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Measures to combat light pollution

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Introduction

In a world of modernization, urbanization, and an exploding human population, the need for widespread use of artificial light is all too real. Lighting has helped around the world to increase productivity, maintain a higher human population density, and build systems of trust and safety. However, like many positively transformative technologies, the increasing prevalence of artificial light has significant drawbacks that must be dealt with appropriately: the psychological detriments associated with reduced sleep and interaction with nature, the immense contribution of light production to global carbon dioxide emissions, speeding the process of climate change and eliciting a host of catastrophic consequences, and light pollution.

Photo Source: http://www.need-less.org.uk

The establishment of measures to combat light pollution has consequences that are far-reaching and worldwide. BBC News recently reported that more than four-fifths of the world's population lives under light-polluted skies, including more than 99% of Europeans. According to Dr. Christopher Kyba of the German Research Center for Geosciences in Potsdam, 14% of humans live in such severely light-polluted regions that they never use their night vision. The same study also reported that one-third of all people will never see the Milky Way galaxy due to light pollution (Morelle).

Unfortunately, stargazing capacity is not the only aspect of our lives impacted by light pollution. An abnormally- or inappropriately-lit night sky in a certain region disrupts the

circadian rhythms of individuals living in said region, causing various health impacts. Although these have not been adequately studied, strong correlations have been demonstrated between light pollution and sleep disorders, breast cancer, and even obesity and early-onset diabetes. The effects of living for prolonged time periods in a light pollution-affected region, it seems, are similar to those of sleep deprivation and disorder—that is, unpleasant for oneself and for one's society and community. A framework to improve the management of light pollution would drastically increase human health and well-being worldwide.

Such a solution would also be beneficial for flora and fauna that have been negatively affected by light pollution as it has become more prevalent worldwide. According to the New York City Audubon Society, several hundred million birds die each year from collisions with communication towers and high-rise buildings in urban centers in North America alone (Chepesiuk); a major factor in this number's dramatic increase has been the escalation of artificial lighting technologies across Canada, Mexico, and the United States. Light pollution can also have more subtle effects on the behavior of animals in aquatic and terrestrial ecosystems, and prevents scientists from conducting experiments (especially in astronomical fields) in many parts of the world (Longcore).

Light pollution occurs in two main forms: "astronomical," which primarily affects humans living in large urban centers, and "ecological," which primarily affects organisms and ecosystems through travelling light from towns and cities. Both types of light pollution, along with individual sources of indoor artificial light, should be dealt with accordingly. In the following sections, you can find an overview of light pollution, along with material for further reading on this pressing issue and its possible solutions.

Definition of Key Terms

Light pollution

Light pollution is an umbrella term that defines the alteration or degradation of night natural lighting levels caused by excessive, obtrusive, and misplaced anthropogenic sources of light1. It is also known as luminous or photo pollution

Zodiacal light

The dim, elongated cone of light which is sometimes present in the night sky, that extends from the horizon along the ecliptic. The phenomenon is caused by the reflection of sunlight from particles of ice and dust within the plane of the solar system.

Glare

The excessive, bright, and uncomfortable lighting that comes off of poorly built lamps which causes irritation to the eyes and a decrease in visibility.

Light Nuisance or Light trespass

Outdoor lighting which spreads and lands in areas where it is not wanted or needed. An example could be the light from a street light illuminating the internal area of a nearby house.

Clutter

Sometimes referred as over lighting, a clutter is the abundance of bright light sources in one area which creates excessive brightness. The phenomenon involves a combination of sky-glow, trespass, and glare; a well-known example is New York City.

Photo Source: http://blog.cityelectricsupply.com/bright-skies-solution-light-pollution/

Urban Sky-glow

Caused by light scattering in the atmosphere, sky glow is the overall brightening of the night sky over densely populated areas which is the result of misplaced artificial lights which point upwards.

Sustainable design

The philosophy of interior, environment, physical, or product design and services which complies with principles of social, economic, and ecological sustainability. When referring to light pollution, sustainable design is used to develop lighting systems and schemes which lower the emission of excessive lighting into the environment. This includes new types of light sources, improved design of illuminating objects and careful urban planning techniques.

General Overview

In 1994, a 6.7 magnitude earthquake shook up the city of Los Angeles, California, causing a major black out throughout the city. In the following hours, preoccupied citizens called up local observatories and emergency services asking what was the big silvery cloud hovering the sky and whether it was that unusual celestial body that had caused the earthquake. They were referring to the milky way. According to the, more than 80% of the world lives under light-polluted skies, with levels reaching 99% in the U.S. and European. The Milky Way is hidden from more than one-third of humanity, explaining why its sighting might have surprised the inhabitants of a such brightly illuminated city2. Light pollution raises the normal level of night sky brightness, which would otherwise be controlled only by natural celestial sources, mainly the Moon, natural atmospheric emission (airglow), zodiacal light, and the Milky Way.

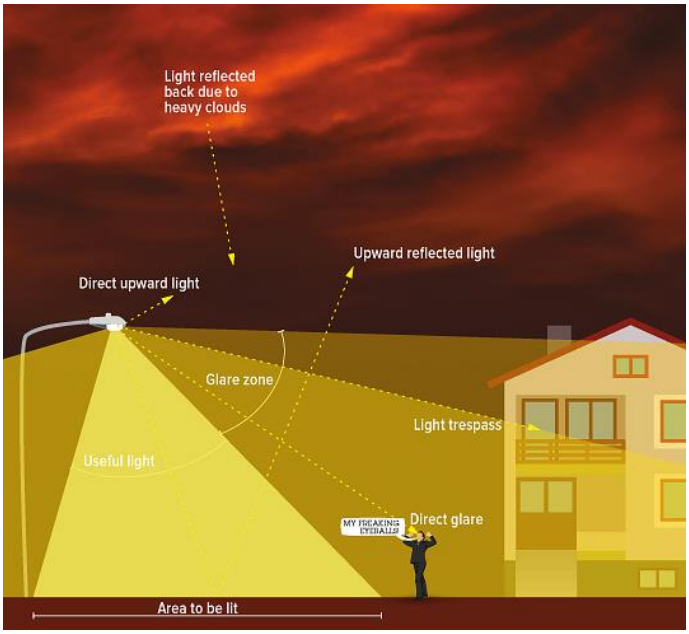

Photo source: http://www.darksky.org/light-pollution/

Causes

Light pollution causes are, by definition, anthropogenic, and they usually arise, not only because of an excessive and irresponsible use of light, but also because of badly designed light sources and because of a general rise in population. This phenomenon is directly related to the industrial civilization and it is a side effect of the advent of cheap and readily available electricity. Causes of light pollution include:

Advertising Billboards and Commercial Centers:

Most of the big electronic advertising sign boards in cities and highways are lit by lights placed below the board, pointing upwards. This, of course, leads to the dispersion of such light, as excess light moves up and reflection on the boards spreads the light horizontally. Furthermore, businesses and commercial centers often use lights to attract customers

through signs which are not directed into a specific direction, increasing the dispersion of such light.

Residential areas:

Garden and landscape lighting, as well as light sources of security systems are widely spread in urban and suburban housing. Usually meant to decorate or increase security in residential areas, such light usually results in light trespassing and glare.

Streetlights, stadiums, and public infrastructures:

An estimation attributes to roadway lighting the 30% to 50% of the total amount of light pollution. Also, stadiums and other sports grounds are heavily and excessively illuminated, including in the nearby car parks. Furthermore, city parks, airports and other public infrastructures often use antiquated lights without shielding, resulting of excess emission of light upwards.

Effects on wildlife and ecosystems

Light pollution can heavily disrupt the life of nocturnal ecosystems, as their usual habitat is altered by the presence of excessive light. First of all, mammals such as raccoons, bats and deer can lose their natural internal night systems due to areas which are excessively lit. This puts them in great danger and it might result in difficulties in finding food, exposure to predators and, overall, in an increase of mortality which determines a decrease in population. Insects tend to fly around artificial sources of light: this makes it easier for predators to hunt them. The decrease in population of insects consequently results in a negative impact on all of the animals which feed on insects as a primary food source. Birds are attracted to artificial sources of light too and it has been estimated that over 100 million birds in the United States die from collisions with lighted buildings. Furthermore, it seems to be that artificial lights interfere with the natural navigation skills of migratory birds which end up not reaching their destination in time, making them miss ideal conditions for nesting. Reptilians are also affected by light pollution. For example, sea turtles lay eggs on sand, however if the beach is close to a brightly illuminated area, the hatchlings might not be able to survive. In fact, baby sea turtles rely on the reflection of the moon in the water as a guide to the sea. Artificial light can instead lead them to roads, where cars could run over them, or they might travel in the wrong direction and die from exhaustion or from predators. The decrease in population of sea turtles can be explained by light pollution, as it becomes harder and harder for mothers to find safe beaches. Furthermore, the croaking at night of frogs and toads is regulated by the absence of light, and if this doesn't occur, their population might also decrease.

Effects on humans

Humans, just like most living species, have a specialized biological system that controls our behavior, so that it is coordinated with the cycle of the day and night. It is called circadian rhythm which is, by definition, a biological process that controls your physical and mental behavior throughout the 24-hour cycle, responding to light and darkness. This system controls temperatures and the release of hormones such as, for example melatonin. Therefore, light pollution can lead to sleep deprivation and disorders such as insomnia. Melatonin further contributes to our health as it does not only induce sleep, but it also has antioxidant properties, enhances the workings of the immune system, lowers cholesterol levels, and supports the functioning of the thyroid, pancreas, ovaries, testes, and adrenal glands. When disruptive and excessive light is introduced in our lives, our normal biological cycle is heavily disrupted, resulting in a suppression of melatonin in our bodies. The results might lead to a series of very dangerous, and sometimes deadly, diseases such as cardiovascular issues, depression, diabetes, and cancer. However, further research must be done to better understand these processes. Not all light affects humans in the same way, in fact blue light coming from LEDs seems to be especially harmful. According to experts at Harvard Medical School, “If blue light does have adverse health effects, then environmental concerns, and the quest for energy-efficient lighting, could be at odds with personal health. Those curlicue compact fluorescent lightbulbs and LED lights are much more energy-efficient than the old-fashioned incandescent lightbulbs we grew up with. But they also tend to produce more blue light.” (Letter)

Effects on scientific research

Even though the effect on research is somewhat smaller than the one on humans and wildlife, it is important to mention that light pollution heavily affects research in the field of astronomy. Firstly, sky glow can lower the visibility of celestial bodies, as there is less contrast in the night sky. Furthermore, light trespassing also causes difficulties in observing the sky with telescopes. Very often, observatories must be placed in extremely remote areas where no artificial light affects the observation of the sky. Spectroscopy is one of the methods used by astronomers to deduce the chemical composition and temperature of celestial objects. This is done by taking the spectra of objects, meaning that the light received by the telescope is split into its component colors. Each color is determined by a line and each line is a unique indicator of the chemical present in the observed object. Furthermore, the spectrum of celestial objects can also give an indication of how fast an object is moving. Light pollution disrupts the functioning of spectrographs, and since there

are no corrective lenses that can prevent the disruption, research through land based astronomy has become difficult to be carried out.

Links to other types of pollution

Besides putting in danger the stability and health of ecosystems and humans, light pollution is also an immense waste of energy and resources. For example, according to the International Dark-Sky Association (IDA), 30% of all outdoor lighting in the U.S. alone is wasted. Because most lighting sources are powered by fossil fuels, more than 21 million tons of carbon dioxide per year is released wastefully with a direct loss of 3.3 billion dollars. It is therefore possible that light pollution is closely linked to climate change. Fortunately, light pollution is determined mostly by a problem in how we design lighting systems, making the resolution of the problem somewhat more achievable.

Major Parties Involved

Governments

National, subnational, and local governments worldwide have begun taking this issue of combatting light pollution quite seriously. According to *USA Today*, citizens living in more than 300 United States counties have passed some sort of “dark-sky ordinance”; these range from measures penalizing households for emitting excess light to regulations limiting installed streetlights to certain types to subsidies for developing countries or other less harmful lighting technologies (Loew).

Other examples of authorities having similar laws include Spain and the United Kingdom. In Tenerife, Canary Islands, various limitations on four types of light pollution, “light contamination, radio-electric contamination, atmospheric contamination, and air routes,” have been in place since 1988. In the UK, the Institute of Lighting Engineers published a set of guidelines in 2002 aimed both at private and public entities; included in these guidelines were clauses about the maximization of both lighting efficiency technologies and consciousness about over-lighting. Most authorities on this issue seem to agree that lighting at or below the horizontal is one of the most effective ways to reduce Light Pollution

Non-Governmental Organizations

NGO’s such as the IDA (International Dark-Sky Association), the Starlight Initiative, NeedLess, GlobeatNight, and others have been instrumental in promoting global awareness and activism on this topic. Light Pollution was largely viewed as a trivial side effect of

economic development until astronomer-led protests started pressuring legislators to limit its harms through various measures (such was the case in Flagstaff, Arizona). Somewhat ironically, the internet has become an important platform for Dark-Sky NGO's—through platforms such as this map, ordinary people can educate themselves about light pollution severity around the world.

Timeline of Key Events

Date	Description of Event
1780	Lisbon becomes the first city to implement public illumination
14 September 1897	The *Los Angeles Times* comments on "Light at Night" (LAN)
April 1958	Flagstaff, Arizona, takes legislative action against light pollution
1959	Full Cutoff Fixtures first become available for the public
1988	Founding of the International Dark Sky Association (IDA)
17 January 1994	Blackout in Los Angeles causes many citizens to panic after seeing certain galactic patterns for the first time
6 February 2012	35th Dark Sky Preserve founded
2030	Number of people living in large cities is expected to reach 5 billion.

UN involvement, Relevant Resolution, Treaties and Events

There has not been any clear or direct involvement of the UN on the issue of light pollution; however there have been various efforts regarding pollution as a whole. With "Towards a Pollution-Free Planet" as the set goal for the 2017 UN Environment Assembly in Nairobi, furthermore, it is likely that light pollution will at some point be discussed. Some examples of UN resolutions dealing with other sorts of pollution with strategies applicable to light pollution can be found below:

- Resolution 44/228, 22 December 1989 (A/RES/44/228)
- Modalities for the United Nations Conference to Support the Implementation of Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development, 23 September 2003 (A/RES/70/303)

- United Nations Conference on Environment and Development, 20 December 1988 (A/Res/43/196)

Previous Attempts to Resolve the Issue

There has been little to no involvement of the UN regarding the issue of light pollution. This environmental problem is generally little-known and often over looked. The lack of awareness general public awareness regarding light pollution translates to reduced governmental interest in the formulation of solutions; other types of environmental policy discussion are often prioritized over those aiming to protect the night sky. The involvement of the international community has been led mostly by UNESCO with, for example, the International Workshop and Expert Meeting "Starlight Reserves and World Heritage - scientific cultural and environmental values", held in Fuerteventura, Spain from 10-11 March 2009. This meeting resulted in a series of recommendations for consideration by the World Heritage Committee, States Parties, Member States of UNESCO, the Advisory Bodies to the World Heritage Convention (IUCN, ICOMOS, ICCROM), other UNESCO programs as well as other UN organizations, scientific institutions and other relevant bodies. Measures to reduce light pollution taken up by cities include switch-off days in which urban areas make an effort to turn off all lights for one night. This usually occurs once or twice a year in occasion of other environmental awareness initiatives, such as Earth Day. Even though it helps with creating sensibility of locals towards the problem of light pollution, it has little to no long-term effect on the real problem at hand and there is no proof that it actually reduces the overall usage or waste of light. Other similar solutions taken up on a regional level include “starlight reserves” or “dark sky parks”. These designated areas have strict regulations regarding the use of light in the surroundings, and they represent hotspots for astronomical research.

Possible Solutions

As previously stated, light pollution is an issue related to the planning and distribution of city lights. This environmental problem is a design problem, and its solution is embedded

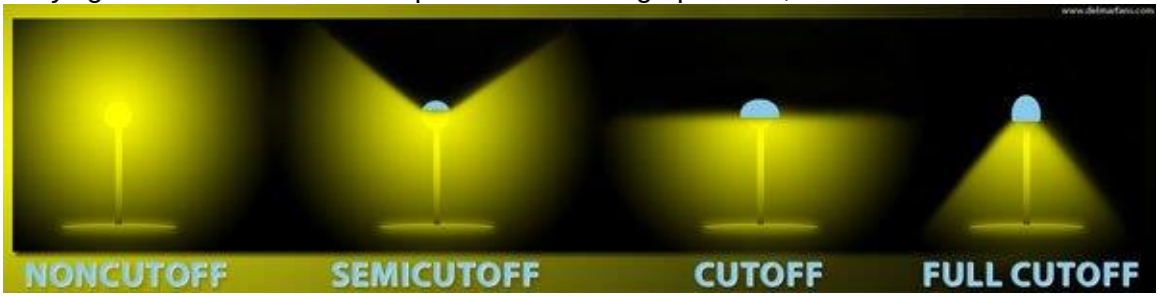

Photo Source: http://www.delmarfans.com/educate/basics/lighting-pollution/

in the concept of sustainable design. Sustainable design follows principles of environmental, social and economic sustainability and low light polluting systems have been created following these ideals. Specific types of lighting have been designed to reduce the upward reflection of light. Lights with cut-off designs ensure that light is only directed into the desired areas, reducing glare, trespass, clutter, and sky glow. Many cities have been implementing regulations to require outdoor lighting and street/highway illumination systems to have cut-off or full cut-off designs.

Furthermore, new technologies have been arising to provide energy-efficient lights. For example, light-emitting diodes (LEDs) and compact fluorescents (CFLs) reduce energy usage. As previously mentioned, blue toned LEDs can have a negative impact on humans; therefore, only warm-white bulbs should be used to reduce energy waste without harm to health. Other smart systems of lighting include motion sensors, timers, dimmers (sensors that adjust illumination depending on traffic), and photocells (sensors that turn light fixtures on only when it's dark) to reduce illumination levels in, for example, rarely used roads, office buildings and private outdoor lighting which usually produces excessive amounts of light resuting in a great deal of energy waste. Despite the complicated history of legislation to reduce excess artifial light, furthermore, governments should consider that smart lighting systems reduce long-term cost in a number of sectors. Lastly, raising awarness and education on the issue promote a smarter use of light and can positively influence choices on lighting systems. An example could be events such as Earth Day.

Appendices

Further reading

Paper on combining urban planning and the night dimension of light:

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Factsheet on light pollution:

Light Pollution Facts. (2017). Aslc-nm.org. Retrieved 15 July 2017, Available http://aslc-nm.org/LightPollution.html Available at http://aslc-nm.org/LightPollution.html

Wikipedia entry on light pollution, in particular on reduction of such:

Light pollution. (2017). En.wikipedia.org. Retrieved 15 July 2017, Available at https://en.wikipedia.org/wiki/Light_pollution#Reduction

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