

# Strategies to outdoor artificial light at night (ALAN): to balance the urban development and human health

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**Abstract:** Light has played a pivotal role in shaping human evolutionary trajectories, and it continues to exert profound effects on human health in contemporary societies. Especially, with the advent of artificial light at night (ALAN), the global application of lighting increased diversely, covering indoor and outdoor building lighting, traffic/street lighting, commercial advertising, electronic entertainment and many other fields. ALAN has become one of the most critical global change phenomena may affect human health through both direct and indirect pathways.

**Keywords:** artificial light at night (ALAN); human health; life-course exposure; prenatal exposure; non-visual effects; environmental exposure assessment

While it is well known, increasing artificial light at night (ALAN) as a sensory physical pollutant has been linked to damage to ocular tissue, such as myopia in children and adolescents<sup>[1]</sup> and age-related macular degeneration in adults<sup>[2]</sup>. Currently, the non-visual health effects of ALAN are receiving increasing attention. Intrinsically photosensitive retinal ganglion cells capture light signal, then the retino-hypothalamic tract transmits the photic information to the suprachiasmatic nucleus to regulate circadian rhythms. Through neural and endocrine pathways, this process also inhibits melatonin secretion, elicits changes in stress responses, affects immune cell activation and oxidative stress, and worsens sleep quality, all of which increase the risk of neurological<sup>[3,4]</sup>, cardiovascular<sup>[5–7]</sup>, metabolic diseases<sup>[8,9]</sup>, and even cancers<sup>[10,11]</sup>. Although systematic entire life cycle studies remain lacking, existing epidemiological evidence across different age has already demonstrated these associations in both indoor and outdoor settings. Recent studies have also observed positive associations between prenatal exposure to ALAN and adverse outcomes in offspring<sup>[12–14]</sup>. For example, a prospective cohort study including 6210 mother-infant dyads indicated an IQR (14.87 nW/cm<sup>2</sup>/sr) increase in outdoor ALAN during pregnancy was associated with 13% (OR = 1.13, 95% CI: 1.00, 1.27) higher odds of macrosomia<sup>[12]</sup>. Another birth cohort study showed each SD increase (12.92 nW/cm<sup>2</sup>/sr) in the entire pregnancy ALAN

was associated with 14% elevated slow weight-for-age z score growth trajectory risks (RR = 1.14, 95% CI: 1.01, 1.29)<sup>[13]</sup>. Likewise, a case-control study (736 cases diagnosed at 0–19y of age and 36,800 controls frequency-matched on birth year) of papillary thyroid cancer nested within a California birth cohort observed statistically significantly increased odds of papillary thyroid cancer (OR = 1.07 per 1 mcd/m<sup>2</sup>)<sup>[14]</sup>. These relationships suggest that ALAN exposure may affect human health via non-visual pathways starting from early life and continue for the whole life course.

Although epidemiological findings suggest that indoor, outdoor or individual-derived ALAN exposure may influence health across the whole life, biological pathways are far from fully explaining these diverse, compounded, and cumulative health impacts of ALAN. Outdoor ALAN marks the global impact of humanity, represents the process of urbanization, energy consumption, and social inequalities, which provides an explanation for the complex links between ALAN and health outcomes beyond biological mechanism. Always, greater ALAN leads to increased energy consumption, greater exposure to high temperature, poor air quality, more noise, reduced space for exercise and other features of health equity related to migrants, some of which may independently contribute to public health. However, areas with greater ALAN are also often inherently linked to higher provisioning supply, such as



housing, traffic, more light designed buildings (environment with less crime) or commercial activity. These characters of urbanization supplied provisioning systems essential for human sustenance, such as housing, transportation, medical care and employment opportunities, etc. To a certain extent, it has a beneficial promoting effect on public health. Exploring the indirect impacts of ALAN on free-ranging human is challenging. Actually, ALAN is often used to predict resource extraction and environmental degradation, and also as “visible energy consumption”, used to track carbon emissions, global warming and extreme weather events. Moreover, socioeconomic responses to ALAN reductions or fluctuations, highlights the daily ALAN as a potential vital tool to informing societal resilience and equity<sup>[15]</sup>.

Obviously, the interplay among these direct and indirect pathways complicates overall health risk assessment of ALAN, it provides a perspective to integrated limits-based ALAN prevention strategies to balance the urban development and human health. Complete reduction in ALAN is impractical. But there is no accepted international consensus or standardization of approaches to communicate ALAN levels and risks. We argue that ALAN “threshold” should be a focus for ALAN research in the future. Currently, satellite-derived outdoor ALAN is the most common method for evaluating ALAN exposure. However, determining the appropriate ALAN based on satellite-derived ALAN still needs more research to supply effective corresponding scenarios between the satellite data and ground lighting. Assessment on the correlation between indoor and outdoor ALAN is also needed in these ground scenarios. Besides, data of night street view is another promising tool to assess ALAN and develop the limits of ALAN.

Ultimately, limits on ALAN and developing strategies to mitigate its effects require a collaborative approach. The governments, businesses, environmental scientists and public health experts need to collaborate to strike a balance of urban development and health perspective. Assessing the benefits of ALAN as important component of provisioning systems (providing housing, work and medical opportunities, security, mobility-connectivity), and estimating losses of ALAN as environmental stressor directly and indirectly (physical and socioeconomic pathway) be harmful to public health. ALAN, as one of great challenges facing humanity in the 21st century, deserves the attention from the whole society as the other global change phenomena.

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