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Artificial Lighting as a Vector Attractant and Cause of Disease Diffusion

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Artificial Lighting as a Vector Attractant

Keywords: lighting, electricity, insect, vector, Chagas' disease, leishmaniasis, malaria

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Abstract

Background Traditionally, epidemiologists have considered electrification to be a positive factor. In fact, electrification as well as plumbing are typical initiatives that represent the integration of an isolated population into modern society, ensuring the control of pathogens and promoting public health. Nonetheless, electrification is always accompanied by night lighting, which attracts insect vectors and changes people's behavior. Although this may lead to new modes of infection and increased transmission of insect-borne diseases, the role of night lighting is rarely considered in epidemiological surveys.

Objectives This paper reviews evidence concerning the role of lighting in the spread of diseases as documented in epidemiological literature, in order to encourage other researchers to consider this element in future studies.

Discussions We present three case studies of infectious vector-borne diseases (Chagas, leishmaniasis, and malaria) and discuss evidence which suggests that use of artificial lighting results in behavioral changes and changes in the prevalence of vector species and modes of transmission.

Conclusion Despite a surprising lack of studies, we conclude that existing evidence supports our hypothesis that artificial lighting leads to a higher risk of infection with vector-borne diseases. We believe that this is not only related to the simple attraction of traditional vectors to light sources, but also to changes in the behavior of both humans and insects that result in new modes of disease transmission. Considering the ongoing expansion of night lighting in developing countries, additional research on this subject is urgently needed.

The expansion of night lighting

The expansion of nocturnal lighting has raised many concerns, the most prominent of which are the consumption of fossil fuels for electric power generation and the obstruction of views of the night sky and astronomical observation. (Claudio 2009). At present, a rising concern is that light pollution is also related to human health, as summarized by Chepesiuk (2009) and Holzman (2010), mainly on the basis of chronobiological disorders. Calling attention to the fact that light pollution is also a major source of alterations to ecosystems, Longcore and Rich (2004) and Rich and Longcore (2006) coined the term “ecological light pollution”. It is thus that, by affecting the trophic web, light pollution can also, indirectly, influence human health.

Alternative energy sources and the new techniques applied in the production of artificial lighting, being more efficient than the traditional means, will increase less privileged populations’ accessibility to them (Mills 2004). They will both decrease the adverse effects of the generation of electricity on the environment and will allow the electrification of more isolated areas (International Energy Agency 2002). From a social point of view, these initiatives are beyond doubt positive. However, we should not forget that the areas lacking electricity are mainly rural areas of the equatorial and tropical regions, where there is, anyway, a greater presence of insect-transmitted diseases (Jones et al. 2008). In view of the fact that artificial illumination is a great attractor for insects, the diffusion of these social services could constitute a risk of epidemic outbreaks both in terms of existing and of emerging diseases.

Traditional views on the role of electrification

Electrification is doubtless important as a means to develop rural areas, and it also has many beneficial effects. According to the IEG World Bank (2008), for example, it operates through a number of channels:

"• Improvements to health facilities

• Better health from cleaner air as households reduce use of polluting fuels for cooking, lighting, and heating (Hutton and others, 2006)

• Improved health knowledge through increased access to television

• Better nutrition from improved knowledge and storage facilities from refrigeration."

Most epidemiological reports cite both electrification and plumbing as positive factors in the control of diseases. As an example, Noor (2008) used "remotely sensed night-time light as a proxy for poverty in Africa", indirectly assuming that artificial lighting is a good social development index. However, electrification also means artificial lighting and artificial lighting is a strong insect attractant.

Although entomologists and epidemiologists traditionally make use of light traps to capture insects, the effect on disease diffusion caused by the expansion of artificial lighting is generally not considered – sometimes it is even denied. Such positions are longstanding: at the beginning of electrification, during the construction of the Panama Canal (Le Prince and Orenstein 1916), Le Prince stated that it was man who attracted insects and artificial lighting did not contribute to the diffusion of malaria. Carlos Chagas, who discovered Chagas' disease, warned that light is a good defense against the diffusion of the disease since *Triatoma*, its vector, does not bite in lighted areas (Chagas 1909).

Indeed, light may inhibit some insects from biting, but in order to understand its role on the diffusion of diseases we need to take into account the behavioral changes brought about in both human beings and insects. In other words, night lighting promotes new lifestyles and this may lead to new modes of disease transmission. However, this phenomenon is scarcely referred to in the literature.

Of course, we are not claiming that the introduction of modern lighting systems increases the risk of emerging diseases immediately and directly. Their diffusion is bound to produce changes in human lifestyles, which are brought about by lighting, radio, television and other electrical equipment. As a result of electrification, activity increases in the evening and in the early night people may stay outdoors longer, either taking exercise or resting in hammocks or even doing other activities close to sources of bright light.

Whereas people might be more exposed to vectors merely by staying outdoors in the evening, lights also increase exposure by affecting vectors. In general, insect attraction to lights is accepted as fact. However, a common misunderstanding is that this attraction represents a positive phototaxis. Contrary to this belief, as noted by D'Arcy Thompson (1917), Verheijen (1958), Mazokhin-Porshnyakov (1969), Janzen (1983) and more recently summarized by Nowinszky (2003), insect attraction to lights is not a positive phototaxis, but rather the result of a navigational confusion. Attraction results from the fact that insects mistake light sources (especially those emitting UV radiation) for the celestial points of reference they normally use for orientation, which may result in a trajectory towards a light. In the vicinity of a light source, however, not all insects are directly attracted to the lamp. While some may be, others may hide in dark places in the surroundings, keep flying in the illuminated area, or land somewhere near the lamp (Nowinsky 2008). Despite all this variation, it is important to stress that even vectors which usually bite only in the dark may be attracted to the surroundings of a light source and thus near to humans. There, they may transmit diseases in non-conventional ways.

In order to demonstrate the potential of night lighting for augmenting people's exposure to vectors and for creating new modes of disease transmission, we give an account of our findings after a comprehensive review of the literature. We have been able to find circumstantial evidence that electrification and lighting may be the source of new modes of transmission for three well-known infectious diseases.

The case of Chagas' disease

Ironically, the first confirmation of the strong impact of artificial lighting on the diffusion of diseases, validated by epidemiologists, came from the Chagas' disease. This is remarkable, considering that its vectors (triatomine bugs, also known as kissing bugs) do not bite in lighted areas and artificial lighting has always been thought of as a good defense against them. Chagas' disease was the kind of illness typically found in people living in adobe huts with straw thatched roofs, excellent hideouts for the bug. It was widespread in pre-Columbian times in the Andean world where domesticated cui or guinea pigs (*Cavia porcellus*) were the primary hosts(Coimbra 1988). The main vector was *Triatoma infestans* – a bug well adapted to poor households. In colonial times, it had spread to the South American lowlands and by 1955-1964 the spread of the disease had reached central and northern Brazil, probably carried from place to place in the baggage of immigrants. The main vectors were species well adapted to living in households: *Triatoma infestans* in Brazil, and *Rhodnius prolixus* in Venezuela, Colombia and the Guyanas (Zeledon and Rabinovich 1981).

Large-scale household insecticide spraying campaigns undertaken in Brazil after the 1970s and in most of Latin America after the 1980s, proved to be effective in controlling Chagas´ disease in Brazil. “By the end of the last century it became clear that continuous control in contiguous endemic areas could lead to the elimination of the most highly domestic vector populations – especially *Triatoma infestans* and *Rhodnius prolixus* – as well as substantial reductions of other widespread species such as *T. brasiliensis*, *T. sordida*, and *T. dimidiata*, leading in turn to the interruption of disease transmission to rural people” (Dias et al. 2002).

During the elimination of the most highly domestic vector populations, new disease outbreaks arose, with a different pattern of diffusion involving a more diverse group of insect vectors and a larger pool of wild and domestic animal hosts. At the same time, a new mechanism of human transmission was discovered. Specifically, vectors are attracted to artificial lighting in areas surrounding homes, instead of entering directly into homes. There, they may rest on plants such as the açai palm (*Euterpe oleracea*), and parasitize opossums or any other warm-blooded animals. Afterwards, fruits contaminated with their faeces may be collected and consumed by people. This means of transmission – oral transmission – is being increasingly observed, and may be a consequence of the vector’s attraction to lighting, as illustrated by the example depicted in Figure 1.

The mechanism of oral transmission was originally proposed by Bertram (1971), and was confirmed by Zeledon and Rabinovich (1981), who reviewed experiments on triatomine bugs and reported that 20 species – including *Rhodnius prolixus* – were attracted to lights. Many researchers have reiterated this hypothesis since then (Feliciangeli et al. 2002; Cuba et al. 2002; Salomon et al. 1999; Teixeira et al. 2001; Zeledon et al. 2001). Whereas in many cases they simply mention the possibility that lighting may have facilitated disease transmission, Walter et al. (2005) explicitly identified a strong association between the spread of Chagas' disease and the use of kerosene lamps and photovoltaic panels. These are modern high intensity lighting systems to which most insects are attracted. Finally, two recent important reviews of Chagas´ disease also concluded that artificial lighting may affect transmission of the disease (Remme et al. 2006, Rojas et al. 2005).

Remme et al. (2006) describe three different transmission cycles, including a domestic cycle involving domestic insect vectors and animal reservoirs that reside in close contact with humans, a sylvatic cycle in which sylvatic insect vectors transmit the disease to wild animal hosts, and a peridomestic cycle in which sylvatic vectors that are attracted to lights in and around homes transmit infection by feeding on domestic animals and humans or indirectly transmit infection by contaminating food consumed by domestic animals and humans. In particular, they note that in the Amazon region, humans have become infected with Chagas disease by eating sugarcane or fruit juice contaminated with the feces of sylvatic Triatominae.

The case of leishmaniasis

A second disease whose spread appears to be augmented by artificial lighting is leishmaniasis. Sand flies (phlebotomines), the vectors of Leishmania, are poor flyers (Dias-Lima et al. 2002) that are attracted to lighted surroundings but are usually not found directly on lamps. In periurban areas, street lighting attracts sand flies to small farms or kitchen gardens where dogs, chickens and other small animals become the hosts. In the case of the phlebotomines, Campbell-Lendrum et al. (1999) showed that both *Lutzomyia intermedia* and *L. whitmani* are attracted to light. Later, dos Santos et al. (2003) argued that this attraction may increase the risk of Leishmania transmission "… in houses where an external light source is situated close to a light-color wall that reflects light, and that have adjacent bushes or trees and domestic animal shelters within 50 meters."

Moreover, we cannot forget that sand flies are also the vectors of a large number of arboviruses that are common in tropical and equatorial regions (Travassos da Rosa et al. 1998), which are the cause of a large number of diseases, generally called "wild fevers". Sand flies are also vectors of infectious diseases in temperate region, including West Nile encephalitis and equine encephalitis.

The case of malaria

The case of malaria is more problematic. Unlike Chagas and leishmaniasis, there have as yet been no specific studies published on the relationship between night lighting and vector attraction. Although mosquitoes are seldom found near lamps and almost never captured by static light traps, they can be captured using CDC, New Jersey or other kinds of suction light traps without heat or carbon dioxide bait (Govella et al. 2009, Jawara et al. 2008, Lee et al. 2009, Suárez-Mutis et al. 2009). Malaria vectors are, therefore, probably just as attracted to lights as Chagas and leishmaniasis vectors are and we should then expect a corresponding change in modes of transmission with increased use of artificial light.

We also know that electrification is changing lifestyles in all isolated areas. In Amazonia, for example, electric lights allow people to spend more time outdoors when vectors are active, particularly between sunset and the first hours of the night. For example, sports and gymnastics are practiced outdoors in the evening under strong artificial lights, and one may observe people resting in hammocks on their porches along the banks of the Amazon River, their electric lights shining brightly. These are all conditions that could affect vector attraction and also facilitate malaria transmission. However, we have not been able to find any epidemiological studies on this matter relating to the Amazon.

Brian Taylor (1997) proposed that increased time spent outdoors at night may have contributed to a resurgence in malaria infections among Solomon Island residents in the early 1980s, which followed substantial declines in infection rates resulting from in-home use of DDT in the 1960s. As Taylor (1975) stressed, “Traditionally, the Melanesian peoples retired indoors at sunset but in more ‘enlightened’ areas this habit broke down (a combination of changed working hours and the money to buy artificial lighting)…”. Malaria control was only regained in the Solomon Islands ten years later when spraying was no longer limited to bed-nets and households (Over et al. 2003). This suggests that night lighting augments human exposure to vectors by enabling people to stay outdoors longer. It is not clear if the vectors themselves were also attracted to lights or if lights affected their feeding behavior, but, given that *Anopheles* are indeed attracted to light traps, these possibilities could be tested with additional research.

Other examples have come from two recent studies. Yamamoto *et al.* (2010), working in Burkina Faso, found that living in a home less than10 years old and living in a home with electricity were both associated with an increased risk of malaria, while a measure of socioeconomic status was not. The authors suggested that vectors might be more likely to bite residents of homes with electricity than residents of non-electrified homes where greater use of biomass fuels would produce smoke that might prevent insects from biting. However, a recent review concluded that smoke does not reduce biting in homes (Biran *et al.* 2007). In South-Africa, Coleman et al. (2010) found that opening windows at night-time increases the risk of malaria transmission, but the authors did not evaluate electrification as an independent risk factor for disease transmission. Researchers did not collect the necessary data to evaluate the role of artificial light directly in either study, consistent with the lack of research on this topic in epidemiological studies.

Conclusion

Although we have presented evidence that artificial light may increase the transmission of only three diseases, we strongly believe that this is a consequence of a lack of studies rather than a lack of an effect, and that the three diseases we have discussed may reflect a general pattern. Artificial night lighting changes the behavior of both people and insects, and thereby promotes contact between human beings and vector species, including some that have not traditionally been involved in human disease transmission. This may lead to new and unpredictable ecological relationships that need to be understood so that electrical energy can be offered to less privileged populations without increasing their risk of acquiring insect-borne diseases.

In order to properly test this hypothesis, the presence of night lighting in or near households must be recorded in epidemiological surveys, especially in recently electrified rural areas. We trust that this contribution may shed light on this hitherto neglected problem and encourage epidemiologists to carry out studies that take into account changes in human and vector behavior related to artificial lighting.

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Figure Legend

Figure 1. A single photograph may be more telling than many written examples. In February-March 2005 the Department of Health of Santa Catarina (Brazil) identified an epidemic of Chagas' disease (Ministério da Saúde, 2007). After intensive research, it was verified that sugar cane juice sold at a road-side kiosk was the source of infection for all 12 confirmed cases. The vector of Chagas´ disease does not live in sugar cane plantations and there was no reason for its being in stored sugar cane. The only positive indication was the high intensity discharge lamp installed in the sugar cane juice kiosk. The bugs (*Triatoma tibiamaculata*) were attracted by the strong artificial light source in the sugar cane juice kiosk, and were crushed together with the sugar cane when the juice was processed. The picture was taken by Luiz Antonio Oliveira Ilha.

169x127mm (96 x 96 DPI)