Research Article

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Impact of Light Pollution on Human Rights and Biodiversity

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Abstract

The goal of the present document review was to analyze and propose alignment of the criteria regarding practical and legal measures to mitigate light pollution, a phenomenon which affects health, quality of life, healthy and balanced environments, spatial rights, and biodiversity. Excessive lighting is a common phenomenon in cities and towns, becoming an environmental problem which must be reviewed and analyzed. This problem represents the situation faced by the global population, and is manifested in scientific studies. These diverse studies and results suggest that socio-legal criteria must be aligned to mitigate the social phenomenon of light pollution, which is exacerbated by a lack of consciousness in the population, together with creating prevention and control policies in line with international standards and the UNESCO 2030 SDGs. We also recommend reaching agreements between various key fields (science, politics, education, economy, business and society) to make inhabitants take responsibility for the existence of this phenomenon, in order to make the public aware that this phenomenon exists.

Keywords: *Light pollution, health, quality of life, spatial rights, human rights*

1. Introduction

Human progress has been accompanied by knowledge about natural processes and human learning to regulate them. This includes the light-darkness process, without considering the imbalances which lighting could provoke in the natural environment and biodiversity (Longore & Rich, 2004). Warnings on the environmental problem came from astronomers, who could no longer clearly observe the stars, planets, and other celestial bodies due to excessive light use. Astronomers understood the disparity between the lighting emitted and the true quality needed (Gonzales et al.,

2020). It is also defined as "the disruption of natural light levels in outdoor environments due to artificial light sources" (Rol et al., 2022). The principle of this phenomenon also obeys convictions linking artificial light with wealth, comfort, safety, tranquility, progress, and more (Pelegrina, 2022), leading to indiscriminate use of lighting. The resulting polyhedric problem requires interventions and contributions from various approaches.

The United Nations (UN) has said that climate change measures will only have effect if governments and citizens commit, act, and exert pressure (Ruiz, 2015). Similarly, the National Environmental Congress-Sustainable Development Summit referred to the importance of *European or national standards* on light source strength. The assented legal initiative in Spain to protect the night sky was Law 31/1988, of 31 October, to protect the astronomical quality of observatories at the Instituto de Astrofísica de Canarias. Along the same lines, the 2030-UNESCO Sustainable Development Goals (SDGs) tied with the same issue are: SDG 7: Healthy, non-polluting energy, SDG 11: Sustainable cities and communities, SDG 13: Climate action, SDG 15: Earth Ecosystems' Life. It is also important to propose boosting the implementation of SDG 18 linked with night sky quality (Rueda, 2022).

The study is *relevant* because, since there is no unification between practical and legal measures for mitigating the problem, the studies reviewed confirm that human rights and biodiversity violations persist (González et al., 2020). It should also be noted that, with lights turned on everywhere, it becomes necessary for all cities to consider legal measures through administrative law, regulating the conservation of night skies, in order to legally protect human beings, flora, and fauna (Huerta, 2019); all proven effects with various impacts on the environment, plants, animals, and humanity (Fontana et al., 2021).

The influence of light pollution on biodiversity has been studied by Aroca & Herrera (2022); del Busto (2021); Escalante et al. (2021); González et al. (2020); Silva et al. (2020); Enríquez (2019); Huerta (2019); Tang et al. (2018); Truyenque (2018); and Ballestero & Alamús (2017). Similarly, the consequences of the study phenomenon upon public health have been researched by Jurado & Solano (2022); and by Barrios (2021). Finally, there are studies about some strategies to decrease the problem, including Castillo & Chamba (2021); Flores (2021); Robles (2021); Santana (2021); Escario (2020); García (2019); and Bustamante (2018). Considering the inquiries about the proposed topic, there are no findings which duly develop a full analysis of the topic under analysis; including a unification of practical and legal measures to mitigate light pollution, aimed at guaranteeing social and biodiversity rights.

Rueda (2022) carried out a bibliographical review about analysis regarding the *effects of light pollution* on plants and animals done within the preceding decade (2012-2022), concluding that these living beings face a serious problem due to direct and indirect light from *artificial nocturnal lighting* (ANL). This situation is evident from plant and animal species' growth levels. Research indicated that the most affected were insects and birds.

Xu et al. (2023) carried out a study to examine the association between ANL exposure and sleep problems in humans. Their results included seven cross-sectional studies with 577,932 participants, and found a higher rate of sleep problems among people with more ANL exposure (22%), with stronger effects indoors than outdoors. They concluded that their findings supported the negative effects of ANL exposure on sleep, and that keeping bedrooms dark was an effective way to decrease sleep problems' prevalence.

The theories which ground the dimensions of this inquiry, among others analyzed, mention that light pollution is a concerning situation because excessive artificial light in urban and rural areas negatively affects health, as well as impacting animals' migratory development (McLaren et al. 2018). Toledo (2019), also mentioned that light pollution is the phenomenon via which artificial light is released in levels, directions, and spectra which are unnecessary for foreseen activities in a given area, causing an alteration in natural nocturnal environments and light reaching the sky.

León (2000) explained that legal recognition of the right to the environment is generated by the social need to live in a healthy, balanced environment which ensures the development of a dignified life, making this discussion relevant from an ethical perspective as well. Similarly, some have sought to add to the planet which can be controlled through natural laws being prioritized over human laws.

In this sense, if we damage the sky, the planet, we are disobeying its rules. The pure ethic of the Planet is the laws of biochemistry" (Lovelock, 1992, p. 175). This is a key incorporation to handle when considering different classic debates about human rights to ensure sufficient living conditions.

In this sense, we formulate the following questions: What is the impact of light pollution which could violate human rights and biodiversity? What are the causes behind the rise in light pollution? What measures are needed to partly or wholly mitigate light pollution?

The objectives presented were: analyzing theories about light pollution impacts which violate human rights and biodiversity; identify the causes generating the rise in light pollution; and defining light pollution mitigation measures?

2. Methodology

The study type is a basic document review, allowing for the analysis of written documents or records, including books, articles, reports, statistics, and others (Meza et al. 2020). The method is qualitative, given its focus on the analysis of subjective and descriptive data such as perceptions, opinions, attitudes and experiences (Hernández & Mendoza, 2018), and the study design is phenomenological. Research was done using indexed databases including Scopus, Scielo, Web of Science and Google Scholar, focusing on review articles, original articles, and reflections published during the period 2018-2023. Literature not related with the study categories and subcategories was excluded. The first data search stage was done by applying the keywords. In the second stage, the inclusion and exclusion criteria were applied, followed by verifying the quality of the studies gathered. For data extraction, a format specially designed for this study was used. After this, a descriptive in-depth analysis of the included texts was done.

3. Results

63 references were of initial interest. Out of this group, 29 complete texts were evaluated due to meeting the criteria in the results and later discussion. These included eight about light pollution in Peru; seven about the effects of this problem on human health and general biodiversity; four on the importance of education, awareness, and citizen participation for light pollution; seven measurements of mitigations for this phenomenon; and three about light pollution, the right to sustainable development, and good governance. The most relevant findings are explained in the following paragraphs.

3.1 Light pollution in Peru

Peru faces a growing problem which affects both health and the environment due to excessive artificial light in urban and rural areas influencing the sleep cycle, increasing risks of heart disease and diabetes. It also affects animal species' migration, reproduction, and survival (Truyenque, 2018). The Bortle scale, developed in 2001, is a key tool to quantify night sky quality. The scale is based on various factors, such as artificial light quantity, cloud presence, humidity, altitude and latitude, and can be used to measure these factors' impact in a specific area (Escalante et al., 2021).

In Peruvian cities, urban expansion and increased artificial light use have significantly contributed to increased light pollution. Public lights are often inadequately designed or located, leading to disperse and improper lighting. Many buildings and businesses also use excessive or unregulated light, contributing to light pollution (López & Miyan, 2020).

On this point, del Busto (2021) mentions that in Lima, the social phenomenon reaches the highest magnitude on the Bortle scale for the number of units in car parks, advertisements, and streetlights, in contrast with other places such as Ica which present lower light pollution due to fewer residents, cars, and ads. The results present a light pollution level between 4 and 5, although in cities' surroundings results as low as 1 occur.

By contrast, in rural parts of Peru, light pollution mainly comes from deforestation and

urbanization in natural zones, leading to more artificial lighting in these areas. It can also arise due to mining and oil drilling using bright lights for nocturnal operations (Enriquez, 2019). Light pollution can affect health, particularly in rural places where darkness is a natural part of nighttime life.

Artificial light can interfere with living things' development phases. Among birds, this mainly affects their reproductive phenology, leading to deaths due to attraction towards light and the accompanying disorientation (Sangiorgi & Medina, 2022). This effect is particularly notable among birds which fly at night and are attracted to lights. Mechanisms are needed to reduce this phenomenon in natural areas and protect biodiversity (Silva et al., 2020).

3.2 Light pollution effects on human health and general biodiversity

Lazzeroni et al. (2020) showed how light pollution has a strong impact on ecosystems, altering natural habitats' spectral characteristics. They mention that environmental luminosity changes can significantly affect human body functions, including body temperature and hormone secretions (Barrios, 2021). Our bodies have also been found to have receptors sensitive to light, vision, and different parts of the body.

Silva (2018) showed that this phenomenon negatively affects human health. One of the most obvious is *dazzlement*, characterized by the unpleasant sensation caused by excessively intense artificial light. This can lead to visual fatigue, temporary blindness and stress due to light intruding into the field of vision. Another important effect is the distortion of the circadian cycle, which is the biological rhythm of living beings including their sleep and waking.

Villarroel (2020) mentioned a lack of deeper consideration of this social fact, although other types of pollution had gained this attention. However, some studies do exist, such as those done by the Global Health Institute of Barcelona in 2018, finding a relation between people exposed to higher artificial light levels and increased prostate and breast cancer risks, perhaps due to circadian rhythm alterations.

3.3 The importance of education, consciousness, and citizen participation for light pollution

Education and consciousness about the subject of light pollution are fundamental to properly handle this problem. Education is essential to understand the damage arising from this phenomenon, and to develop management strategies (Escario, 2020). Greater public awareness is also needed about the topic in order to reduce light pollution, since after learning about the problems which it causes, people can take measures to reduce it and protect themselves and the environment.

Education about pollution should include information about harmful health impacts from artificial light, such as interruptions in the sleep cycle and melatonin production, as well as its environmental implications, in order to sustain wildlife and biodiversity. Artificial nighttime lights can affect many animal species' behavior patterns and survival, particularly those based upon natural light cycles for their daily activities.

3.4 Light pollution mitigation measures

Escario (2020) mentioned three aspects to consider for light pollution mitigation in his study. The first was *direction,* which is when light winds up being aimed upwards, which has no surface benefits and should be avoided, or when horizontally emitted light has negative effects without being useful to people. For *color*, the recommendation was to avoid using blue light during the afternoon and night, since this light tone is more dazzling, especially for the elderly. Finally, *strength* must be regulated and controlled from the source to decrease pollution.

Bustamante (2018, cited by Pérez & Villarreal, 2016), carried out a project to replace high-pressure sodium vapor lights with LED lights for the public lighting within the Miraflores-Perú district, in order to show that LED lights are more efficient and effective by comparison. The effectiveness of LED lights was concluded, together with them having a longer service life, since they consume 60% less energy

than conventional lights and have lower environmental impact. García (2019), also mentioned that ground lighting is essential for lamps, and that they must be placed far apart enough to keep their light cones from becoming superimposed, making it important to turn off unnecessary lights.

Castillo & Chamba (2021) mentioned that various measures have been implemented in Chile, including turning off lights or maintaining as few as possible in places where animals have been observed to be affected. Lighting could also be improved by replacing white lights with green lights, which has helped significantly reduce the number of birds impacted, along with developing animal rescue and liberation programs.

Education and awareness raising about the topic can help reduce energy consumption and minimize the negative effects of light pollution. Citizen collaboration in the design and planning of urban lighting can also ensure its efficient and sustainable use. Santana (2021) mentioned that one key mitigation measure is proper illumination point orientation, using motion sensors.

One measure to reduce light pollution is replacing incandescent lights in public spaces with LEDs (light-emitting diodes). Robles et al. (2021) indicated that important changes were made in the color and brightness of the Madrid sky following the 2015-6 change in part of the municipal streetlights, changing from high-pressure sodium (HPS) to LEDs. They also found that night sky brightness detected in the Johnson B band became darker by 14% between 2011 and 2015, and lighter by 32% between 2015 and 2019. Within the municipality of Los Molinos near Madrid, this also represented a 65% cost savings (Comunidad Madrid, 2022). Another way to correct light pollution is by correcting its underlying causes, such as opting for streetlights with null flow into the upper hemisphere (FHS= 0%), complemented with legislation setting time limits for lighting use and maximum lighting limits, among other aspects which have been suggested for many years (Herranza et al., 2006)

As indicated by the SPDA, decreasing excessive artificial lighting implies not affecting the lives of many bird species, such as newborn petrels, in order for them to not get lost (at the expense of predators within cities) and reach the ocean. It also keeps sea turtles and various insects from becoming disoriented and suffering disruptions in their routine which would alter the food chain, as well as generally maintaining balance in nocturnal ecosystems and not losing biodiversity.

3.5 *Light pollution, the right to sustainable development, and good governance*

Given these circumstances, there is a notable need to set limits and regulations to control excessive artificial light and protect the right to a healthy environment and adequate quality of life (de Luis, 2018). It is also relevant to handle this problem with an integral perspective, considering both individual and collective rights (Magoja, 2020).

The rights to both sustainable development and good governance are compromised by light pollution, since both rights are closely linked. Sustainable development includes mechanisms to improve quality of life in the present without compromising future generations' capacity to do the same. Similarly, light pollution and good governance are closely linked, since good governance is a decision-making system which is transparent, responsible, and participative, and approaching a problem of this magnitude is sure to require proper decision-making.

4. Discussion

When considering the *consequences of light pollution*, Truyenque (2018), Sangiorgi & Medina (2022), and Lazzeroni et al. (2020), agree that excessive artificial light in both urban and rural areas interferes with plant and animal species' life phases, such as their migration, reproduction and survival, and can even increase mortality. In turn, Truyenque (2018); Lazzeroni et al. (2020); Jurado & Solano (2022); Barrios (2021), Silva (2018), and Salgado et. al (2021) agree that dazzlement can interfere with sleep cycles, the biological clock of body temperature, and bothersome sensations in the human body, because it decreases the levels of melatonin hormones produced by the pineal gland. Fontana et al. (2021) said that this hormone plays a relevant role in regulating immunity, preventing cancer, inflation, and antioxidants.

These descriptions align with the knowledge presented about light pollution by McLaren et al. (2018); Gonzáles (2019); La Sorte et al. (2022) and Rueda (2022) who indicated that excessive artificial light can damage health and biodiversity. They also used the Botler scale which Escalante et al. (2021) mentioned and which Busto (2021) said they used for measurements within the city of Lima, demonstrating the existence of high light pollution levels.

Similarly, considering the *causes of light pollution*, López & Miyan (2020) and Silva et al. (2020) mentioned that excessive lighting in cities is due to lack of regulatory measures, and that this situation even occurs in natural areas. This is grounded in the theory from León (2000) stating that the right to the environment implies the protection of human beings' needs, together with the flora and fauna in the environment, for an overall environmental balance. Fontana et al. (2021) and Salgado (2021) mentioned that another cause is the use of LED systems for their blue light content which we find in computers, cellular phones, and televisions which use this system, all of which suppress melatonin releases.

For the *analysis and evaluation of some light pollution mitigation proposals and measures,* Villarroel (2020) said that although there are studies about this pollution, there has been no serious inquiry about its real problems. Escario (2020) and Apaza (2019) also said that education could improve energy use efficiency, and that strategies could be developed by the population themselves. Alcalá et al. (2020), Castro (2022), and Santana (2021) agree that more public awareness could be achieved, encouraging behaviors to reduce pollution and demanding policies and regulations from the authorities.

Along these lines, Robles (2021) warned about the lack of planning integration, energy sustainability policies, and guidelines for climate change and environmental protection; while de Luis (2018), recommended accepting and executing European or international standards for light source strength. As mentioned by López & Miyan (2020), this will be possible with good governance. One important proposal about artificial light use and control appears in Escario (2020); others appear in Bustamante (2018), García (2019), and Flores (2021) regarding the use of more efficient LED lights, planting more trees to block reflections from lighting, and the use of high and low pressure sodium bulbs including the management of the solid wastes which are generated.

5. Conclusions

The health consequences of light pollution include its impact on human sleep cycles due to decreased melatonin hormone production. It also alters the biological clock of temperature control, causing discomfort and possibly leading to exposure to diseases such as cancer, among others, along with generating weight gain, high blood sugar values, etc. There are further consequences for biodiversity, particularly given progress in urban and rural areas, among others.

The causes behind the rise of this fact include indiscriminate use of public and private artificial lighting, due to a lack of proper regulation and measures to block avoidance; deforestation; urbanization in natural areas; mining and oil drilling activity; and the use of LED systems for blue light in devices such as computers, cell phones, and televisions. However, these factors have not been appraised by environmental protection authorities which need to be mindful of balanced and healthy development, the right to dignity, and quality of life.

To mitigate light pollution, authorities in each State need to align practical and legal measures regarding the following points. First: determine light pollution control and prevention policies in line with energy sustainability policies, climate change accords, and environmental protection, along with European or international standards on light source strength and the 2030-Unesco SDOs. Second: pass rules for prevention, control, and sanctions on light pollution. Third: train authorities to carry out these light pollution policies and regulations through Good governance and pertinent use of management tools including plans, projects, manuals, guides, and others. Fourth: promote citizen participation to receive their contributions and experiences in order to generate new strategies, not only to fulfill norms. Fifth: encourage best practices such as using and controlling adequate LED lights, planting trees to block light reflections, and other practices based on education and awareness. Sixth: update policies, regulations and measures, in line with best practices from other countries and

recommendations from international organizations. These criteria could imply that States assume that technology provides us with opportunities to control responsible light use, although a specific budget must be determined to consider acquiring equipment such as regulators, sensors, timers, and more, after analyzing the costs and benefits and whether there is effective profitability.

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