

Light pollution causes and effects in the Anthropocene: impacts on ecosystems and human health - a narrative review

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Abstract

Artificial light at night (ALAN) is a poorly studied but ubiquitous type of environmental pollution that has profound ecological, physiological, and societal consequences. This mini-review is a synthesis of existing knowledge about the causes and effects of ALAN. It highlights the variety of effects it has on both ecosystems and human health. Excessive or improperly directed outdoor lighting is defined as ALAN. It causes various effects, including disturbances to astronomical observations, wildlife behavior, and human circadian rhythms. The environmental effects consist of disrupted migration, breeding, and nesting behaviors of animals, insects, and birds, and reduced hatching rates of sea turtles and coral reefs around the coast. In humans, ALAN has been linked to cancer, especially breast cancer, metabolic disorders, and mood disturbances as a result of disruption to the circadian rhythm. Although there is an increasing level of awareness of the problem, both through digital distribution and grassroots movements, successful mitigation has yet to be achieved. Urban lighting is expanding at a rate of more than 2 percent per year. This review classifies the types of lights that contribute to ALAN, explores its oncogenic processes, and considers citizen-led efforts to curb light pollution. We emphasize that interdisciplinary research and policy intervention are urgently required to tackle the environmental and health aspects of ALAN and suggest a range of measures, including less nighttime lighting, implementing blue-light-blocking devices, and increasing environmental surveillance. The lack of funds and research priorities is an additional reason to create global activities aimed at saving natural darkness and reducing the overall impact of ALAN.

Keywords: *Artificial light at night, light pollution, circadian rhythms, ecological impacts, cancer, citizen action*

Introduction

Light pollution is a combination of excessive, unnecessary, and often uncontrolled artificial lights, which negatively impact nature, lifestyles, nocturnal animals, and space research. The severe effects of the unrestrained and dangerous use

of various kinds of artificial light sources, whether indoor or outdoor, have been overlooked by the majority of people in the world, who have little or no awareness that they are exposed to such a type of pollution every day. Numerous studies and interventions have supported beyond doubt the existence and impacts of air, water, soil, and noise pollution. Nevertheless, there are very few references describing the environmental threat of light pollution. Light from outdoor sources is a big problem for astronomical studies. In general, light pollution is a combination of difficulties in seeing the stars or any other celestial bodies at night due to the use of different artificial light sources (Zielińska-Dabkowska et al., 2020). Many organizations and observatories that conduct research in the field of astronomy, for example, the International Dark-Sky Association (IDA), have been discussing this problem for almost the 20th century. The use of ALAN has been increasing worldwide. It has been noted that this phenomenon causes damage to a plethora of organisms (Oyabu et al., 2024). In the world of fauna, light pollution changes many day-to-day activities. Extreme light pollution near coastal areas also adversely affects marine organisms (Rosenberg et al., 2019). Insects are sensitive to the concentrated lights. It also affects human routine, and several times it may become oncogenic (Duarte et al., 2019). Apart from serious diseases, it is also a matter of energy wastage. ALAN has experienced a drastic increase nowadays, primarily for the benefit of humans (Hölker et al., 2010).

With the rapid advancement of technology, there have been many green energy discoveries, such as LEDs, that are now becoming more popular. Stevens says that "Light pollution is still way down the list of important environmental issues needing study. That is why it is so hard to get funds to research the issue." (Chepesiuk, 2009). This study aims to present an in-depth, evidence-based summary of the peer-reviewed papers and diverse effects of ALAN as a form of pollution in the Anthropocene, focusing on the ecological, biological, and social impacts all at once. More specifically, the review seeks to (1) characterize the primary sources of light pollution resulting from urban sprawl, poorly designed light fixtures, spill light from commercial and promotional neon signs, and lighting from Traffic and Aviation sources as well as from residential building (2) assess the ALAN impacts on wildlife, dealing specially with altered migration, reproductive, nesting and foraging activities in birds, insects, turtles (3) the impacts of ALAN on human beings, mainly focussing at the consequences of circadian disruption, higher rates of cancer, unregulated blood sugar and psychological disorders stemming from the artificial night light; (4) Describing the societal, economic and astronomical consequences of ALAN, to the detriment of energy efficiency, light-trespass, and darkness over the night sky, and its quantifiable measures (5) evaluating the effectiveness and difficulties of light pollution advocacy and grassroots activism, focusing on the importance of technology, advocacy, and legal frameworks and (6) outlining the interdisciplinary mitigation measures, including emerging technology to block blue light, enhanced ALAN monitoring, and other ecologically oriented measures, to resolve the health and ecological effects of ALAN.

Table 1. Categories of artificial light at night (ALAN) and their primary causes, and mechanisms

Category	Causes	Mechanisms	Examples	References
Urban Development	Growth of cities and infrastructure due to urbanisation	Light to escape upward or outward, contributing to sky glow.	Street lamps, parking lot lights, illuminated buildings	John C. Wells Planetarium. (2025).
Lighting Design & Infrastructure	Unshielded or inefficient fixtures	About 30 percent of the light emitted by regular streetlights is directed towards the sky.	Cobra-head streetlights, unshielded residential lights	John C. Wells Planetarium. (2025).
Commercial & Advertising	illuminated signboards, neon signs, display advertising	In many cases, lights are too bright and left on all night, contributing to light clutter and trespass.	Digital billboards, The commercial district displays	Wang et al. (2023)
Industrial & Transportation	Vehicle headlights, ports, airports, and industrial areas	Sources that are in motion and add to local light pollution and glare.	Headlights from cars, lights from shipping facilities, and runway lights	Wang et al. (2023)
Domestic Sources	Residential outdoor lighting, electronic devices	The use of LED and electronic appliances increases the exposure of ALAN in home environments.	Garden lights, security lights, and light from smartphones and tablets are used.	Zhu et al. (2024)

Artificial light at night nuisance: categories of lighting types

Humans have drastically altered the nocturnal light environment outside. Natural dim and bright lights were relatively constant across extended geological and evolutionary time periods. However, the introduction of artificial illumination,

especially electric lighting, has significantly disrupted this balance. There are several different components to this disturbance, which originates from both public and private illumination sources, such as street lights, advertising lights, home and vehicle lights (Gaston et al., 2015). Based on the research performed and the analyzed cases, the authors have confirmed different existing categories of lighting types (Figure 1) (Zielińska-Dabkowska et al., 2020). Table 1 lists the categories of ALAN and their primary causes and mechanisms.

Table 2. Key Effects of Artificial Light at Night (ALAN)

Category	Specific Effects	Impacts	Mechanisms	References
Human Health Impacts	Circadian rhythm disruption	Circadian rhythm disruption, Melatonin suppression, sleep disorders (delayed sleep-phase syndrome, insomnia)	Melatonin release is suppressed, and metabolic control through the circadian rhythm is compromised.	Zhang et al. (2024)
	Cardiovascular and metabolic effects	Cardiovascular and metabolic effects	There is an amplified risk of high blood pressure, being overweight, diabetes, and heart malfunction. A study has been conducted to investigate the relationship between diabetes occurrence and changes in HbA1c levels, fasting glucose, and heart rate variability.	Zhang et al. (2024)
	Mental health issues	Depression, anxiety, depressive-like behavior	Circadian rhythm and sleep disturbance exacerbate mood disorders	Wang et al. (2023)
Ecological Impacts	Wildlife behavior and ecosystem disruption	Animals (birds, insects, fish, for instance) foraging, reproduction, and predation regulation	Artificial light at night (ALAN) disrupts natural light patterns that animals use for migration, nesting, and feeding in their habitats.	Pulgar et al. (2023)
	Soil system changes	Soil respiration has significantly decreased, and microbial and nematode community changes have occurred.	The content of soil water and biomass is changed indirectly by ALAN; thus, soil ecosystem processes are being reallocated.	Cesarz et al. (2023)
	Marine ecosystem disruption	Confusion of baby sea turtles, changes in the decision-making of intertidal fish	Causes the diversion of sea-going hatchlings and changes the fish's favourite places to live due to the noise.	Pulgar et al. (2023)
Societal & Economic Effects	Energy waste and climate change	The U.S. wastes nearly \$2.2 billion every year due to inefficient lighting, which is the major cause of energy waste.	Contributing to the release of more fossil fuels and carbon dioxide.	John C. Wells Planetarium. (2025)
	Light trespass and clutter	Glare that makes it difficult to see, and light that escapes from a room to the neighbors' homes	Impairs the safety and the visual environment, especially in areas with high urbanization.	John C. Wells Planetarium. (2025)
Astronomic & Cultural Effects	Loss of night sky visibility	Stars become less visible, and the Milky Way appears faint	Being a source of excessive illumination for the sky, the deep night, the stars, or the moon, thus cultural and scientific work is endangered.	Hartley (2023)

Light pollution and cancer

ALAN has always collaborated with many diseases, both cancerous and non-cancerous. Several genes are involved in the genesis of cancer due to light exposure. Core clock genes and their impact on the cell cycle are crucial in this context (Walker et al., 2020). Light affects the circadian rhythms of cancer-producing cells due to frequent exposure to ALAN, which is an important scenario (Schernhammer et al., 2001), particularly for malignancies that depend on hormones to flourish, such as prostate and breast cancers. While blind individuals, who are unlikely to be exposed to or perceive LAN, have demonstrated lower risks, women who work night shifts have demonstrated greater rates of breast cancer (Hahn, 1991). Circadian rhythms govern several key processes involved in causing cancer. Any obstruction of circadian rhythms influences oncogenesis. There is a strong relation between ALAN and tumour developmental stages (Figure 2). There may be some strategies to mitigate the oncogenic effects, such as turning off the night lights, using blue lights, and seeking medical help for the variations in melatonin (Walker et al., 2020).

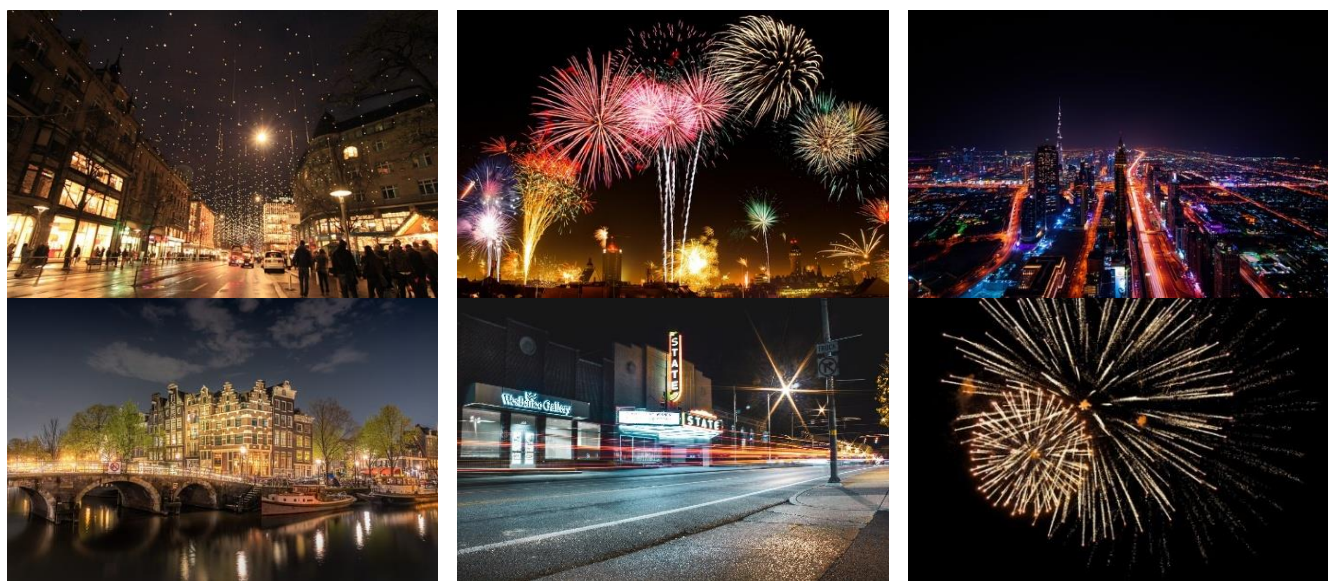


Figure 1. Different kinds of artificial light at night

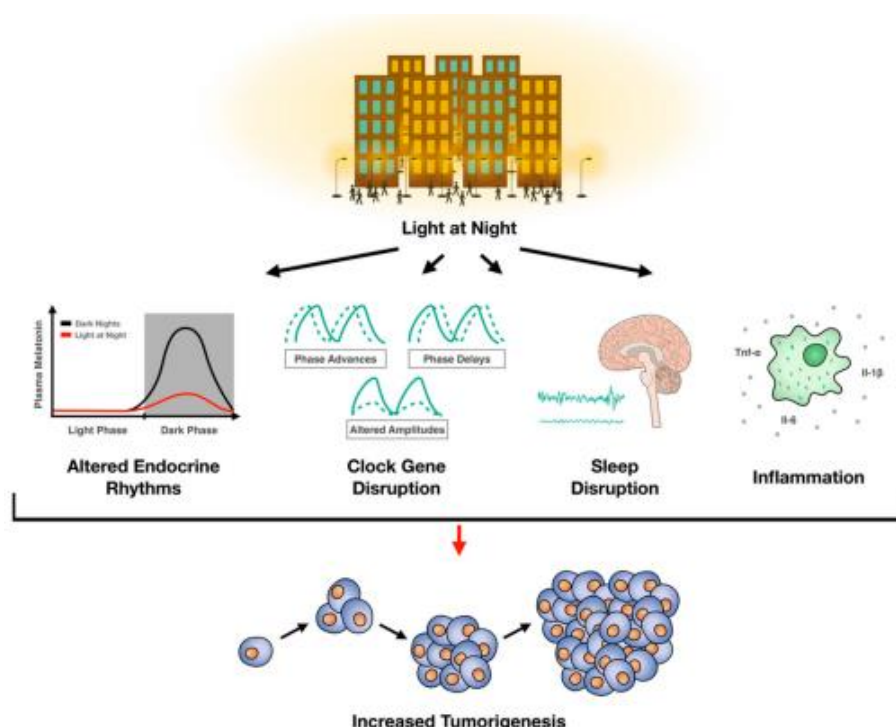


Figure 2. Summary of the effects of artificial light at night on tumorigenesis (Source: Walker et al., 2020) (This figure is under CC BY license)

Assessment of citizens' actions against light pollution

People today have access to factual information about the detrimental effects of artificial light at night (ALAN) on their dark skies, as well as their health and well-being, thanks to the extensive coverage of scientific research in the media and technological tools like web browsers, the Internet, and the World Wide Web (WWW). They can now take the necessary steps and make informed decisions to protect their communities and themselves from harmful light pollution. Although this move is commendable and positive, research shows that not all initiatives of this kind have been fruitful (Zielińska-Dabkowska et al., 2020). Media reports covering a wide range of scientific research and technological tools, such as the World Wide Web (WWW), the Internet, and web browsers, have made factual information accessible to people. This information includes the effects of artificial light at night (ALAN) on the darkness of the skies, health, and well-being of humans. As a consequence, citizens can now make informed choices and take the first steps in the fight against light pollution, which affects not only their environment but also their health. Lights Out is a voluntary program that started in New York City in 2005. Its objective is to lessen the 600 million birds that are thought to die annually as a result of accidents with lit buildings in North American cities (Horton et al., 2019). Although our understanding of this ground movement is deepening, further studies are required to complete a comprehensive picture of the current situation worldwide. Various actions are taken by citizens, along with the challenges, methods, and tools involved, regarding good practices initiated by grassroots activism aimed at reducing existing and potential light pollution. There has been an increase in the number of legal cases related to light pollution due to the rise in public awareness, the availability of scientific knowledge via the Internet, and the ability to take accurate lighting measurements and perform lighting simulations (Shostak, 2017). An Environmental Impact Report (EIR) prepared by experts for different authorities (central government, province, or municipality) is also highly advised in the future, before any new construction or renovation activity related to outdoor lighting is planned in residential or natural environments. This is done to assess potential health and environmental impacts. To effect positive change with local government, citizens can voice their complaints to local municipal officials and exert pressure on them to pursue the matter further. Towns and communities can install ecologically and biologically responsible lighting by implementing anti-light pollution legislation (Zielińska-Dabkowska et al., 2020). Additionally, over the last few years, a new digital tool for digital participation in the form of online petitions has emerged as a new movement to mitigate light pollution. Based on this data, a framework involving suggestions for citizen action has been developed. Accordingly, new frameworks and policies were formulated for urban areas for adaptation (Zielińska-Dabkowska et al., 2020). In the past, astronomers also noticed the sky glow interrupting the passage through atmospheric layers (Riegel, 1973). Some 40 years later, environmentalists also became publicly vocal about the negative impact of the use of artificial light at night (ALAN) on the environment and biosphere as a whole (Gaston et al., 2015). Different patterns were witnessed regarding the avoidance of suitable habitats, alterations in reproduction and seasonal migration routes, as well as the reduction in numbers or even the extinction of some important species. In 2008, the EPA filed a case to review light pollution, aiming to monitor and reduce regional night disturbances of the sky under the Clean Air Act (Zielińska-Dabkowska et al., 2020).

Policy recommendations and future directions

To mitigate the widespread impacts of ALAN on the environment and human health, evidence-based policy guidelines advocate for regulatory policies that favor energy-efficient, shielded lighting technologies. For example, regulations must require public streetlights to be fully shielded to reduce sky glow and light trespass, as advocated by the American Medical Association, which points to potential health advantages such as a decrease in circadian disruption (Motta, 2024). Also, urban planning policies would include ALAN thresholds during environmental impact studies, borrowing from critiques that support point-source regulation to limit urban spread of light pollution (McDermott, 2023). Globally, guidelines such as those by the International Dark-Sky Association advocate the use of spectrum-based controls, that is, the application of LED lights with warmer colors (less than 3000K) to limit blue-light emissions, which have been linked to oncogenic pathways. Financial instruments, such as subsidies for retrofitting inefficient fixtures, could reduce energy waste in the U.S., estimated at \$2.2 billion annually, and facilitate the integration of ALAN monitoring into clean air legislation, as proposed to the EPA in 2008 (National Park Service, 2025). The next movement concerning the ALAN study has to be the focus on multiple disciplinary frameworks that erase the ALAN cumulative impacts and thus do not confuse them with other factors, including co-occurring stressors like urbanization and noise (Marangoni et al., 2022). An alarming question is how we can assess the extent of ALAN-caused biodiversity loss in each facet. At the same time, there is an instant need for uniform monitoring methods that utilize satellites and ground sensors (Kocifaj et al., 2023). Artificial light at night (ALAN) that affects water ecology warrants in-depth study, particularly in the context of disturbances to predator-prey relationships and the changes that occur when organisms are exposed to specific light wavelengths (Tidau et al., 2021). Longitudinal epidemiological studies of the combined impact of ALAN and air pollution on cognition are needed. They should use innovative methods of fine-scale spatial epidemiology to do so. The absence of studies on non-urban conditions is a significant obstacle in conservation efforts that focus on nighttime darkness to evaluate the effects of adaptive management on mitigation strategies worldwide (Hölker et al., 2021).

Conclusion

As human communities and lighting technologies evolve, artificial lights increasingly encroach on dark refuges in space, time, and across different wavelengths. At a certain given latitude, illuminated natural regimes have been quite stable during the recent evolutionary period. The rapid global increase in artificial lighting is seen as a significant alteration to the Earth's global cycles of light and darkness. Organisms use natural light not only as a resource but also as a source of information about their environment. Artificial light might make it impossible for organisms to utilize environmental resources and for the flow of information in ecosystems. Among others, research on artificial lighting at night will most probably find that artificial night lighting is a strong force determining local communities by intervening in competition and relations between predators and prey. Those researchers will be confronted with the problem of how to separate the confounding and cumulative effects of other human disturbance factors that are closely related to artificial night lighting, such as roads, urban development, noise, exotic species, animal harvest, and resource extraction. In order to achieve that, light disturbance measurements need to be part of the standard environmental monitoring protocols, such as the NSF's National Ecological Observatory Network (NEON). Confirmatory studies will reveal an increasing role for artificial lighting in nature, making it a leading factor in ecosystem disruption, which is highly challenging to preserve in the long run.

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Not applicable.

AI tool usage declaration

The authors did not use any AI and related tools to write this manuscript. For English language improvement, Grammarly software is used.

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