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FOCUS ARTICLE

Accidents caused by kerosene lamps—New evidence from African household data

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The use of kerosene for lighting, cooking, and heating in developing countries is often considered a major health threat as it can cause accidents like thermal injuries, poisonings, fires, or explosions. The evidence to prove this is extremely scarce, though. The present paper is one of the first to investigate the link between kerosene-based lighting and accidents at the household level. We use survey data from 3,326 nonelectrified households in Burkina Faso, Rwanda, Senegal, and Zambia and observe very heterogeneous kerosene lamp usage rates. In some regions, accidents with kerosene lamps occur in a substantial share of the population, but the absolute incidence is rather low.

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household data, kerosene lamps, sub-Sahara Africa, thermal injuries

1 | INTRODUCTION

Globally almost 1 billion people without electricity access light their homes with kerosene lamps or other polluting fuels (World Health Organization [WHO], 2016). Kerosene is an easily accessible but highly flammable fuel, often accused of causing poisonings, fires, explosions, and in particular thermal injuries, or so-called burns (Schwebel, Swart, Hui, Simpson, & Hobe, 2009; The Economist, 2015). The source of accidents are malfunctioning appliances, fuel adulteration, poisoning through accidental ingestion—in particular by children—, or generally improper appliance use, such as unstable placement of lamps. WHO (2011, 2016) argue that "the use of kerosene (paraffin) stoves and lanterns […] are major risk factors for burn injuries" and that "millions of people suffer burns from using kerosene lamps every year". Such statements are often used to motivate the need for more modern lighting sources, suggesting that these sources have substantial positive health impacts with regards to thermal accidents (The Economist, 2015). At the same time, the WHO raises concerns, stating that "evidence that household kerosene use presents a substantial safety risk [is of] moderate quality".

Studies to substantiate safety risks rely mostly on data from hospitals and health centers. The evidence shows that kerosene-related accidents account for a considerable share of thermal injury admissions (Dongo et al., 2007; Ghaffar, Munnawar, & Shameen, 2008; Laloë, 2002; Liu, Khatri, Shakya, & Richard, 1998; Shanmugakrishnan, Narayanan, & Thirumalaikolundusubramanian, 2008).[1] Other surveys of health facilities stress a risk of kerosene ingestion (Malangu & Ogunbanjo, 2009).[2] These results suggest substantial health costs to households and society from accidents related to kerosene. The studies are unable, though, to draw a conclusion about the prevalence of thermal injuries and kerosene ingestion among the population, because they do not relate the number of accidents to the catchment population of these health facilities. The few studies available that rely on household data show that on the population level, incidence rates are rather low, reporting burn incidences within 1 year among 2.6% of households surveyed in Bangladesh (Mashreky et al., 2009) and 4.2% in

South Africa (Matzopoulos, Jordaan, & Carolissen, 2006). A study in India (Chamania et al., 2015) reports 23 burn incidences among 1,042 households over 5 years, translating into a yearly incidence rate of 0.04%. To our best knowledge, there are no additional surveys on the risk of kerosene ingestion or explosions based on household data.[3]

This paper fills this gap and provides a descriptive analysis of cross-country kerosene usage for lighting, and the number of accidents it provokes using self-collected data from 3,326 rural households in four Sub-Saharan African countries: Burkina Faso, Rwanda, Senegal, and Zambia. Sub-Saharan Africa is where almost half of the 1.1 billion people without access to electricity live (Sustainable Energy for All SE4All, 2015). Consequently, many interventions to provide modern lighting sources focus on this continent.[4] According to WHO (2016), 53% of households in Africa use kerosene and oil lamps as their primary lighting source. This is higher than for example in the South-East Asia Region (32%) that has the second lowest rural electrification rate following Africa.

The amount of kerosene consumed, though, is highest in Asia and Oceania, where more than half of the global kerosene demand of roughly 1 million barrels per day is consumed. India is the most important consumer with around 160,000 barrels, that is, around 17% of the global consumption. Africa accounts for around 11% of global kerosene consumption. The countries looked at in this paper—Burkina Faso, Rwanda, Senegal, and Zambia—consume each around 200–300 barrels of kerosene per day (EIA, 2017). Also on a per capita basis, Indian consumption stands out at almost 20 L per day per 1,000 people compared to between 1.5 and 4.5 L per day per 1,000 people in the four Sub-Saharan countries analyzed here.

Not all of this kerosene is used for lighting—the energy service we look at in this paper—but also for heating, cooking, and possibly also fuel adulteration. Unfortunately, more precise data on domestic consumption of kerosene does not exist. Yet, the global kerosene consumption patterns illustrate that kerosene consumption varies strongly over countries and continents. In Asia and especially India, people rely most on kerosene. In Sub-Saharan Africa, less kerosene is consumed, but it still serves an important share of the population as the primary lighting source.

Our data from Sub-Saharan Africa shows rather modest accident rates that are comparable to those in previous household surveys from Bangladesh, India, and South Africa (Chamania et al., 2015; Mashreky et al., 2009; Matzopoulos et al., 2006). These findings suggest that kerosene accidents may be a large burden in terms of absolute numbers, but any household level interventions to improve safety may be difficult due to the low population incidence rates.

2 | DATA AND METHODS

Our analysis relies on household data from Burkina Faso, Senegal, Rwanda, and Zambia, that was collected between 2010 and 2014. The data stem from comprehensive evaluation studies of rural electrification interventions that provide detailed information on households' energy consumption and socioeconomic characteristics.[5] Table 1 presents main survey characteristics.

None of the surveyed households has access to electricity or other modern lighting sources, such as grid connection, solar home systems, or car batteries. Hence, we observe households that depend on biomass, kerosene, candles, and dry-cell batteries as their main lighting source. For an illustration of kerosene lamps typically used in the areas, see Figure 1. The household data stems from household samples of between 2 and 50 villages per country. While the households are randomly sampled from the villages and are thus representative for the village, the villages are not necessarily representative for the country. All villages are target areas of rural electrification activities surveyed just before corresponding electrification activities started. More information on the village selection can be found in Table 1. Our total sample size is 3,326 households.

Our main outcome variable is based on the survey question "How many accidents caused by the fire of kerosene lamps occurred in the last 12 months?" Only in Senegal, people gave their retrospective answers for a 6 months period. To

TABLE 1 Studies and surveys used in this paper

Study	Year	Sample size	Sample selection	Location
Burkina Faso	2010	799	40 villages representative for Kénédougou province	Rural area with slightly above-average income opportunities due to cotton farming
Rwanda I	2011	307	15 villages, random sample in the country's off-grid periphery	Very remote rural areas
Rwanda II	2011	1,437	50 villages, representative sample of rural areas with on-grid electrification activities	Nationally representative
Senegal I	2011	375	21 villages in Peanut Basin and Casamance selected by electrification project	Remote rural area, partly above-average soil fertility
Senegal II	2014	312	45 villages in Thiès area and Peanut Basin selected by electrification project	Average to remote rural area, partly relatively well connected
Zambia	2011	96	Two villages (selected by electrification project) located close to planned small hydropower plant	Remote rural area with above-average incomes due to large farming and tourist facilities

FIGURE 1 Lighting devices based on kerosene. Source: Gunther Bensch

harmonize answers across the studies, we multiply the number of accidents per household in Senegal by two. Our most important explanatory variable is ownership of kerosene lamps that are in use.

Hence, the data we use is self-reported, and the survey question captures different types of fire-related accidents. Kerosene ingestions are not considered in this question. In addition, our survey question on accidents does not elicit the severity of accidents. However, qualitative interviews with the surveyed population, which accompanied all data collection efforts, indicate that fire-related accidents are mainly thermal injuries and to a smaller degree also property damages. Most of the accidents do not severely injure household members, and only in very few cases a health facility is consulted for injury treatment. Households and health facilities in the surveyed areas, which have also been interviewed qualitatively, have coherently reported this information.

3 | RESULTS

This chapter provides descriptive statistics on two phenomena: First, relying on a large sample size, Table 2 quantifies the prevalence of kerosene lamp use among households. Second, Table 3 quantifies accident prevalence among lamp users, partly based on small sample sizes due to low lamp usage rates. Lastly, it provides some evidence on household characteristics that are associated with kerosene lamp use and accidents.

We observe very heterogeneous usage rates of kerosene lamps across countries (see Table 2). Kerosene lamps are most common in Rwanda, where almost two thirds of the surveyed households use a hurricane or a tin lamp. The majority of Senegalese households, by contrast, have abandoned kerosene lamps and use battery-driven LED lamps instead (not shown). The fact that many households have already abandoned kerosene lamps is very interesting when thinking about possible impacts of modern lighting technologies within this population. In line with Bensch, Peters, and Sievert (2017), it shows that also in absence of interventions to disseminate modern lighting technologies, people switch from kerosene to more convenient lighting sources in many Sub-Saharan African countries. Given decreasing prices of LED-products, this trend can be expected to continue in the coming years. Accordingly, interventions to tackle kerosene safety may become obsolete in these countries.

Among households that use kerosene lamps, the absolute number of lamps is highest in Burkina Faso (2.24) and Senegal (2.41). While lamps are rather few in absolute numbers, they are used substantially, as reflected in the per lamp daily lighting hours shown in Table 2. Both the number of lamps, and the lighting hours per lamp vary between countries. This is mainly due to the differences in household sizes between the countries.[6] Taking into account household size, the number of lamps is much more homogenous across countries (not shown in the Table). Lamps per household member range between 0.22 and 0.34.

TABLE 2 Share of kerosene lamp users, number of lamps per household conditional on lamp use, and daily lighting hours per lamp, by country

Country	*N*	Share of households that use lamp	Conditional mean number of lamps	Mean daily lighting hours per lamp
Burkina Faso	799	0.31	2.24	5.54
Rwanda	1,744	0.64	1.31	2.76
Senegal	687	0.05	2.41	4.25
Zambia	96	0.19	1.33	2.57

Note: For details on data sources, see Table A3.

TABLE 3 Occurrence and number of accidents among lamp users, and number of accidents conditional on accident, within preceding 12 months, by country

Country	*N*	Share of lamp users with accident	Mean number of accidents among lamp users	Mean number of accidents among accident victims
Burkina Faso	246	0.03	0.05	1.5
Rwanda[a]	1,089	0.10	0.23	2.4
Senegal	31	0.06	0.06	1.0
Zambia	18	0.00	0.00	-

[a] Values for Rwanda exclude one outlier household with 61 accidents within the 12 months preceding the survey. For details on data source see Table A3. The number of observations are lower than the number of lamp users listed in Table 2 due to missing values: 36 Burkinabé households, 63 Rwandan, and 7 Senegalese households did not answer the question whether or not they had an accident. There is no reason to believe that values are missing systematically for particularly endangered or not endangered households.

The share of households that experienced accidents within the last 12 months among all households that use a kerosene lamp ranges between 0% in Zambia and 10% in Rwanda (see Table 3). Yet, the numbers from Zambia and Senegal have to be interpreted with care; the samples are very small because only few households use kerosene lamps. Among households that experience accidents, the absolute number of accidents per household is rather low in all countries, amounting to on average between 1.0 and 2.4 accidents within 12 months, and peaking at seven accidents in one household (not shown).[7] To further illustrate this: among 1,744 Rwandan households, 1,116 use kerosene lamps. 1,089 of them answered our question on accident occurrence, of which 109 households experienced on average 2.4 accidents in 1 year. Note that these incidents refer to all household members, and include accidents involving young children, often suspected as particularly affected. The magnitude of the problem is lower in Burkina Faso and Senegal, and close to zero in Zambia. These numbers are in line with the existing evidence from household surveys in Bangladesh, India, and South Africa (Chamania et al., 2015; Mashreky et al., 2009; Matzopoulos et al., 2006).

One might expect the number of accidents to be related to the regularity of using a lamp. Higher usage might create higher risk due to higher exposure, but also less risk due to learning effects from frequent use. These two effects might also cancel each other out. We do not observe such a relationship in the data. Furthermore, the type of lamp used might affect the number of accidents. Tin lamps, for instance, are often less stable than hurricane lamps. We cannot disentangle this relationship due to a high correlation between type of lamp and country, that is, 97% of Senegalese lamp users use hurricane lamps only and 95% of Burkinabé lamp users rely on a tin lamp. Rwandan households use both kinds of lamps, yet there is no difference in the number of accidents by lamp type.

Tables A4 and A5 display results from a Linear Probability Model, correlating a set of socioeconomic characteristics, first, with kerosene lamp use and, second, with accident experience. In a first step, we pool the data for all countries. Bigger households and relatively wealthier households own kerosene lamps. Looking at each country separately, it becomes clear that results differ substantially across countries and that the overall results are driven by the largest sample from Rwanda. Here, the relatively wealthier and better-educated households use kerosene lamps. The less-attractive alternatives used are mostly candles and very simple hand-crafted LED lamps (not shown here). Some households even do not use any lamp but rely on indirect light from the fireplace only. In Burkina Faso, Zambia, and Senegal by contrast, the alternative to kerosene lamps are usually advanced, readymade LED lamps. Here, propensity to use a kerosene lamp is higher for less-educated households.

With regard to accident experience among kerosene lamp users over all countries, the bigger and poorer households experience more accidents. Again, these results are driven by the Rwanda sample. In Burkina Faso, households with a high share of children, but also those who own a means of transport have a higher probability to experience accidents. The Senegal sample is too small to draw meaningful conclusions. In Zambia, nobody experiences accidents.

Additional to the household surveys used in this paper, we have conducted a wide range of surveys in the past 10 years on energy access in poor and rural Eastern and Western Africa. They include in-depth interviews with public health institutions and household focus group discussions on questions related to fuel and lighting use.[8] Households frequently complain about kerosene's bad smell and its impacts on household air quality, which is also documented in the literature (Lam, Smith, Gauthier, & Bates, 2012). In addition, animal attacks like scorpion bites due to insufficient lighting have been named. Accidents, though, have hardly been mentioned. The qualitative, anecdotal evidence confirms that the incidence rate of kerosene-related injuries and damages on the population level is rather low.

4 | CONCLUSION

In spite of scarce empirical household evidence, there is a perception that kerosene lamps pose a major risk to health. Statements as "burns, scalds and house fires caused by tipped-over kerosene lamps and heaters are sadly common" (WHO, 2016)

raise debates on how to combat this risk. Schwebel et al. (2009), for instance, emphasize the urgent need for interventions to foster safety knowledge and practices.

We call for considering two arguments, before making investments into household paraffin safety interventions. First, health facility surveys that are the basis of most evidence are not a good foundation for deciding on the necessity for and especially on prospects of such interventions since they do not illustrate prevalence rates on the population level. Our household data from Sub-Saharan Africa, by contrast, is able to shed light on population prevalence rates of accidents caused by kerosene lamps. We find that kerosene lamp usage varies strongly, and is still substantial among some rural households. We observe heterogeneous accident rates (between 0 and 10%) among kerosene lamp users, most likely being burns, or fire-related property damages. The number of total accidents per year is very low, though. Altogether, most people seem to act with caution or to apply safe practices, potentially resulting from households' long-standing experiences in handling kerosene and the appliances it still powers. The results suggest that any household level intervention to improve safety may be difficult due to the low population incidence rates.

While our study relies only on—partly small—household samples from four different Sub-Saharan countries, our findings are in line with the low-population incidence rates observed in previous household level studies from India, Bangladesh, and South Africa. Hence, the phenomenon is apparently not restricted to Sub-Saharan Africa only. However, larger samples from more countries are needed to assess the external validity of our findings.

Second, African households increasingly replace kerosene lamps with LED lamps without external incentive (Bensch et al., 2017). LED lamps are widely available at reasonable prices, providing less harmful and brighter light than kerosene lamps. These developments are likely to reduce the size of the problem over time. Such time trends are even more important to note, as the evidence available comes mostly from the 1980s and 1990s—times since which great changes in fuel and appliance use occurred.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

NOTES

[1]Please see Table A1 for an overview of studies on thermal injuries from kerosene use. Also see Mills (2012, 2016) for literature overviews on the health and safety impacts of fuel-based lighting.

[2]See Table A2 for an overview of studies on kerosene ingestion, limited to studies that started after 1995.

[3]Note that there is some evidence on the effect of kerosene-based cooking or heating on thermal injuries and ingestion. One paper also reports the incidence of accidents with kerosene without distinguishing the purpose kerosene is used for (Kimemia, Vermaak, Pachauri, & Rhodes, 2014). It is not covered by our literature overview, as our data does not provide evidence on accidents from kerosene-based cooking or heating here. Nevertheless, very few households in our sample actually cook with kerosene: rates range between 0% in Senegal and 2.1% in Burkina Faso. No data is available for Zambia. Heating is generally not practiced.

[4]See for example the flagship program for off-grid energy, Lighting Global, that aims at providing access to certificated Pico-PV kits to 250 million people by 2030.

[5]Corresponding more comprehensive analyses of the data sets have been published as shown in Table A3.

[6]The average household size of households using kerosene lamps is 12.75 in Senegal, 9.34 in Burkina Faso, 5.04 in Rwanda and 4.94 in Zambia.

[7]Excluding one outlier household in Rwanda that states having experienced 61 accidents over the last 12 months.

[8]For survey examples see Table A3.

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REFERENCES

Ahuja, R. B., & Bhattacharya, S. (2002). An analysis of 11,196 burn admissions and evaluation of conservative management techniques. *Burns*, *28*(6), 555–561. https://doi.org/10.1016/S0305-4179(02)00069-4

Asuquo, M. E., Ngim, O., & Agbor, C. (2008). A prospective study of burn trauma in adults at the University of Calabar Teaching Hospital, Calabar (south eastern Nigeria). *Eplasty*, *8*(1), 370–376.

Balme, K., Roberts, J. C., Glasstone, M., Curling, L., & Mann, M. D. (2012). The changing trends of childhood poisoning at a tertiary children's hospital in South Africa. *South African Medical Journal*, *102*, 142–146.

Barradas, R. (1995). Use of hospital statistics to plan preventive strategies for burns in a developing country. *Burns*, *21*(3), 191–193.

Belonwu, R. O., & Adeleke, S. I. (2008). A seven-year review of accidental kerosene poisoning in children at Aminu Kano teaching hospital. *Nigerian Journal of Medicine*, *17*(4), 380–382. https://doi.org/10.4314/njm.v17i4.37415

Bensch, G., Grimm, M., Huppertz, M., Langbein, J., & Peters, J. (2018). Are Promotion Programs Needed to Establish Off-Grid Solar Energy Markets? Evidence from Rural Burkina Faso. Renewable and Sustainable Energy Reviews (forthcoming).

Bensch, G., Grimm, M., Langbein, J., & Peters, J. (2013). *The provision of solar energy to rural households through a fee-for service system. Public private partnership GDIS-NUON. Implemented by FRES and the local company Yeelen Ba.* Final report on behalf of the policy and operations evaluation department (IOB) of the Netherlands Ministry of Foreign Affairs.

Bensch, G., Peters, J., & Sievert, M. (2011). Report on ERSEN baseline study. Baseline Report on Behalf of the German Technical Cooperation (GTZ).

Bensch, G., Peters, J., & Sievert, M. (2013). Fear of the Dark? - How Access to Electric Lighting Affects Security Attitudes and Nighttime Activities in Rural Senegal. Journal of Rural and Community Development *8* (1): 1–19.

Bensch, G., Peters, J., & Sievert, M. (2017). The lighting transition in rural Africa – From kerosene to battery powered LED and the emerging disposal problem. *Energy for Sustainable Development*, *39*, 13–20.

Chamania, S., Chouhan, R., Awasthi, A., Bendell, R., Marsden, N., Gibson, J., … Potokar, T. S. (2015). 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. *Burns*, *41*(3), 595–603.

Chibwana, C., Mhango, T., & Molyneux, E. M. (2001). Childhood poisoning at the Queen Elizabeth Central Hospital, Blantyre, Malawi. *East African Medical Journal*, *78*(6), 292–295.

Clarke, E. E. K. (2004). The experience of starting a poison control centre in Africa—The Ghana experience. *Toxicology*, *198*(1), 267–272. https://doi.org/10.1016/j.tox.2004.02.001

Dongo, A. E., Irekpita, E. E., Oseghale, L. O., Ogbebor, C. E., Iyamu, C. E., & Onuminya, J. E. (2007). A five-year review of burn injuries in Irrua. *BMC Health Services Research*, *7*(1), 1. https://doi.org/10.1186/1472-6963-7-171

EIA. (2017). International energy statistics. "Kerosene Consumption in 2013." Retrieved from: http://bit.ly/2rBpu9r

Ghaffar, U. B., Munnawar, H., & Shameen, J. R. (2008). Thermal burn: An epidemiological prospective study. *Journal of Indian Academy of Forensic Medicine*, *30*(1), 10–14.

Grimm, M., Munyehirwe, A., Peters, J., Sievert, M. (2017). *A first step up the energy ladder? Low cost solar kits and Household's welfare in rural Rwanda* World Bank Economic Review, *31*(3), 631–649.

Grimm, M., Peters, J., Sievert, M. (2013). *Impacts of Pico-PV systems usage using a randomized controlled trial and qualitative methods.* Final Report on behalf of the Policy and Operations Evaluation Department (IOB) of the Netherlands Ministry of Foreign Affairs. Retrieved from: http://www.iob-evaluatie.nl/resources/impacts-pico-pv-systems-usage-using-randomised-controlled-trial-and-qualitative-methods

Gupta, M., Bansal, M., Gupta, A., & Goil, P. (1996, 1996). The kerosene tragedy of 1994, an unusual epidemic of burns: Epidemiological aspects and management of patients. *Burns*, *22*, 3–9. https://doi.org/10.1016/0305-4179(95)00082-8

Gupta, S., Govil, Y. C., Misra, P. K., Nath, R., & Srivastava, K. L. (1998). Trends in poisoning in children: Experience at a large referral teaching hospital. *National Medical Journal of India*, *11*, 166–168.

Jayaraman, V., Ramakrishnan, K. M., & Davies, M. R. (1993). Burns in Madras, India: An analysis of 1368 patients in 1 year. *Burns*, *19*(4), 339–344. https://doi.org/10.1016/0305-4179(93)90124-Q

Kanchan, T., Menezes, R. G., & Monteiro, F. N. P. (2009). Fatal unintentional injuries among young children–A hospital based retrospective analysis. *Journal of Forensic and Legal Medicine*, *16*(6), 307–311. https://doi.org/10.1016/j.jflm.2008.12.017

Khadka, S. B. (2005). A study of poisoning cases in emergency Kathmandu medical college teaching hospital. *Kathmandu University Medical Journal*, *3*(4,12), 388–391.

Kimemia, D., Vermaak, C., Pachauri, S., & Rhodes, B. (2014). Burns, scalds and poisonings from household energy use in South Africa: Are the energy poor at greater risk? *Energy for Sustainable Development*, *18*, 1–8.

Kohli, U., Kuttiat, V. S., Lodha, R., & Kabra, S. K. (2008). Profile of childhood poisoning at a tertiary care centre in North India. *The Indian Journal of Pediatrics*, *75*(8), 791–794. https://doi.org/10.1007/s12098-008-0105-7

Kumar, P., Chirayil, P. T., & Chittoria, R. (2000). Ten years epidemiological study of paediatric burns in Manipal, India. *Burns*, *26*(3), 261–264. https://doi.org/10.1016/S0305-4179(99)00109-6

Laloë, V. (2002). Epidemiology and mortality of burns in a general hospital of eastern Sri Lanka. *Burns*, *28*(8), 778–781. https://doi.org/10.1016/S0305-4179(02)00202-4

Lam, N. L., Smith, K. R., Gauthier, A., & Bates, M. N. (2012). Kerosene: A review of household uses and their hazards in low-and middle-income countries. *Journal of Toxicology and Environmental Health, Part B*, *15*(6), 396–432.

Lang, T., Thuo, N., & Akech, S. (2008). Accidental paraffin poisoning in Kenyan children. *Tropical Medicine & International Health*, *13*(6), 845–847. https://doi.org/10.1111/j.1365-3156.2008.02067.x

Lari, A. R., Alaghehbandan, R., & Nikui, R. (2000). Epidemiological study of 3341 burns patients during three years in Tehran, Iran. *Burns*, *26*(1), 49–53. https://doi.org/10.1016/S0305-4179(99)00102-3

Lenz, L., Munyehirwe, A., Peters, J., & Sievert, M. (2017). Does Large Scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda's Electricity Access Roll-Out Program. *World Development*, *89*(17), 88–110.

Liu, E. H., Khatri, B., Shakya, Y. M., & Richard, B. M. (1998). A 3 year prospective audit of burns patients treated at the western regional hospital of Nepal. *Burns*, *24*(2), 129–133. https://doi.org/10.1016/S0305-4179(97)00103-4

Majeed, H. A., Bassyouni, H., Kalaawy, M., & Farwana, S. (1981). Kerosene poisoning in children: A clinico-radiological study of 205 cases. *Annals of Tropical Paediatrics*, *1*(2), 123–130. https://doi.org/10.1080/02724936.1981.11748074

Malangu, N. (2008a). Characteristics of acute poisoning at two referral hospitals in Francistown and Gaborone. *South African Family Practice*, *50*(3), 67–67c. https://doi.org/10.1080/20786204.2008.10873722

Malangu, N. (2008b). Acute poisoning at two hospitals in Kampala–Uganda. *Journal of Forensic and Legal Medicine*, *15*(8), 489–492. https://doi.org/10.1016/j.jflm.2008.04.003

Malangu, N., Du Plooy, W. J., & Ogunbanjo, G. A. (2005). Paraffin poisoning in children: What can we do differently?: Original research. *South African Family Practice*, *47*(2), 54–56.

Malangu, N., & Ogunbanjo, G. A. (2009). A profile of acute poisoning at selected hospitals in South Africa. *Southern African Journal of Epidemiology and Infection*, *24*(2), 14–16.

Mashreky, S. R., Rahman, A., Chowdhury, S. M., Khan, T. F., Svanström, L., & Rahman, F. (2009). Non-fatal burn is a major cause of illness: Findings from the largest community-based national survey in Bangladesh. *Injury Prevention*, *15*(6), 397–402. https://doi.org/10.1136/ip.2009.022343

Matzopoulos, R., Jordaan, E., & Carolissen, G. (2006). Safety issues relating to paraffin usage in Eshane, KwaZulu-Natal. *Journal of Energy in Southern Africa*, *17*(3), 4–7.

Mills, E. (2012). *Health impacts of fuel-based lighting.* Paper presented at 3rd International Off-Grid Lighting Conference, Dakar, Senegal.

Mills, E. (2016). Identifying and reducing the health and safety impacts of fuel-based lighting. *Energy for Sustainable Development*, *30*, 39–50. https://doi.org/10.1016/j.esd.2015.11.002

Mukerji, G., Chamania, S., Patidar, G. P., & Gupta, S. (2001). Epidemiology of paediatric burns in Indore, India. *Burns*, *27*(1), 33–38. https://doi.org/10.1016/S0305-4179(00)00058-9

Neelsen, S., Peters, J., & Bensch, G. (2011). Renewable energy based electricity generation for isolated mini-grids, Zambia. Baseline Report on the GEF Project on Behalf of the United Nations Industrial Development Organization (UNIDO).

Oduwole, E. O., Odusanya, O. O., Sani, A. O., & Fadeyibi, A. (2003). Contaminated kerosene burns disasters in Lagos, Nigeria. *Annals of Burns and Fire Disasters*, *16*(4), 208–212.

Olaitan, P. B., Fadiora, S. O., & Agodirin, O. S. (2007). Burn injuries in a young Nigerian teaching hospital. *Annals of Burns and Fire Disasters*, *20*(2), 59–61.

Oludiran, O. O., & Umebese, P. F. A. (2009). Pattern and outcome of children admitted for burns in Benin City, mid-western Nigeria. *Indian Journal of Plastic Surgery*, *42*(2), 189–193. https://doi.org/10.4103/0970-0358.59279

Peck, M. D., Kruger, G. E., van der Merwe, A. E., Godakumbura, W., & Ahuja, R. B. (2008). Burns and fires from non-electric domestic appliances in low and middle income countries part I. The scope of the problem. *Burns*, *34*(3), 303–311. https://doi.org/10.1016/j.burns.2007.08.014

Peters, J., Sievert, M., Munyehirwe, A., & Lenz, L. (2014). The provision of grid electricity to households through the electricity access roll-out Programme. Final Report on behalf of the Policy and Operations Evaluation Department (IOB) of the Netherlands Ministry of Foreign Affairs. Retrieved from: http://www.iob-evaluatie.nl/EARP

Pillai, G. K., Boland, K., Jagdeo, S., & Persad, K. (2004). Acute poisoning in children. Cases hospitalized during a three-year period in Trinidad. *The West Indian Medical Journal*, *53*(1), 50–54.

Raizada, A., Kalra, O. P., Khaira, A., & Yadav, A. (2012). Profile of hospital admissions following acute poisoning from a major teaching hospital in North India. *Tropical Doctor*, *42*(2), 70–73.

Reed, R. P., & Conradie, F. M. (1997). The epidemiology and clinical features of paraffin (kerosene) poisoning in rural African children. *Annals of Tropical Paediatrics*, *17*(1), 49–55. https://doi.org/10.1080/02724936.1997.11747863

Schwebel, D. C., Swart, D., Hui, S. K. A., Simpson, J., & Hobe, P. (2009). Paraffin-related injury in low-income south African communities: Knowledge, practice and perceived risk. *Bulletin of the World Health Organization*, *87*(9), 700–706. https://doi.org/10.1590/S0042-96862009000900014

Shanmugakrishnan, R. R., Narayanan, V., & Thirumalaikolundusubramanian, P. (2008). Epidemiology of burns in a teaching hospital in south India. *Indian Journal of Plastic Surgery*, *41*(1), 34–37. https://doi.org/10.4103/0970-0358.41108

Shepherd, J. E., & Perez, F. A. (2008). Kerosene lamps and cookstoves—The hazards of gasoline contamination. *Fire Safety Journal*, *43*(3), 171–179. https://doi.org/10.1016/j.firesaf.2007.08.001

Shotar, A. M. (2005). Kerosene poisoning in childhood: A 6-year prospective study at the Princes Rahmat Teaching Hospital. *Neuroendocrinology Letters*, *26*(6), 835–838.

Singh, D., Singh, A., Sharma, A. K., & Sodhi, L. (1998). Burn mortality in Chandigarh zone: 25 years autopsy experience from a tertiary care hospital of India. *Burns*, *24*(2), 150–156. https://doi.org/10.1016/S0305-4179(97)00106-X

Soltani, K., Zand, R., & Mirghasemi, A. (1998). Epidemiology and mortality of burns in Tehran, Iran. *Burns*, *24*(4), 325–328. https://doi.org/10.1016/S0305-4179(98)00017-5

Sustainable Energy for All SE4All. (2015). Progress toward sustainable energy. Global Tracking Framework 2015. Retrieved from: http://www.se4all.org/sites/default/files/GTF-2105-Full-Report.pdf

Tagwireyi, D., Ball, D. E., & Nhachi, C. F. B. (2006). Toxicoepidemiology in Zimbabwe: Admissions resulting from exposure to paraffin (kerosene). *Clinical Toxicology*, *44*(2), 103–107. https://doi.org/10.1080/15563650500514277

The Economist. (2015). *Africa. A brightening continent.* In Special report. Energy and technology. Let there be light: 6-7. 17 January. Retrieved from: http://www.economist.com/news/special-report/21639018-solar-giving-hundreds-millions-africans-access-electricity-first

World Health Organization. (2011). *Burn prevention. Success stories and lessons learned.* Venice, Italy: World Health Organization.

World Health Organization. (2016). *Burning opportunities: clean household energy for health, sustainable development, and wellbeing of women and children.* Geneva, Switzerland: World Health Organization.

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APPENDIX A

TABLE A1 Studies on kerosene burns

Author	Country	Type of study	Study period	Sample size	Share of kerosene lamp burns to total burns
Ahuja and Bhattacharya (2002)	India	Health facility survey	January 1993–December 2000	11,196 burns	2.5% of the over 16 years olds
Asuquo, Ngim, and Agbor (2008)	Nigeria	Health facility survey	February 2005–January 2008	59 burns	32.2% (lantern and stove explosions)
Barradas (1995)	Mozambique	Health facility survey	1988–1991	7,985 burn patients	44.7% of 76 deaths (kerosene or petrol lamp, 1989–1990)
Dongo et al. (2007)	Nigeria	Health facility survey	January 2002–December 2006	72 burn admissions	31.9% (lanterns and stoves)
Ghaffar et al. (2008)	India	Health facility survey	July 2005–July 2007	403 burn cases	14.2%
Gupta, Bansal, Gupta, and Goil (1996)	India	Health facility survey	February–April 1994	303 burn cases, 118 severe ones	All burns due to contaminated kerosene, 37 out of 118 severe burns were followed by death
Jayaraman, Ramakrishnan, and Davies (1993)	India	Health facility survey	May 1987–April 1988	1,368 burns	9.1%
Kanchan, Menezes, and Monteiro (2009)	India	Health facility survey	1994–2007	75 fatal unintentional injuries of children aged 10 years and below	9.3%
Kumar, Chirayil, and Chittoria (2000)	India	Health facility survey	1989–1998	309 burn injuries among children	14.6%
Laloë (2002)	Sri Lanka	Health facility survey	July 1999–June 2001	345 burn injuries, 221 unintentional	41.18% of unintentional burns
Lari, Alaghehbandan, and Nikui (2000)	Iran	Health facility survey	1995–1998	3,341 burn patients	10.8% (due to kerosene in general)
Liu et al. (1998)	Nepal	Health facility survey	3 year period	237 burns	20% (lamps, mostly driven by kerosene)
Mashreky et al. (2009)	Bangladesh	Household survey	January–December 2003	171,366 households, 819,429 individuals (1,362 burn injuries)	2.6% (≙ 7% of flame burns)
Matzopoulos et al. (2006)	South Africa	Household survey	April 2002	404 households	2.72% reported paraffin-related fires, 4.21% paraffin-related burns
Mukerji, Chamania, Patidar, and Gupta (2001)	India	Health facility survey	1993–1999	110 burns of children aged 0–14 years	10.0% (includes fire, matches, candles, kerosene lamps, and other non-specifies reasons)
Oduwole, Odusanya, Sani, and Fadeyibi (2003)	Nigeria	Health facility survey	October–November 2001	139 kerosene burns (contaminated kerosene)	96.4%
Olaitan, Fadiora, and Agodirin (2007)	Nigeria	Health facility survey	2000–2004	36 burn injuries	19.4% (lamp and stove explosions)
Oludiran and Umebese (2009)	Nigeria	Health facility survey	January 2002–December 2006	62 burns (children aged 0–16 years)	51.6% (lantern/stove explosions)
Peck, Kruger, van der Merwe, Godakumbura, and Ahuja (2008)	Sri Lanka	Personal communication	1998–1999	487 burn patients (12 years and older)	31.0% (unintentional)
Shanmugakrishnan et al. (2008)	India	Health facility survey	100-day period	150 burns	6.8% (out of 103 for which the reason is given/known)
Shepherd and Perez (2008)	Sri Lanka	Estimation of yearly values	—	—	40% of the burns in Sri Lanka attributed to kerosene bottle lamps, 150 to 200 deaths per year
Singh, Singh, Sharma, and Sodhi (1998)	India	Health facility survey	1971–1996	729 burn deaths (21–40 age group)	3.16%
Soltani, Zand, and Mirghasemi (1998)	Iran	Health facility survey	March 1994–march 1995	1,239 burns	Most common cause of burns and death was kerosene

TABLE A2 Studies on kerosene ingestions

Author	Country	Type of study	Study period	Sample size	Share of poisonings among admissions
Balme, Roberts, Glasstone, Curling, and Mann (2012)	South Africa	Health facility survey	2003–2008	2,872 children with poisoning	Paraffin (kerosene) was the commonest agent (n = 692, 24%)
Belonwu and Adeleke (2008)	Nigeria	Health facility survey	January 1999–December 2005		Kerosene poisoning constituted 1.2% (55 cases) of all pediatric admissions
Chamania et al. (2015)	India	Household experiment	January 2012–August 2013	23 kerosene lamp burns among 1,042 households during 5 years	
Chibwana, Mhango, and Molyneux (2001)	Malawi	Health facility survey	January–December 1998	144 cases of poisoning (children aged 3 months to 14 years)	16.7% due to paraffin
Clarke (2004)	Ghana	Evaluation at poisoning center	2002–October 2003	22 cases of poisoning reported	Accidental ingestion of kerosene (paraffin) among children aged 6 years and below which accounted for 17% of enquiries
Gupta, Govil, Misra, Nath, and Srivastava (1998)	India	Health facility survey	1989, 1991, 1993	185 children admitted due to poisonings	47% of poisonings due to kerosene, 6 deaths
Khadka (2005)	Nepal	Health facility survey	April 2001–march 2003	67 cases of poisoning	Kerosene responsible for 13.4% of child poisonings
Kohli, Kuttiat, Lodha, and Kabra (2008)	India	Health facility survey	July 2004–July 2006	111 children with poisonings	27.9% of poisonings due to kerosene
Lang, Thuo, and Akech (2008)	Kenya	Health facility survey	January 2005–December 2006	48 children admitted with accidental kerosene poisoning	≙ 62% of all poisoning cases
Majeed, Bassyouni, Kalaawy, and Farwana (1981)	India	Health facility survey		205 children	All with kerosene poisoning
Malangu (2008a)	Botswana	Health facility survey	January–June 2005	116 admissions due to poisoning to two hospitals	Poisoning by household chemicals, particularly paraffin, affected mainly children under 12
Malangu (2008b)	Uganda	Health facility survey	January–June 2005	276 cases of poisoning	Household chemicals responsible for 22.1%
Malangu and Ogunbanjo (2009)	South Africa	Health facility survey	January–June 2005	424 patients with poisonings in eight different hospitals	Household chemicals were the most commonly implicated poisons (45.7%). Among the household chemical agents, paraffin was the most commonly ingested (26.9%)
Malangu, Du Plooy, and Ogunbanjo (2005)	South Africa	Health facility survey	January 2000–June 2001	145 children	All admitted with paraffin poisoning
Pillai, Boland, Jagdeo, and Persad (2004)	Trinidad	Health facility survey	January 1998–December 2000	169 cases of poisoning	Kerosene responsible for 19.5%
Raizada, Kalra, Khaira, and Yadav (2012)	India	Health facility survey	3-year period	584 cases of poisoning	
Reed and Conradie (1997)	South Africa	Health facility survey		111 children under 5 years	All with kerosene poisoning, constitutes 9.1% of total ward admissions in this age group
Shotar (2005)	Jordan	Health facility survey	January 1996–December 2001	122 children	All with kerosene poisoning
Tagwireyi, Ball, and Nhachi (2006)	Zimbabwe	Health facility survey	January 1998–December 1999	327 admissions over eight different hospitals	All due to kerosene ingestion (≙11.8% of poisoning admissions)

TABLE A3 Evaluation studies and related publications

Study	Publications
Burkina Faso	Bensch, Grimm, Huppertz, Langbein, and Peters (2018). Bensch, Grimm, Langbein, and Peters (2013).
Rwanda I	Grimm, Munyehirwe, Peters, and Sievert (2017). Grimm, Peters, and Sievert (2013).
Rwanda II	Lenz, Munyehirwe, Peters, and Sievert (2017). Peters, Sievert, Munyehirwe, and Lenz (2014).
Senegal I	Bensch, Peters, and Sievert (2011). Bensch, Peters, and Sievert (2013).
Senegal II	Baseline data collection for impact evaluation of ENERSA S.A. on behalf of the Dutch development company, FMO.
Zambia	Neelsen, Peters, and Bensch (2011).

TABLE A4 Determinants of kerosene lamp usage (linear probability modell)

Use of kerosene lamp	LPM All	LPM Senegal	LPM Burkina	LPM Rwanda	LPM Zambia
Head of household's years of schooling	−0.000	−0.002	−0.020	0.013	−0.025
	(0.982)	(0.004)***	(0.000)***	(0.008)***	(0.012)**
Total number of members of household	0.005	−0.001	0.014	0.017	−0.008
	(0.013)**	(0.653)	(0.010)***	(0.014)**	(0.663)
Share of children in household	0.009	0.048	0.058	−0.107	0.122
	(0.827)	(0.461)	(0.480)	(0.067)*	(0.446)
Large animals in household dummy[a]	−0.011	−0.018	−0.065	−0.014	0.074
	(0.608)	(0.641)	(0.179)	(0.563)	(0.599)
Head of household is subsistence farmer	0.031	−0.025	−0.018	0.087	0.177
	(0.208)	(0.144)	(0.764)	(0.023)**	(0.171)
Household owns means of transport dummy	0.077	0.013	0.094	0.090	0.164
	(0.009)***	(0.482)	(0.234)	(0.049)**	(0.002)***
Country dummies (base = Senegal)					
Burkina	0.244				
	(0.000)***				
Rwanda	0.648				
	(0.000)***				
Zambia	0.173				
	(0.000)***				
_cons	−0.072	0.061	0.175	0.460	0.219
	(0.082)*	(0.183)	(0.091)*	(0.000)***	(0.053)*
Observations	3,215	605	793	1,730	87

Note: pval in parentheses denote statistical significance.
[a] Large animals include buffalos, cows, donkeys, goats, horses, pigs, and sheep. Standard errors are clustered at the village level.
* $p < .1$. ** $p < .05$. *** $p < .01$.

TABLE A5 Determinants of accident experience (linear probability modell)

Experienced accident	LPM All	LPM Senegal	LPM Burkina	LPM Rwanda
Consumption of kerosene for lighting in lit. Per month	−0.003	0.003	0.001	−0.005
	(0.477)	(0.746)	(0.766)	(0.519)
Head of household's years of schooling	−0.003	−0.020	0.000	−0.002
	(0.268)	(0.354)	(0.991)	(0.354)
Total number of members of household	0.008	0.002	−0.004	0.018
	(0.006)***	(0.812)	(0.142)	(0.002)***
Share of children in household	−0.037	−0.234	0.187	−0.086
	(0.276)	(0.253)	(0.024)**	(0.035)**
Large animals in household dummy[1]	−0.066	0.024	0.015	−0.084
	(0.002)***	(0.702)	(0.532)	(0.001)***
Head of household is subsistence farmer dummy	−0.031	0.150	−0.011	−0.036
	(0.159)	(0.542)	(0.827)	(0.140)
Household owns means of transport dummy	0.023	0.073	0.030	0.024
	(0.312)	(0.362)	(0.099)*	(0.327)
Country dummies (base = Senegal)				
Burkina Faso	−0.001			
	(0.982)			
Rwanda	0.092			
	(0.107)			
Zambia	−0.054			
	(0.368)			
Constant	0.047	0.076	−0.058	0.122
	(0.385)	(0.397)	(0.332)	(0.000)***
Observations	1,366	29	242	1,079

Note: pval in parentheses denote statistical significance.
[a] Large animals include buffalos, cows, donkeys, goats, horses, pigs, and sheep. Standard errors are clustered at the village level.
* $p < .1$. ** $p < .05$. *** $p < .01$.