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Identifying and reducing the health and safety impacts of fuel-based lighting

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ABSTRACT

The inequity of costly and low-quality fuel-based lighting is compounded by adverse health and safety risks including burns, indoor air pollution, poisoning due to accidental ingestion of kerosene fuel by children, compromised visual health, maternal health issues, and reduced service in health facilities illuminated solely or sporadically with fuel-based lighting. This article compiles and synthesizes information on the health and safety impacts of fuel-based lighting from 135 reports spanning 33 countries. Energy efficient, off-grid lighting solutions offer the most promising and scalable means to eliminate adverse health outcomes, while lowering lighting costs and reducing greenhouse-gas emissions. Deployments seeking the greatest possible health benefit should target the most impacted geographical and demographic user groups. Because women and children are disproportionately impacted, improved lighting technologies for use by these groups will yield particularly significant health benefits.

Context

Approximately 1.3 billion people throughout the developing world (one-fifth of humanity), lack access to electricity and rely instead on fuel-based lighting (IEA, 2014).[1] Uncounted businesses also find themselves in the same situation, and additional users on the electric grid face routine outages or energy costs forcing reversion to fuel-based light sources. Today, more people than the world's population at the time Edison introduced electricity spend nearly USD 40 billion annually (100 times the cost of an equal amount of electric light) to operate highly inefficient lamps (Mills, 2005). Lighting fuels are burned largely indoors and in close proximity to people, raising the question of more direct health and safety risks. Fuel-based lighting also contributes to climate change—itself a health and safety risk and compounder of poverty—by releasing substantial amounts of greenhouse-gas emissions (Mills, 2005) and black carbon (Lam et al., 2012a).

Many fuels are used to generate light, including kerosene,[2] propane, diesel, candles and a variety of biofuels. Quantifying health impacts is of critical importance. Adverse health effects are recognized (Baker and Alstone, 2011) but specific data and statistical indicators are rarely used in making the business case for alternatives. Improved information on current risks and potential health benefits of alternatives could also help identify and prioritize policy and market-based initiatives to replace fuel-based lighting with grid- and grid-independent alternatives powered by electricity.

The toxicity of lighting fuels has long been established within the medical literature (Pattle and Cullumbine, 1956). For example, direct exposure of kerosene is reported to have a wide range of consequences, including chemical pneumonia from ingestion, drying of skin and dermatitis from skin contact, symptoms consistent with CNS depression (e.g. headache, vertigo) from inhalation, neuralgia, memory loss, and effects on blood, kidney, and respiratory function (Gad and Pham, 2014). Kerosene contains known carcinogens such as benzene (American Cancer Society, 2006) and probable ones such as formaldehyde (US EPA, 2012), but studies have not focused on the cancer risks associated with indoor concentrations resulting from combustion in lanterns. Complicating such assessments, the composition of kerosene varies by refiner.

Kerosene is the most common fuel used for lighting in most countries (UNEP, 2013), although candles are dominant in some areas. The use of kerosene for lighting is far more common than as a "clean" primary fuel for cooking, and combustion in stoves is far more complete, producing fewer particulate emissions per unit of fuel burned than when burned in lanterns. Kerosene is a primary cooking fuel among only 4% of urban populations and 25% of rural populations in less-developed countries (Legros et al., 2009).

Scope and review methods

Documentation of off-grid lighting risks is far more extensive than typically cited in the energy and development literature, yet less extensive and academically rigorous than that of other energy-related risks such as those from cooking with solid fuels. Assembling a comprehensive

[1] This article was also published in report form by UNEP (Mills, 2014a).
[2] Common synonyms for kerosene include paraffin, no. 1 oil, coal oil, and lamp oil.

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picture of the existing knowledge requires assessing a broader range of sources than found in peer-reviewed scientific literature, including news reports, informal reports, and other documents.

This body of literature paints a detailed picture of multiple risks, including: unhealthful indoor air quality, injuries, poisonings, and compromised visual health. Moreover, the low quality of fuel-based illumination has negative impacts on the delivery of healthcare in poorly lit facilities. Violence against women is also inversely correlated with light availability. Few prior efforts (Mills, 2012; Lam et al., 2012b) have been made to synthesize or conduct a meta-analysis of the literature and reported data. This article provides the broadest review to date, comprising 135 reports of health issues related to off-grid lighting spanning 33 countries (Table 1). Underpinning the summary provided in this report, a database with additional detail has been posted online.[3]

While the source material varies widely, the base of evidence for lighting-related health impacts is firmly rooted in the peer-reviewed literature. Peer-reviewed studies include field reports (e.g., burns and accidental kerosene ingestion) as well as lab-based studies (e.g., pertaining to indoor air pollution from fuel-based lighting). The majority of relevant peer-reviewed studies are authored by medical professionals studying outcomes for patients in individual hospitals. While hospital reports provide a measure of risk prevalence, they capture only a small subset of impacts, especially in developing countries where hospitals are often inaccessible or injuries otherwise go unreported. Also, hospital records can attribute lighting to acute impacts, such as injuries (e.g., burns, poisonings), but not to disease from chronic exposures (e.g., poor indoor air quality). Some topics, such as house fires, are described primarily in gray-literature studies by local NGOs or news reports.

Synthesis of current understanding

The literature synthesized in this article provides a high-level, global picture of morbidity and mortality risks associated with fuel-based lighting:

- Fuel-based lighting is a significant cause of severe burn injuries, with particularly high death rates (24% of those admitted to hospitals, on average) in cases where kerosene is adulterated with other fuels and results in explosions, and a 6% mortality rate in other cases. Where destructive house fires are involved, decimating the hard-earned wealth of uninsured poor people, the resulting poverty and deprivation from being homeless can lead to additional harms.
- Indoor pollutants from fuel-based lamps include concentrations of particularly unhealthful PM2.5 particles an order of magnitude higher than health guidelines. Correlations with cataract and tuberculosis have been observed, but require further study to confirm and quantify causal links to off-grid lighting. Risks from fuels other than kerosene have not been studied.
- Unintentional ingestion of kerosene is the leading cause of child poisoning in the developing world. It is typically the number-one cause of child poisoning in developing countries, with an average mortality rate of 7% for the studies reviewed.
- Illumination levels from fuel-based lanterns are only 1% to 10% of those recommended by lighting authorities in industrialized countries. Users complain of vision-related problems and eye irritation, but formal measures of health and welfare impacts are limited. Inadequate illumination in clinics creates visual performance challenges that impede the delivery of quality healthcare, and discourages patients from seeking care. Some reports detail the risks of adverse outcomes in clinics such as maternal and infant mortality as well as difficulties maintaining good sanitation, which can lead to increased incidence of infections.
- Existing data suggest that fuel-based lighting injuries and pollutant exposures disproportionately affect women and children.
- Replacing intrinsically dangerous fuel-based lighting with electric light sources is the most promising and scalable way to reliably eliminate these risks.

There are few large-scale or statistically representative assessments of health impacts associated with off-grid lighting. As described below, many studies report that accidental ingestion of kerosene is the primary case of child poisoning in the developing world. In South Africa, 79,750 very young children are estimated to unintentionally ingest kerosene each year (160 per 100,000; occurring in 3.6% of all households) of which 60% develop a chemically induced pneumonia (Paraffin Safety Association, 2004). Also in South Africa, over 200,000 people are estimated to be injured or lose property each year due to kerosene-related fires, or 400 per 100,000 (Paraffin Safety Association, 2012a). Kimemia et al. (2014) estimate that 40%, or 400 to 700 of all settlement fires in South Africa are attributed to candles, and 14% of burn injuries. In Bangladesh, kerosene lamps are responsible for 23% of infant burns (Mashreky et al., 2008), corresponding to about 17,000 annual injuries nationally. Three multi-year reviews of admissions to Nigerian hospitals attributed approximately 30% of all burn cases to kerosene lamp explosions (Asuquo et al., 2008; Oludiran et al., 2009; Olaitan et al., 2007). Even higher burn rates (approximately 40% of all burns) are attributed to kerosene lamps in Sri Lankan homes, with 150 to 200 lives lost annually, with a cost for associated medical care of USD 1M annually (Shepherd and Perez, 2007).

A complex array of social, political, and behavioral factors contribute to the problem, including lack of product safety labeling or warnings, illiteracy (inability to receive communications about risk), overcrowding (contributes to rapid spread of fires and peoples' proximity to lantern emissions), corruption and fuel subsidies (resulting in fuel adulteration; Mills, forthcoming-b), unsupervised children, poverty (inability to afford child-safe containers for fuels), cultural practices such as keeping lamps next to young children while they sleep, to ward off “evil spirits” (Mashreky et al., 2008), ineffective or counterproductive folk remedies (for example, inducing vomiting after kerosene ingestion which causes undesirable aspiration of kerosene into the lungs) (Azizi et al., 1994), and, unwillingness or inability to seek professional care following injuries.

Self-reported risks and symptoms

Users of fuel-based lighting exhibit widely varying awareness of the risks. For example, a statistically representative survey of 3300 fuel-based lighting users across five sub-Saharan African countries found 26% to express related health concerns (Baker and Alstone, 2011). Within this group, perceived risk of fuel-based lighting on health varied widely: 57% in Zambia, 44% in Kenya, 21% in Tanzania, 14% in Ghana, and 4% in Ethiopia. Fig. 1 summarizes the users' specific concerns.

In another proxy of user awareness, a study in the Philippines found that only 9% of users cited perceived safety and health benefits as a reason for seeking alternatives to fuel-based lighting (Planete d'Entrepreneurs, 2011). The only demographic factor reported to correlate with reduced injury is income, with wealthier individuals using safer practices (Schwebel et al., 2009a).

The following sections provide further details, organized by type of health and safety risk.

Burns

There is no global estimate of burn-injuries attributable to fuel-based lighting. However, more than 95% of deaths worldwide from all types of burns occur in the low- and middle-income countries (WHO,

[3] Online database of health-related impacts from kerosene lighting (https://docs.google.com/a/lbl.gov/spreadsheet/ccc?key=0Avq_VXuy99CEdFVMaHJySWVsNnVvZkF2Nm4tN2pqMXc#gid=0).