

3.3.2. *Social acceptability*

The cost of illumination for one room was drastically reduced by 85% from INR 1800 per year (on kerosene) to INR 262 for 12 months of illumination. This cost benefit was very well understood by the villagers.

The overall response has been very satisfactory; 99.34% of the population considered the lamp socially acceptable. We were welcomed to the villages that took part in the project and both the LED lamp and the solar lantern were equally satisfactory. Both lamps lasted for more than 12 months, exceeding their warranty period of 6 months with the majority still being used.

The quality of illumination was deemed good, and the lamps have been used to visit outdoors at night and for general illumination at home for cooking, eating, and reading. Most homes have discontinued the use of kerosene lamps after receiving the new lamps and have already recognized the economic benefit after 1 year. However, they do still have kerosene at home for starting the wood fire for cooking. Indore does not face harsh winters, and thankfully indoor heating is not required.

3.3.3. *Use of kerosene lamps (Fig. 5)*

The supply of LED lamps and solar lamps dramatically reduced the number of kerosene lamps used. At the baseline study, 914 kerosene lamps were in use; by 6 months, this had reduced to 78 ($p = 0.0008$). These homes experienced the advantage of using a safer and more economical lamp but did not actually purchase a second lamp for their second room. One of the reasons is the distance: the lamps were being sold in the city 50 km away and the villagers did not go there very often. They were daunted by the prospect of going to the city and searching for the lamps.

4. Discussion

Around 74 million households in the rural areas of India have no stable supply of electricity, yet the Indian government's efforts to expand and improve the national electricity grid into rural areas continue to progress at a halting tempo [9]. Needless to say, the rising demand for electricity is much higher than the current production capacity [10]. The problem of power shortage is prevalent across the country. The state of Madhya Pradesh is only one among many. Examples of other states in India include the following:

- Bihar: 95% of people use kerosene.
- Jharkhand: 50% of 32,000 villages lack electricity.
- West Bengal: 65% use kerosene to light homes.
- Orissa: 40% have no access to electricity.
- More than 35% of the population in these states live in poverty [11].

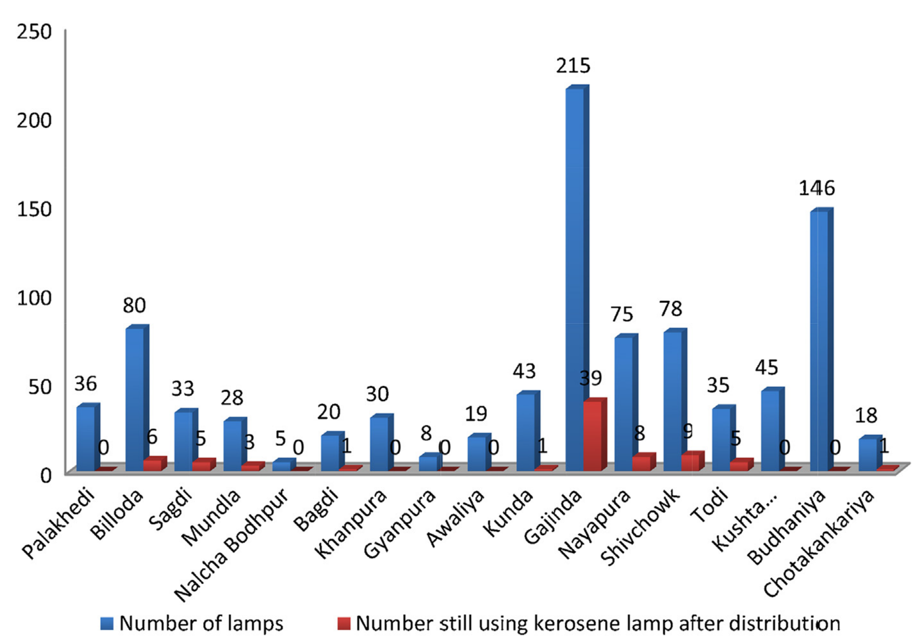

Fig. 5 – Number of LED/solar lamps distributed to each area and the number of homes that continued to use kerosene lamps after distribution, due to additional rooms in their homes.

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This is not going to be resolved in the short term; a long-term solution has to be sought for this huge population [12].

The results from our study have been promising. The LED and solar lanterns were accepted and preferred by the majority of the population. The use of kerosene lamps reduced significantly and the alternative lamps were not discarded or sold. The alternative options were both cheaper and more robust. All of the villagers were interested in purchasing the lamps when the current models were no longer functional.

With regard to comparing the two models (the LED lamp and the solar lantern), both were found to be equally effective and provided a cheaper and more effective replacement to kerosene lamps after 6 months. One limitation is that solar lanterns are only available online, making it a less feasible option for people in rural villages with no access to the Internet.

The incidence of burns prior to lamp replacement was lower than expected and not statistically significant compared with the incidence at 6 months. We had expected a much higher incidence based on our clinical data; flame burns due to kerosene lamps are the most frequent cause of burns at homes in rural or low-income urban homes. In India, around 2.5 million people (350,000 of them children) suffer severe burns each year, primarily due to overturned kerosene lamps [13]. This could be explained by the fact that hospital data and community surveys are different issues. Probably, we need to study a much larger population to assess the community-based aetiology of flame burns. It is possible that we get a false history from the hospitalized patient when the fact may be something else.

This study highlighted a lack of awareness about the alternative sources available in the local market and the cost, efficacy and safety advantages. In our study of 914 homes, only 83 people knew that solar lamps were available, and they did not know how to procure them. The LED lamp was even less known. This ignorance can be addressed by the media and an increased availability of retail outlets in the district headquarters. Initially, the sales representatives should visit villages to offer residents information about these products and their availability.

There have been several projects in India to replace kerosene lamps with alternative lightings like biofuel [14], an NGO called labl, lighting a billion lights, has evaluated that 74 million rural homes do not have access to electricity and they have provided 51,3444 households with illuminations [8], project HiLight India [10], Atmosfair providing solar lamps designed by d.light, and a project in Laxmikantapur, India, providing a decentralized solar grid as a solution for illumination [15]. GravityLight is a revolutionary new approach to storing energy and creating illumination [16]. It takes only 3 s to lift the weight that powers GravityLight, creating 30 min of light on its descent, for free. There are no batteries in this light. London based designers Martin Riddiford and Jim Reeves spent 4 years developing GravityLight. This is yet to be mass produced and distributed, but shows promise. We need to network with all these initiatives and create a nationwide effort to deliver safe and sustainable illumination for poor homes in India.

There are several limitations of our study. First, we are not public health experts and have limited experience of doing this kind of work. This was a pilot study with limited funds and human resources.

5. Conclusions

This pilot study highlights the viability of the approach of replacing kerosene lamps with alternative light sources as an effective primary prevention strategy for reducing burns in rural areas. As long as kerosene is stocked in homes for everyday use, the chances of burn will remain high. Though there is still a need to stock kerosene for cooking, by introducing the concept of non-kerosene-based solution to lighting, we have reduced the need to stock kerosene in large quantities in rural, low-income homes. However, barriers remain to the wider adoption of these lamps, due to the limited accessibility and availability of these replacements and the general lack of awareness that other light sources exist. Educating the large rural population of India and ensuring these alternative light sources are more available must be tackled.

Conflicts of interest statement

The WHO provided a grant ($9485.00) to help carry out this project. However, we wish to confirm that there is no known conflict of interest associated with this publication and the financial support for this work has not influenced its outcome in any way.

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Appendix

Solar Lantern Questionnaire

Name –　　　　　　　　　　Address –
Occupation –　　　　　　　Monthly Income –

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1. Type of house
   Kuccha( )　　Pucca( )　　Semi Pucca( )
2. No. of rooms in house
   1( )　　2( )　3( )　>3( )
3. Electricity provided by govt. in village?
   Y( )　　N( )
4. If yes, then how many hours?
   4 hr( )　　6 hr( )　　8 hr( )　　>8 hr( )
5. Do use chimney for light?
   Y ( )　　N ( )
6. Do use it in day time?
   Y ( )　　N ( )
7. Do you take direct connection from the main line on the road?
   Y ( )　　N ( )
8. Do you use chimney at night during sleeping time?
   Y ( )　　N ( )
9. How much monthly expense on use of chimney?
   100rs ( )　150rs ( )　　200rs ( )　　>200rs ( )
10. Is kerosene easily available?
    Y ( )　　N ( )
11. Do you know use of chimney is harmful to you?
    Y ( )　　N ( )
12. Do you know, another resource is available in the market?
    Y ( )　　N ( )
13. Do you know which are they?
    Lantern ( )　solar lamp ( )　inverter ( )　other (　　　　)
14. Would you like to use another source of light cheaper than chimney?
    Y ( )　　N ( )
15. How much quantity of kerosene, you store?
    1 litre ( )　　2 litres ( )　3 litres( )　>3litres ( )
16. If yes, where do you store it?
    ____
17. Do you use kerosene stove?
    Y ( )　　N ( )
18. Do your children study in chimney light?
    Y ( )　　N ( )
19. Has any family member met with burn accident? – Y ( )　N ( )
20. If yes, when -------------
21. Any loss in accident –casualty ( )　　　Material ( )　　Body part ( )
22. Age and sex of the expired -----
23. Accident/suicide/homicide----------------

Lamp distribution follow-up survey

Name-- Age----- Sex------ Education------------

Address--

Family members----- Female----- Male---- Children------

1. Did you have any burn incidence since you started using the lamp provided by us?

If yes:

2. How did it occur?

3. Do you still use chimney?- Y ( ) N ( ) Why----------------------------

4. Did you use solar/LED continuously after distribution?- Y ( ) N ( ) Why------

5. Have you faced any maintenance problem in charging the solar/LED?-

   Y ( ) N ( )

6. How much time it takes to charge a solar/LED?----------------

(a) Do you remember?--------

(b) Has the lamp been stolen ?-----------

7. Is solar/LED useful to you? Are you satisfied from its light? Y ( ) N ( )

8. Do you use it in day time?--

9. How was it useful at night?--

10. Do you use it in sleeping time? –Y ( ) N ( )

11. Are you willing to purchase new one after it becomes non functional? Y ( ) N ( )

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