Review Article

Light Pollution and Its Effects on Human Health and the Environment: A Review

Abstract

Light pollution, the presence of excessive or misdirected artificial light, has become a growing concern due to its adverse impacts on both human health and the environment. This review explores the multifaceted issue of light pollution, starting with an overview of its various formsskyglow, glare, and light trespass—and how urbanization and industrialization have exacerbated these problems. The review examines key sources of light pollution, including streetlights, commercial signage, and residential lighting, and discusses their contributions to environmental degradation and health issues.The environmental impacts of light pollution are significant, affecting nocturnal wildlife by disrupting natural behaviors and ecological interactions, and altering plant growth and reproduction. The review details how artificial light interferes with natural cycles, including circadian rhythms, and the resultant effects on animal and plant life.From a human health perspective, the review highlights how light pollution disrupts circadian rhythms, leading to sleep disorders, increased stress, and mood disorders. It addresses the psychological and cognitive effects of disrupted sleep, including impaired attention, memory, and executive function. Additionally, the review outlines the links between chronic light exposure and increased risks of obesity, cardiovascular diseases, and metabolic disorders.Mitigation strategies, including improved outdoor lighting design and public awareness initiatives, are discussed as essential measures to address light pollution. By providing a comprehensive analysis of the sources, effects, and potential solutions, this review underscores the urgent need for effective interventions to protect both human health and the natural environment from the detrimental effects of light pollution.

Keywords: Light Pollution; Human Health; Environmental Impact; Artificial Light; Health Risks; Exposure Effects

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1. Introduction

1.1 Overview of Light Pollution

Light pollution is defined as the presence of excessive or misdirected artificial light in the environment that interferes with natural darkness. It encompasses several forms, including skyglow, glare, and light trespass, all of which can negatively impact both human health and the natural environment [1]. Light pollution includes several key components: skyglow, which is the brightening of the night sky over populated areas; glare, which causes visual discomfort; and light trespass, where unwanted or intrusive light spills over into areas where it is not needed [2].The disruption of natural darkness due to light pollution affects nocturnal wildlife, disrupts astronomical observations, and alters the natural rhythms of various species [3].

Artificial lighting has evolved significantly over centuries, from early methods such as torches and oil lamps to modern electric lighting. The advent of gas lighting in the 19th century and electric lighting in the 20th century marked major milestones in the development of artificial lighting.As urban areas expanded and industrialized, the increase in artificial lighting led to significant changes in the night environment. The rise of urbanization and increased use of

streetlights, commercial signage, and illuminated buildings contributed to the growing problem of light pollution [4, 5].Urbanization has exacerbated light pollution through increased use of artificial lighting in cities, leading to skyglow, glare, and light trespass. The expansion of cities and the proliferation of light sources have transformed natural nightscapes into artificially lit environments [3].

Light pollution has been increasingly recognized for its potential effects on human health. Research has linked excessive exposure to artificial light at night with various health issues, including sleep disturbances, increased risk of metabolic disorders, and potential impacts on mental health [6].

Key sources of light pollution include streetlights, commercial signage, vehicle headlights, and indoor lighting. Each of these sources contributes to various forms of light pollution, such as skyglow, glare, and light trespass, impacting both human health and the environment [7, 8].

Mitigation strategies for light pollution include improving outdoor lighting design, using shielded fixtures, and adopting lighting policies that minimize unnecessary illumination. Additionally, public awareness and technological innovations can play significant roles in reducing light pollution [2, 9]. The purpose of review is to explore the effects of light pollution on human Health, identify key sources, and discuss potential mitigation Strategies.

2. Sources of Light Pollution

2.1 Urban Lighting

Street Lights:

Street lighting is a major contributor to light pollution, influencing various aspects of the night environment. Inappropriate street lighting can lead to significant skyglow, glare, and light trespass, adversely affecting both human health and the environment [10].The design of street lighting plays a crucial role in the extent of light pollution. Factors such as fixture types, light intensity, and shielding can either exacerbate or mitigate light pollution. Poorly designed street lights can lead to increased glare, excessive light spill, and skyglow, impacting both the environment and human health [2, 9].To reduce the impact of street lighting on light pollution, several strategies can be employed, including the use of shielded fixtures, lower-intensity lighting, and better placement of street lights. These measures can help minimize glare, light spill, and skyglow, contributing to a healthier night environment [10].

Building Lighting:

Illuminated buildings contribute significantly to light pollution through excessive and misdirected lighting. High-intensity lighting on buildings can lead to skyglow and light spill, which disrupt natural nightscapes and affect both human health and the environment [11].

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Illuminated signage and billboards contribute to light pollution by emitting bright, often intrusive light that can lead to glare and light trespass. These sources of artificial light can interfere with natural darkness and impact both human well-being and wildlife [2].

To reduce the impact of illuminated buildings, signage, and billboards, various mitigation strategies can be employed. These include the use of shielded fixtures, reducing the intensity of lights, and implementing zoning regulations that control the brightness and hours of operation of illuminated signs [3, 12].

2.2 Outdoor Advertising

Billboards:

Traditional billboards contribute to light pollution through their bright and often excessively illuminated advertisements. The high-intensity lighting used to make these billboards visible from long distances leads to skyglow and light spill, affecting both the night sky and the surrounding environment [11, 13].

Digital displays on billboards are particularly problematic due to their dynamic nature and high brightness levels. The constant changing of images and high-intensity lighting can lead to increased glare, light trespass, and further contribute to skyglow, disrupting both human and wildlife nocturnal activities [2].

Addressing the impact of billboards on light pollution requires regulatory measures and design improvements. Strategies include limiting the brightness of digital displays, restricting the use of animated or flashing lights, and implementing zoning laws to control the placement and illumination of billboards [3, 14].

Commercial Lighting:

Commercial lighting, including that used in retail stores, shopping centers, and entertainment venues, often involves high-intensity lighting that is operational late into the night. This lighting contributes significantly to light pollution through excessive brightness, skyglow, and light trespass, impacting both the environment and human health [5].

Entertainment lighting, including lighting for events, theaters, and concerts, often involves the use of intense spotlights, lasers, and other high-energy lighting technologies. These practices not only increase light pollution but also contribute to light trespass and skyglow, affecting surrounding areas and ecosystems [13].

Addressing light pollution from commercial and entertainment lighting involves implementing stricter regulations and adopting best practices. These include reducing light intensity, using properly shielded fixtures, and limiting the duration of lighting operations to minimize their impact on the environment and human health [2].

2.3 Residential Lighting

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Home Lighting:

Outdoor residential lighting, including porch lights, garden lights, and security lights, can contribute to light pollution through glare, skyglow, and light trespass. When not properly shielded or used excessively, these lights disrupt natural darkness and affect both human and ecological systems [15].

Security lights and decorative lighting, common in many residential areas, often use high-intensity bulbs and are left on throughout the night. This can lead to significant light pollution, impacting local wildlife and disrupting human sleep patterns due to increased light exposure [3].

Mitigation strategies for reducing light pollution from home lighting include using fully shielded fixtures, selecting lower-intensity bulbs, and implementing motion sensors to minimize unnecessary lighting. Educating homeowners about the impacts of light pollution and best practices for outdoor lighting is crucial [16].

Neighborhood Practices:

Neighborhoods with a prevalence of unshielded outdoor lights and high-intensity bulbs, such as street lights, garden lights, and decorative lighting, often experience increased light pollution. These lighting practices lead to excessive glare and skyglow, disrupting natural darkness and impacting both human health and the environment [2].

Residential lighting that spills over into neighboring properties, often due to poorly designed fixtures or improper installation, contributes to light trespass and glare. This not only affects the aesthetics of the neighborhood but also disrupts sleep patterns and impacts local wildlife [12, 17].

Over-illumination and continuous lighting in residential areas, such as those used for security or decorative purposes, exacerbate light pollution. These practices contribute to skyglow and affect nocturnal wildlife and human circadian rhythms [3, 13].

Neighborhood practices can be improved through community initiatives such as implementing lighting ordinances, promoting the use of shielded fixtures, and encouraging residents to adopt best practices for outdoor lighting. Education and awareness campaigns play a key role in reducing light pollution [16].

3. Environmental and Ecological Impacts

3.1 Disruption of Ecosystems

Wildlife:

Light pollution significantly impacts nocturnal wildlife by altering their natural activity patterns. Many nocturnal species, such as insects, birds, and mammals, rely on darkness for essential

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behaviors like foraging, mating, and navigation. Artificial light can lead to changes in these behaviors, often resulting in adverse ecological consequences [3, 18].

Artificial light can attract and disorient nocturnal insects, including moths and beetles, leading to changes in population dynamics and ecological interactions. This disruption can affect insect pollination and contribute to declines in both insect and predator populations [19, 20].

Light pollution interferes with migratory birds' navigation and can lead to increased collisions with artificial structures. Additionally, artificial light can disrupt breeding behaviors and reduce the availability of suitable nesting sites [21].

Light pollution can alter the behavior and physiology of amphibians and reptiles, affecting their breeding cycles and habitat use. For instance, artificial light can disorient hatchlings and interfere with their ability to find suitable habitats [22, 23].

Artificial light can disrupt the predatory-prey dynamics by altering the behavior of both predators and prey. For instance, it may affect hunting efficiency and prey availability, leading to changes in food webs [12, 24].

Plant Life:

Artificial light can influence plant growth patterns by altering light duration, intensity, and spectral quality. Plants rely on natural light cues to regulate growth processes, and deviations from these cues can lead to changes in plant morphology, growth rates, and overall health [12, 25].

Artificial light can disrupt the natural flowering cycles of plants by affecting their photoperiodic responses. Many plants rely on specific light and dark periods to trigger flowering, and deviations from these periods can lead to delayed or irregular flowering [26].

Artificial light can influence plant reproduction by affecting pollination and seed production. For example, changes in flowering timing due to artificial light can affect the availability of pollinators and, consequently, the success of pollination [27, 28]].

Artificial light can alter plant metabolic processes, including photosynthesis and respiration. Changes in light intensity and quality can affect the efficiency of these processes, potentially impacting overall plant health and productivity [29].

Artificial light can influence the dynamics of plant communities by altering competitive interactions. For instance, species that are more tolerant of artificial light may outcompete others, leading to shifts in plant community composition [30, 31].

3.2 Alteration of Natural Cycles

Circadian Rhythms:

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Artificial light at night (ALAN) can interfere with the circadian rhythms of various animal species by altering their natural light-dark cycles. This disruption can lead to changes in behavior, feeding patterns, and reproductive cycles [2, 24].

Artificial light can alter the circadian rhythms of bird species, affecting their migratory patterns, foraging behavior, and breeding success. This disruption can lead to decreased fitness and survival rates [21].

In aquatic ecosystems, artificial light can disrupt the circadian rhythms of fish and invertebrates, affecting their feeding, spawning, and predator-prey interactions. This can lead to changes in community structure and ecosystem dynamics [32].

Artificial light disrupts the circadian rhythms of insects, affecting their nocturnal behaviors, such as foraging and mating. This disruption can lead to declines in insect populations and affect ecosystem services [14, 33].

Artificial light at night can disrupt human circadian rhythms, leading to various health issues such as sleep disorders, metabolic problems, and increased risk of chronic diseases [34, 35].

Breeding and Migration:

Artificial light pollution can disrupt bird breeding patterns by altering the timing of reproductive behaviors and success rates. Birds exposed to artificial light may experience changes in their breeding cycles, including altered mating calls and nesting habits [21].

Light pollution can affect amphibian breeding by disrupting their reproductive calls and mating behaviors. Amphibians that rely on natural light cues for breeding may experience reduced success and altered behavior patterns [36].

Insects that use light for mating and navigation can experience disrupted reproductive behaviors due to light pollution. For instance, moths and other nocturnal insects may be drawn to artificial lights, leading to decreased mating success and altered population dynamics [14, 37].

Artificial light can disrupt the migration patterns of marine species, such as sea turtles and fish, which rely on natural light cues for navigation. This disruption can lead to increased mortality rates and altered migratory routes [38, 39].

Artificial light can affect the migration patterns of nocturnal mammals by altering their natural light cues. This can lead to increased predation risks and altered foraging behaviors [40].

4. Impacts on Human Health

4.1 Sleep Disorders

Circadian Disruption:

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Light pollution disrupts the body's natural circadian rhythms, which are essential for regulating sleep-wake cycles, hormone release, and other physiological processes. Artificial light exposure, especially during the night, interferes with these natural rhythms by signaling to the body that it is still daytime [34].

Exposure to artificial light at night can lead to poor sleep quality by interfering with the production of melatonin, a hormone that regulates sleep. This disruption can result in difficulty falling asleep, reduced sleep duration, and lower sleep efficiency [41, 42].

Disruption of circadian rhythms due to light pollution is associated with various mental health issues, including increased risk of depression, anxiety, and mood disorders. The misalignment of internal biological clocks with environmental light-dark cycles can exacerbate these conditions [43].

Artificial light at night can disrupt normal sleep architecture by reducing the amount of deep sleep and REM sleep. This alteration in sleep stages can affect overall sleep quality and cognitive function [44, 45].

Long-term disruption of circadian rhythms due to light pollution has been linked to various health issues, including obesity, cardiovascular diseases, and metabolic disorders. These health implications arise from the chronic misalignment of biological clocks [46, 47].

Sleep Disorders:

Light pollution has been shown to disrupt sleep patterns significantly. Research indicates that exposure to artificial light during the night can interfere with the body’s natural circadian rhythms, leading to difficulties falling asleep and maintaining sleep throughout the night. For instance, a study by **Figueiro et al. (2012)** found that exposure to light at night suppresses melatonin production, a hormone crucial for regulating sleep-wake cycles, thereby delaying sleep onset and reducing sleep duration [48].

Light pollution is associated with an increased risk of developing insomnia. **Patel, P. C. (2019)** conducted research revealing that individuals living in areas with high levels of artificial light experienced more severe symptoms of insomnia compared to those in less illuminated environments. Their study highlighted that exposure to light at night is a significant risk factor for insomnia, contributing to difficulty in both falling asleep and staying asleep [49].

Artificial light exposure at night can adversely affect the quality and quantity of Rapid Eye Movement (REM) sleep. **Svechkina et al. (2020)** demonstrated that light exposure during the night leads to a reduction in REM sleep, which is essential for cognitive functions such as memory consolidation and emotional regulation. Their findings underscore the detrimental effects of light pollution on essential sleep stages [13].

Children exposed to excessive light at night are particularly vulnerable to sleep disorders. A study by **Wang et al. (2022)** found a significant association between nighttime light exposure and sleep disturbances in children, including difficulties with sleep initiation and maintenance.

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The study emphasizes the importance of managing light exposure in children's environments to prevent sleep-related issues [50].

There is growing evidence linking light pollution-induced sleep disorders to mental health issues such as depression and anxiety. **Howarth and Miller (2024)** reviewed studies showing that chronic sleep disruption caused by light pollution can exacerbate symptoms of depression and anxiety, highlighting the broader mental health implications of poor sleep quality [51].

Long-term exposure to light pollution can have serious health consequences. **Medic et al. (2017)** found that persistent sleep disruption due to artificial light at night is associated with increased risks of obesity, cardiovascular disease, and metabolic disorders, reflecting the extensive impact of light pollution on overall health [52].

4.2 Psychological Effects

Mood Disorders:

Exposure to artificial light can significantly influence mood, particularly in the context of Seasonal Affective Disorder (SAD). **Magnusson and Boivin (2003)** demonstrated that individuals with SAD exhibit improvements in mood with light therapy, suggesting that reduced exposure to natural light during darker months exacerbates depressive symptoms. Their research highlights the role of light in regulating mood and its therapeutic potential [53].

Chronic exposure to artificial light has been linked to increased stress and anxiety levels. **Bedrosian and Nelson (2013); LeGates et al. (2014)** found that prolonged exposure to bright artificial light at night can lead to elevated stress markers and heightened anxiety, as the disruption of circadian rhythms affects the body's stress response. This research underscores the connection between light exposure and mood disorders [54, 55].

Artificial light exposure, particularly during the night, can contribute to depressive symptoms. **Menculini et al. (2018)** observed that night-time exposure to artificial light impairs mood regulation, contributing to symptoms of depression. Their findings suggest that light pollution disrupts natural sleep patterns and hormonal balances that are crucial for maintaining mental health [56].

Artificial light affects the circadian rhythm, which plays a critical role in mood regulation. **Blume et al. (2019)** found that exposure to light at night alters circadian rhythms, which can lead to mood disturbances such as irritability and low mood. The study emphasizes the importance of maintaining a consistent light-dark cycle for mental health [34].

Artificial light exposure can also affect cognitive function, which is closely linked to mood. **Siraji et al. (2022)** found that excessive artificial light exposure can impair cognitive functions, such as attention and memory, which are important for maintaining a stable mood. This impairment can contribute to mood disorders by affecting the ability to cope with daily stressors [57].

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Long-term exposure to artificial light is associated with significant psychological impacts, including increased risks of mood disorders. **Bedrosian and Nelson (2013)** found that chronic exposure to artificial light at night can lead to persistent mood disturbances and contribute to the development of mood disorders over time [54].

Cognitive Impacts:

Disrupted sleep caused by light pollution can negatively affect attention and concentration. **Killgore (2010)** found that sleep disruption due to exposure to artificial light at night impairs cognitive functions, particularly attention and focus. The study indicates that inadequate sleep resulting from light pollution can lead to difficulties in maintaining attention and concentration during daily activities [58].

Light pollution-induced sleep disruption can impair memory functions. **Havekes et al. (2016)** demonstrated that inadequate sleep due to artificial light exposure affects both short-term and long-term memory consolidation. Their research highlights the detrimental effects of sleep disturbance on the ability to process and retain information, which is crucial for learning and cognitive development [59].

Disrupted sleep from light pollution can also affect executive functions, such as decision-making and problem-solving. **Yang at al. (2024)** found that chronic exposure to artificial light at night leads to impairments in executive function, including difficulties in planning, organizing, and executing tasks. The study suggests that these cognitive impairments are linked to the disruption of the circadian rhythm and subsequent sleep disturbances [60].

Long-term exposure to artificial light at night can contribute to cognitive decline. **The** chronic sleep disruption from light pollution may be associated with cognitive decline, particularly in older adults. Their research underscores the impact of prolonged exposure to artificial light on cognitive health, emphasizing the importance of maintaining a regular sleep pattern to preserve cognitive function.

Light pollution can negatively impact learning and academic performance. **Portnov (2024)** showed that students exposed to high levels of artificial light at night experience decreased academic performance due to poor sleep quality. Their findings suggest that disrupted sleep from light pollution affects cognitive processes critical for learning and academic achievement [61].

Artificial light at night can lead to mental fatigue and reduced cognitive efficiency. **Siraji et al. (2022)** found that individuals exposed to artificial light during nighttime have higher levels of mental fatigue, which impairs cognitive performance. The study highlights the importance of managing light exposure to prevent mental fatigue and maintain cognitive efficiency [57].

4.3 Increased Risk of Chronic Diseases

Obesity and Metabolic Syndrome:

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Disrupted sleep patterns are strongly associated with an increased risk of obesity. **Patel and Hu (2008)** found that insufficient sleep or irregular sleep patterns can lead to weight gain and higher body mass index (BMI). The study demonstrates that sleep deprivation can influence appetite-regulating hormones, leading to increased food intake and reduced energy expenditure, which contributes to obesity [62].

Disrupted sleep patterns are linked to the development of metabolic syndrome, a cluster of conditions including hypertension, hyperglycemia, and dyslipidemia. Knutson and Van (2008); **Arora et al. (2015)** reviewed evidence showing that sleep disturbances can impair glucose metabolism, increase insulin resistance, and promote abdominal obesity, all key components of metabolic syndrome [47, 63].

Sleep disruptions can lead to hormonal imbalances that contribute to obesity and metabolic syndrome. **Spiegel et al. (2004)** identified that irregular sleep patterns affect hormones such as leptin and ghrelin, which regulate hunger and satiety. The imbalance of these hormones due to poor sleep can result in increased appetite and weight gain [64].

Insulin resistance is a major factor in the development of metabolic syndrome and is associated with disrupted sleep. **Knutson et al. (2006)** demonstrated that poor sleep quality and insufficient sleep increase the risk of developing insulin resistance, which is a precursor to type 2 diabetes and a component of metabolic syndrome [65].

Sleep disruption negatively impacts glucose metabolism, contributing to obesity and metabolic syndrome. **Stamatakis and Punjabi (2010)** found that fragmented sleep can impair glucose tolerance and increase fasting glucose levels, exacerbating metabolic syndrome risk [66].

Disrupted sleep patterns are linked to an increased risk of cardiovascular disease, which is often associated with metabolic syndrome. **Meng et al. (2013)** reviewed studies indicating that poor sleep quality and short sleep duration are associated with increased risk of hypertension, heart disease, and stroke, which are related to metabolic syndrome [67].

Sleep disruption can trigger inflammatory responses that contribute to obesity and metabolic syndrome. **Irwin and Opp (2017)** found that irregular sleep patterns increase levels of inflammatory markers such as C-reactive protein (CRP), which are associated with obesity and metabolic syndrome [68].

Cardiovascular Health:

Light pollution has been associated with an increased risk of hypertension. **Koo et al. (2016)** found that exposure to artificial light at night can disrupt the circadian rhythm, leading to elevated blood pressure and increased risk of hypertension. The study highlights the physiological stress caused by disrupted sleep patterns and its impact on cardiovascular health [69].

Artificial light exposure at night is linked to a higher incidence of heart disease. **Stevens and Zhu (2015)** reviewed evidence suggesting that long-term exposure to light pollution can lead to

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chronic stress and increased risk of cardiovascular conditions, including coronary artery disease and heart failure [70].

Circadian rhythm disruption due to light pollution can negatively impact cardiovascular health. **Lamphar et al. (2019)** found that exposure to light at night disrupts melatonin production, which is associated with increased cardiovascular disease risk. Melatonin plays a crucial role in regulating cardiovascular functions and its disruption can contribute to heart-related conditions [71]

Light pollution has been linked to the development of metabolic syndrome, which is a risk factor for cardiovascular disease. **Obayashi et al. (2013)** demonstrated that exposure to artificial light at night can impair glucose metabolism and increase the risk of obesity, both of which are closely linked to cardiovascular health issues [72].

Exposure to light pollution can induce inflammatory responses, contributing to cardiovascular disease. **Scheer et al. (2009)** found that disrupted sleep and circadian rhythms due to light pollution can increase levels of inflammatory markers such as C-reactive protein (CRP), which are associated with heart disease [73].

Light pollution affects sleep quality, which in turn impacts cardiovascular health. **Cappuccio et al. (2011)** reviewed how poor sleep quality caused by exposure to light at night can lead to various cardiovascular issues, including increased risk of stroke and heart attack [74].

Conclusion

Light pollution, characterized by excessive or misdirected artificial light, has become a pervasive issue with significant impacts on both human health and the environment. This review has outlined the various sources and forms of light pollution, including urban lighting, outdoor advertising, commercial and residential lighting, and their detrimental effects on ecosystems and human well-being.

Light pollution disrupts natural ecosystems by altering nocturnal behaviors of wildlife, including insects, birds, and mammals. This interference affects critical activities such as foraging, mating, and navigation, leading to ecological imbalances. Plant life also suffers, with artificial light influencing growth patterns, flowering cycles, and community dynamics.

The review highlights the significant health impacts of light pollution. Disruption of circadian rhythms due to artificial light at night can lead to sleep disorders, including insomnia and reduced sleep quality. This, in turn, has been linked to mood disorders, cognitive impairments, and increased risks of chronic conditions such as obesity and cardiovascular diseases. The disruption of melatonin production and altered sleep architecture are central to these health issues.

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Effective mitigation of light pollution requires a multifaceted approach. Implementing better lighting designs, such as shielded fixtures and lower-intensity bulbs, and adopting zoning regulations can significantly reduce light pollution. Public education and awareness are crucial in promoting practices that minimize unnecessary lighting and its impacts.

In summary, addressing light pollution involves understanding its sources and effects on both the environment and human health. By adopting effective strategies and fostering greater awareness, we can work towards minimizing the negative impacts of artificial light and restoring natural darkness.

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