

ADDIS ABABA UNIVERSITY
COLLEGE OF DEVELOPMENT STUDIES
CENTER FOR ENVIRONMENT AND SUSTAINABLE
DEVELOPMENT



Magnitude, Awareness and Management of Light Pollution
in Bole Sub-city, Addis Ababa

By: Mahder Mesfin

Advisor: Professor Degefa Tolossa

**A thesis Submitted to Addis Ababa University College of Development
Studies, Department of Environment and Sustainable Development
Fulfillment of the Requirements for the Degree of Master of Art**

July, 2022

Addis Ababa, Ethiopia

Approved by the board of examination

This thesis, by Mahder Mesfin is accepted in its present form by the board of examiners as fulfilling for the degree of masters of art in environment and sustainable development.

Signed by the examining committee:

Advisor

Professor Degefa Tolossa

Full name

Signature

Date

Internal Examiner

Dr. Shimeles Damene

Full name

Signature

Date

External Examiner

Dr. Messay Mulugeta

Full name

Signature

Date

External Name of Chairman

Full name

Signature

Date

Chairperson of the Center or Graduate Program Coordinator

Declaration

I, the undersigned, declare that this thesis is my original work; prepared under the supervision of Professor Degefa Tolossa. All sources of materials used for the thesis have been duly acknowledged. I further confirm that the thesis has not been submitted either in part or in full to any other higher learning institution for the purpose of earning any degree.

Student's Name

Date &Signature

Acknowledgement

My first and prime gratitude goes to almighty God. I am grateful for providing me the strength to overcome challenges in order to accomplish my study. My heartfelt sincere acknowledgment also goes to my advisor Professor Degefa Tolossa for his invaluable guidance. I would like to thank Addis Ababa University, College of Development Studies center for Environmental and developmental Studies for giving me this opportunity. I am very thankful to my beloved family and friends for their uninterrupted support.

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Acronyms

AACR:	American Association of Cancer Research
ALAN:	Artificial light at night
CIE:	International Commission on Illumination
EFCCC:	Environmental Forest and climate change commission
EPGDC:	Environmental Protection and Green Development Commission
FDA:	Food and Drug Administration
IARC:	International Agency for Cancer Research
IDA:	International Dark-Sky Association
LED:	light-emitting diode
LP:	light pollution
MDD	major depressive disorder
MTF:	Multi-Tier Framework's
NELM:	Naked Eye Limiting Magnitude
SNNP:	Southern Nations, Nationalities and Peoples
SPSS:	Statistical Packages for Social Sciences
UV:	Ultraviolet
WHO:	World Health Organization

Abstract

Light pollution is a modern civilization/urbanization unfavorable outcome. It is excessive or inappropriate use of artificial light which can have serious environmental consequences for humans, wildlife, energy consumption and our climate. The impact of light pollution is multi-faceted. Almost all living organisms are impacted to changes in the quality and intensity of natural light in the environment. The objective of this study is to assess the level of awareness and practical management of light pollution among government institutions and dwellers around Bole area who are believed to be more vulnerable to the effect as well as to measure light pollution level for a period of 4 months in Bole area, Addis Ababa. The methods used to assess awareness level is by directly collecting survey data from selected environmental governmental organization as well as surrounding dwellers in the study area. Light pollution measurement was undertaken by internationally recognized and approved digital measurement software called Loss of the Night and Bortle scale classification technique and observation of the practice and management related to light pollution is also included. Findings of this study have shown that outcome of Light pollution measurement of Bole area, Addis Ababa was found to be 19.51 mag/arcsec². The awareness level was also found to be low among environmental governmental organizations and dwellers. The result of the measurement has shown that the light pollution level is at borderline margin which could be alarming considering the current development status of the country and potential increase with expected upcoming development. Governmental policies need to be revised incorporating also evolving types of pollutions including regulating practice; and it is also critical to engage on a comprehensive awareness-building mechanism for light pollution issues.

Keywords: *Light Pollution, Artificial Light, Light Trespass, Glare, Over-illumination, Blue light.*

Chapter One

Introduction

1.1 Background to the study

The environmental pollution is triggered by environmental and ecological changes as a result of the evolution of the economic and technological development human of the present century. The environmental crisis is a result of the degradation of the environment caused by many types of pollution, the depletion of natural resources as a result of the rapid rate of exploitation and the increasing dependence on energy consuming and ecologically damaging technologies (Appannagari, 2017).

Among the various forms of pollution, light pollution is one of the least known. Nonetheless, it still has a major impact on our physical environment. Excessive presence of artificial light in the night lower atmosphere has impact on global warming and it affects human health, animals and plants growth as well as interacts and threatens the balance of the entire ecosystem and it implicates a waste of energy (Karol *et al.*, 2010).

In the early 20th century, in 1908 Mount Wilson Observatory looking over the scant lights of Los Angeles, recognition of the deleterious effects of light pollution began, but the efforts undertaken to bring out the effects did not begin until the 1950s. During the 1980s, a global dark-sky movement started with the founding (IDA, 2020). There are many educational and advocacy organizations around the world focusing on light pollution are emerging presently.

Light pollution is considered by many environmentalists, naturalists, and medical researchers to be one of the fastest rising and most growing types of environmental pollution. Artificial light has helped society, for example, extending the duration of the productive day, and also for light-needing leisure activities. But when artificial outdoor lighting becomes irritating, and unnecessary, it is known as light pollution (Chepesiuk, 2009).

The invention of electric lighting and the rapid growth of human communities, transport networks and economic activity contributed to the influence of artificial light at night in large

areas of the globe. This is due to the diffuse dispersion of light in the area, both direct illumination and sky glow. In 2001, 19% of the world's land surface was reported to be above a light level set for polluted status, and 21% of the world's population live in places where light pollution obscures the Milky Way views (Bennie *et al.*, 2014). In recent years, there have been concerns about the consequences of the night sky since the number raised by more than double.

The number of uses of artificial lights is growing in relation to economic development. This is true for many countries, but some even outpaces the economic affluence. Ironically, adding higher quality and cheap lights leads to increased use, which exacerbates the degree of light pollution. Thus, it can be argued that most urban areas are now experiencing light pollution and vice versa in both developed and developing countries of the world (Azman *et al.*, 2019).

Africa Protected area were impacted by increasingly severe artificial lights during 1992–2018, with all three light indices showing an accelerating increasing trend. The number of light-polluted protected areas also rapidly increased, with more than 80% of protected areas experiencing aggravated light pollution as of 2018 (Zheng *et al.*, 2021). Different types of protected areas had heterogeneous light pollution, which penetrates indiscriminately into all protected area regulation levels. Light pollution in African protected areas was divided into three types, including outside invasion, internal sources, and mixed pollution. Human activity intensity surrounding the protected areas was highly correlated with light pollution within them.

The topic of light pollution is at embryonic stage in Ethiopia. Like all the capitals of developing countries, the brightness of the night sky is on the rise in Addis Ababa (World light pollution map, 2021), the population of Addis Ababa has increasing time to time. This population growth also creates an increase in the need for energy and a need for electrification. It is noticeable to observe an increase in the dense surface from year to year with very strong areas of nighttime lighting. This encourages pursuance of research in the subject area.

Many consider Addis Ababa as darkest city however, according to (World Bank, 2018) assigned Addis Ababa with high value using Multi-Tier Framework's (MTF) measurement, which was developed to address the specifics of energy-access needs defined in the Sustainable Development Goals (SDGs) of the United Nations. Households are assigned to a tier based on the level of service provided, as determined by various thresholds (Pinto *et al.*, 2019). While Tier

0 households have no access to electricity, high tiers values are defined by higher capacity and longer availability of supply (Padam et al., 2018; Rysankova et al., 2015). With this criterion, 91.1% of households in Addis Ababa ranked high tier value (3-5) compared to access in the regions such as Amhara (65.4%) and Southern Nations, Nationalities and Peoples (SNNP) (68.2%) which are tier 1 and Oromia (24.7%) which is Tier 1. In addition as per (World light pollution map, 2015) Addis Ababa especially Bole Sub-city area is one of the illuminated area comparable to other African cities.

In view of the fact that the availability of lighting, people in Addis Ababa have been lighting up nighttime environments for the reason of advertisement, security and recreational purpose. The expansion of lighting infrastructure, which is intimately linked to economic development, is accelerating this rapid change (World Bank, 2015). This is especially true in urban areas, where expansion of lighting infrastructure is imminent, and electricity along with lights become more widely available. Artificial lights often excessive and poorly designed, creating light pollution when it leaks or reflects into the night sky. The city of Addis Ababa, like other global change drivers, is at a critical juncture in ensuring that its economic trajectory does not compromise human and environmental health.

1.2. Statement of the problem

Light pollution, which is the alteration of night natural lighting levels caused by anthropogenic sources of light, is considered one of the emerging leading risk factors for environmental pollution and economic sustainability (Shariff *et al.*, 2019). In many countries, population growth has been rapid, and the growth of outdoor lighting has been even faster than population growth. This continues to pose a concern as the demand for artificial lighting increases as we move towards growing urbanization and globalization, to allow people to live safely and comfortably.

The impact of light pollution is multi-faceted. Almost all living organisms are sensitive to changes in the quality and intensity of natural light in the environment (Longcore, 2017). Light pollution has effects on flora and fauna, and socioeconomic and physiological effects on humans (Lechner and Arns, 2013).

Related to human health, light pollution can cause increased levels of anxiety and lack of sleep; visual acuity loss can also be caused by artificial light. Fatigue and anxiety can lead to medically defined stress, such as hypertension and headaches, which can cause further health problems (Davis *et al.*, 2001). According to monographs meeting and solid evidence, light exposed society tended to have a more adverse risk profile for chronic diseases compared to those who never exposed one and the light at night has been classified as a Group 2A carcinogen by the International Agency for Cancer Research (IARC, 2019).

From ecological point of view, depending on the synodic month cycle, animals, bugs, and all other creatures, especially nocturnal animals, adjust their life activity. Unfortunately, as artificial light disrupted the duration of night sky brightness, it hindered their harmonious life cycle (Shariff *et al.*, 2019). As artificial lighting distorted their nocturnal behavior, which included foraging, mating, hatching and night navigation activities, the nighttime routine of insects, birds and turtles became endangered (Kyba *et al.*, 2011). Artificial light in the nighttime environment cause plants to respond physiologically, changing their phenology, growth shape, and resource allocation. Artificial light is also likely to affect the physiology, behavior, and ecology of herbivores and pollinators (Bennie *et al.*, 2016).

In regard to economic sustainability, the massive emission of artificial lights at unnecessary sites as well as inappropriate way is a waste of resource, wasting of energy has major economic and environmental impacts (Shariff *et al.*, 2019).

In terms of impact on astrological observation, anyone involved with the night sky, either professionally or just as a casual observer, would realize that over the last few decades, stars have faded from view, getting lost in the increasing glow of the sky from the cities. Astronomers are unable to receive the faint signals of light from distant objects in outer space without dark skies. A critical scientific resource for understanding the mysteries of the universe is the dark skies and dark skies with sufficiently eliminated stars are also a significant part of the cultural and natural heritage of all civilizations (Shariff *et al.*, 2018). The obvious effect of light pollution in this regard is thus the limitation in observable astronomical bodies detected by naked eye (Bashiri and Hassan, 2014). The ability to see the Milky Way with the naked eye has already been lost by two thirds of the U.S. population and more than half of the European population

(Chepesiuk, 2009). Either directly or indirectly, each person is potentially affected by light pollution. Artificial light is a threat to our climate, animals, human health, and other species.

In the case of Addis Ababa two comparable figures 1 and 2 show that in 2012 the level of light pollution was insignificant and when we see in the year of 2021 the light pollution level within the difference of 9-year period of time light pollution status of Bole area in Addis Ababa has increased. This light pollution level increment with in this short period of time may be a serious problem in the near future especially when we compare with respect to the country developmental status. In general, there seems to exist a gap in awareness about this emergent concern for environmental pollution, as can be reflected in scarcity of researches as well as absence of dedicated policies. This study will contribute to endeavors of filling the gap by providing insight to understand the extent of light pollution in Addis Ababa specifically in Bole area and to understand the existing perception of concerned bodies on light pollution.

1.3. Objectives

- *General Objective*

- The general objective of this study is to determine the magnitude of light pollution and assess awareness among vulnerable dwellers and relevant stakeholders including management practices in Bole sub-city, Addis Ababa, Ethiopia.

- *Specific Objectives*

- Magnitude of light pollution in Bole sub-city in Addis Ababa.
- Awareness of relevant stakeholders and vulnerable dwellers on light pollution.
- Management practice of light pollution by relevant stakeholders.

1.4. Research questions

1. What is the current level of light brightness measurement in Bole, Addis Ababa?
2. Do dwellers have awareness on significant health problem of light pollution?
3. Is there enough awareness among vulnerable dwellers and environmental governmental organization towards the cause and effect of light pollution?
4. Is there a standard or regulatory policy focusing on light pollution?

1.5. Significance of the study

This study will shed a light on the current level of light pollution in Bole, Addis Ababa as well as to have an understanding of perception towards the existence, the extent as well as the risk of light pollution. This will help inform future researches and give a baseline data to studies which works to acquire national level data on extent of light pollution and to monitor the trend.

This study might also serve as a ground address the gaps on issues of awareness creation, raising consciousness on light pollution; improving ultimate design of ways which influence future generations on issues of light pollution and putting light pollution issue on the environmental agenda of the general public, environmental activists, the relevant opinion-leaders, change agents, governmental organizations and policymakers which in the long run will contribute to all rounded perspective to sustainable development. The result of this study will aid in the practice of better lighting designs and sustainable technology. In addition, the output of this research will fill the knowledge gap on a society that struggle to have excess amount of light in the study area. This research will also help for policy improvement and local intervention practices and can use it as a reference.

1.6. Limitations of the study

This research will not represent the whole population of Addis Ababa, rather it covers only selected setting that is believed to be relatively affected. Additionally, the nature of sky brightness measurement process suggests to look more to seasonal tie and seasonal variation for the sky brightness measurement, however in the study owing to time limitation 4-month data was collected. There was also limitation of similar literature because there was no similar study in the area and studies made based on measurement and awareness of light pollution in Ethiopia. As a result, it became difficult for this study to compare the result with other similar studies. In addition to this, this study has focused on only the health impact and astrological impact however ecological and economic impact are not included in this study.

1.7. Scope of the study

Light pollution causing factors are vast in Bole, Addis Ababa due to rapid growth of urbanization, fast development schemes like skyrocketing buildings construction, increasing

road light distributions and other sources of artificial light which may increase the magnitude of light pollution. Due to the increased rapid growth and potential prevalence of light pollution, the scope of this research is mainly limited to Addis Ababa.

The study was conducted in one of the eleven sub-city of Addis Ababa in Bole sub-city area it was selected intentionally and only one sub-city was included for light pollution measurement due to probability of light pollution occurrence. On the other hand, the study covered the time period between April, 2021 and July, 2021. The scope of the study was to investigate the level of light pollution living around Bole sub-city area. The study also focused on evaluating the awareness and practical management and a cross-sectional study design was used to measure level and observe the practice of light pollution in Bole, Addis Ababa.

The study is further restricted to governmental organizations that are responsible directly or indirectly for the management and control of light pollution for the survey. Other non-governmental organizations and agencies which might work on related issues is out of scope of this study due to relative higher significance of responsibility by the governmental bodies other than governmental bodies dwellers are probably in high risk of light pollution area are included.

1.8. Organization of the thesis

This thesis is categorized into five major parts which includes introduction comprised background, description of study areas, statement of the problem, objectives of the study, research questions, significance of the study, scopes and limitations of the study and organization of the study, literature review deals with brief explanation about the concept and definition of light pollution of present data sources, impacts it causes in human and animals lives regarding light pollution. The information shall be collected from different reference sources and finally analyzed in context with selected topics, research methodology: the research design and sample size determination, method of data collection methods was carried out, and also, the light brightness measurement devices were applied in the study area, data analysis and presentation: such as personal observation, questionnaires, interviews and focus group discussion analysis were held in depth and findings conclusion and recommendation. Here, what had been found in the literature review was linked up with new research findings.

Chapter Two

Literature Review

2.1. Basic concepts

Light plays an essential role in our daily lives and has evolved into a valuable instrument for fulfilling the demands of the twenty-first century. Light-based technologies preserve human health and safety, supply sustainable energy, enable space explorations, develop lighting options in rural regions, enable Internet connection, and hold the promise of unlimited opportunities to improve human welfare and protect the environment.

Light pollution is a serious issue that has repercussions for biodiversity, human health, scientific study, energy use, global warming, and the ageless pastime of night sky observation. Not only for astronomical science, public health, ecological balance, but also for the economy, light pollution is a threat, making it one of the key dangers to the concept of sustainability. To curb the impact of light pollution, a well-rounded initiative needs to be pioneered (Shariff et al., 2019).

Light pollution refers to the light flow emitted at night by artificial light sources that are insufficient in intensity, direction or spectral spectrum, inappropriate for the purpose of carrying out the role they are intended for, or when artificial lighting is used in particular sites, such as observatories, natural areas or sensitive landscapes. It shows the highest immediate risks of all causes that have a detrimental impact on the quality of the night sky, but it can be minimized by viable solutions at the same time. Irresponsible lighting includes over-illumination, which makes the use of artificial light excessive and wasteful, as well as poorly designed luminaires that trigger glare or glow in the sky (Marin, 2011).

Light pollution is a serious problem recognized by many governments around the world. The amount of lighting is almost that of a sunny day in many modern cities, such as New York City and Las Vegas. This is a recent phenomenon that stems from the over-saturation of electronic billboards and other types of illuminated advertising. Among other cities in the world, situations such as these are not uncommon, and the issue is only getting worse as cities expand (Mangu-Ward, 2009).

Light pollution is a broad term that refers to multiple problems, all of which are caused by inefficient, unappealing, or unnecessary use of artificial light. Specific categories of light pollution include light trespass, over illumination, glare, light clutter, and sky glow. A single offending light source often falls into more than one of these categories (Rajkhowa, 2014).

2.2. Theoretical foundations

As a theoretical basis we can underline that light pollution is described as the brightness of the night sky caused by excessive city lighting (Grijalva-Salazar *et al.*, 2020), and it is thought to have an impact on human health through affecting hormone control (Falchi *et al.*, 2011). Other environmental pollutants are also increased as a result of light pollution. The amount of pollution released by power plants is increased by the excess energy used to power unnecessary artificial night lighting (Artiola *et al.*, 2019).

Light pollution is viewed as a significant driver behind the erosion of provisioning (for instance, the loss of light-sensitive species and genotypes), regulating (for example, the deterioration of nocturnal pollinators such as moths and bats) and cultural ecosystem services (for example, the abatement of aesthetic values such as the visibility of the Milky Way). As the world becomes more and more illuminated, many light-sensitive species, especially in or near highly illuminated urban areas, will be lost. However, as is described for other human disturbances, some species, particularly those with short generation times, may be able to adapt to the new stressor through rapid development (Holker *et al.*, 2010). Lighting is responsible for one-fourth of all global energy use, and case studies have demonstrated that numerous types of over-illumination, including the non-beneficial upward direction of evening lighting, are energy wastage (Lechner and Arns, 2013) .

The discharge of greenhouse gases is the by-product of electrical illumination generated by the burning of fossil fuels. Global warming and the exhaustion of non-renewable resources are responsible for these gases. Many other environmental impacts are caused by light pollution. The animal world, the vegetable kingdom and humanity are involved in adverse effects. Although light exposure is highly detrimental to nocturnal and migratory animals and flying animals, adverse effects on plants are also caused (Rajkhowa, 2014).

Increase in human population density in a certain location parallels with growth in economic and social infrastructure. However, through their streetlights and giant building spotlights, this unstoppable economic development and population growth cultivates a huge light intensity that is directly proportional to light pollution. This trend continues to deteriorate, without individuals understanding that it could affect the environment and the health of living things. The truth is people find other issue more important although they concerned about the environment (Faid *et al.*, 2016).

Light pollution is the effect of inefficient and unnecessary artificial outdoor lighting (Chepesiuk, 2009). The most significant source of light pollution is street lighting. Commercial lights, light from urban areas, yard lights, road lights, and decorative lights are examples of other sources. The full list of light pollution sources is significantly larger (Lyytimäki *et al.*, 2013). Sky glow, trespass, glare, and over-illumination are all terms used. Sky glow is the halo over urban areas, light trespass is unwanted artificial light spilled over adjacent properties, glare is unused light that shines horizontally, and over-illumination is nonfunctional use of light and there are five management options to reduce light pollution: reduction of duration, trespass, intensity, and spectrum of lighting, and preservation of unlit areas (Chepesiuk, 2009).

Types of light pollution

Light pollution is a broad term that refers to a variety of problems, all of which are caused by the inefficient, unattractive, or unnecessary use of artificial light. Specific types of light pollution include light trespass, over illumination, glare, light clutter, and sky glow (Rajkhowa, 2014). A single offending light source generally falls into more than one of these categories.

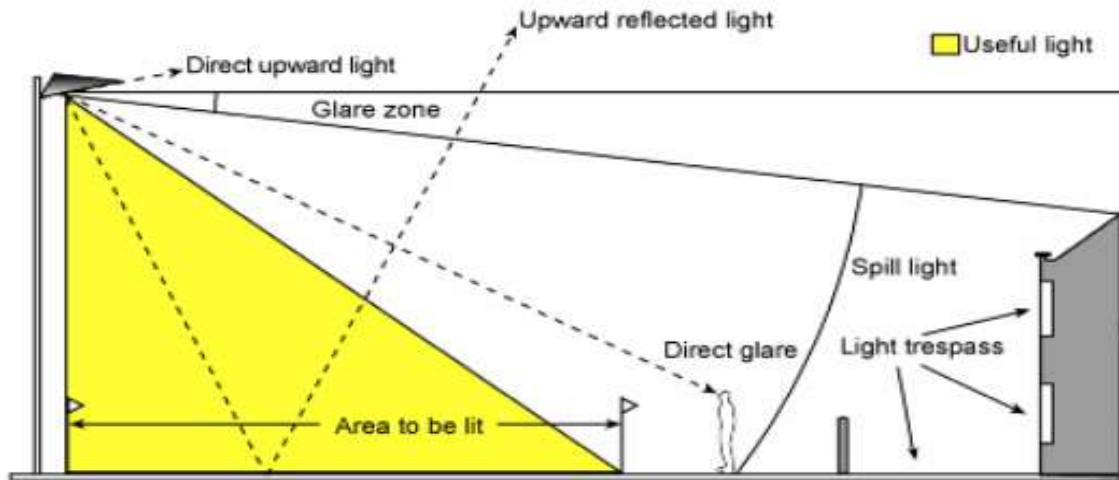


Figure 1. Instruction of lighting energies

Source: Adapted from Institution of Lighting Engineers

1. Light trespass

Light trespass is light being cast where it is not needed, trespassing adjacent areas. It is the foremost common type in large cities (Pattini *et al.*, 2005). It occurs when unwanted light enters one's property, as an example, by shining over a neighbor's fence a standard light trespass problem occurs when a robust light enters the window of one's home from outside, causing problems like sleep deprivation or the blocking of a night view. It affects the family environment and people's privacy.

2. Glare

Glare is regularly the end result of excessive contrast among bright and dark regions in the field of view (Rajkhowa, 2014). For example, glare related to directly viewing the filament of an unshielded or badly shielded light. Caused by excessive contrast among light and dark areas, glare also can make it hard for the human eye to regulate to the differences in brightness.

According to Srikanth *et al.* (2020), Glare can be categorized into different types. Disability glare describes effects which contain being blinded by oncoming automobile lights, or light scattering in fog or in the eye, reducing contrast, in addition to reflections from pattern and different dark

areas that reduce them bright, with significant reduction in sight capabilities. Discomfort glare does now no longer normally reason a risky situation in itself, though it is disturbing and annoying at best. It can probably cause fatigue if experienced over prolonged periods. Glare is predominantly an issue in road safety, as bright and/or badly shielded lights around roads may partially blind drivers or pedestrians unexpectedly, and contributes to accidents.

3. Sky glow

According to International Dark Sky Association (IDA) Light pollution causes sky glow, which is the artificial brightness of the night sky. Overly bright, uncovered lights that are kept on overnight are scattered by dust and gas molecules in the atmosphere, resulting in a brilliant sky.

White or blue-rich light significantly contributes more to sky-glow than equivalent amounts of yellow light due to this effect and the eye's increased sensitivity to white or blue-rich light sources when adapted to very low light conditions. Sky glow is of particular irritation to astronomers (Rajkhowa, 2014), because it reduces the contrast in the night sky to the point where you may not be able to see more than the brightest stars.

4. Over-illumination

Over use takes place when there is an excessive use of energy consequent from the lighting levels and times and/or the spectral distribution (Pattini *et al.*, 2005). It is caused by misuse of lights. Lights that are always on, or even street lights that are not adapted to daylight saving time, will waste millions of barrels of oil (Rajkhowa, 2014). It can directly affect the cost of utilities in an area and disrupt natural sleep patterns.

Over-illumination causes from several factors: (Azman *et al.*, 2019) Not using timers, occupancy sensors, or other controls to turn off lights when they are not needed, Improper design, particularly on workplace spaces, by specifying more light than is required for a given task, Incorrect fixture or light bulb selection, which does not direct light into areas where it is required, Inadequate hardware selection results in the use of more energy than is required to complete the lighting task. Inadequate training for building managers and occupants on how to use lighting systems effectively, "Daylight lighting" may be required by citizens to reduce crime or by shop

owners to attract customers, so excessive illumination may be a design choice rather than a fault. In both cases, the achievement of the target is questionable. Lighting techniques that use indirect lighting, such as lighting a vertical wall to bounce photons on the ground.

Ethiopia's energy consumption increases continuously from year to year. The demand for night lighting necessitates a large amount of energy, some of which is often inefficiently, resulting in over-illumination, light trespass, glare and sky glow of the surrounding area. Light pollution is one of the side effects of rapid industrialization and modernization, especially in densely populated areas (Kocifaj, 2011) which make Bole, Addis Ababa inclusive given that Addis Ababa, is home to 25% of the country's urban population (World Bank, 2015) and advertising, business, security, and street lighting, light emitted from poorly built and directed lighting fixtures which most of them are located in Bole area. While some light is unavoidably reflected upward from illuminated surfaces, much of it spills outside of the region it is intended to brighten, causing glare, light-trespass and sky glow.

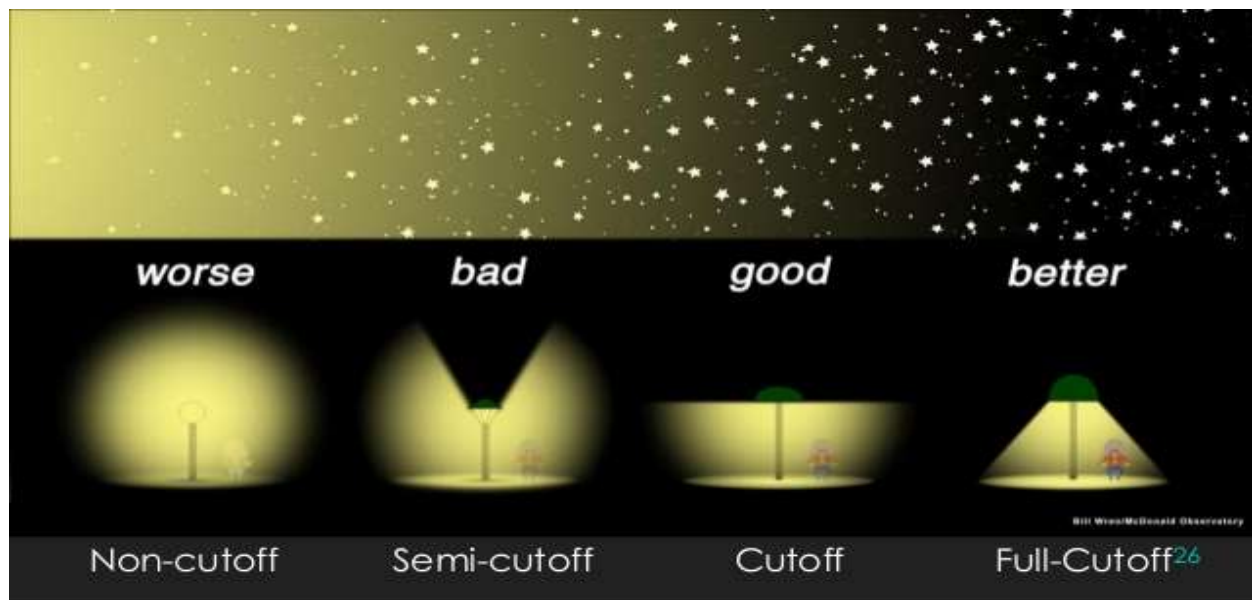


Figure 2. Main Types of Cutoff Lights

Source: The Nguyen Manh, slide 26

The other form of light pollution is artificial source of blue light which comes from computer/laptops and smartphones, and digital tablets lights with short wavelengths have more

energy (Canale, 2020). Light rays with short wavelengths have more energy, and those with longer wavelengths have less energy.

Blue light is considered to be a new portion of environmental pollution in terms of irradiation; dissimilar with exposure to sunlight, which has a daytime rhythm, exposure to blue light can occur anywhere and at any time (Falchi *et al.*, 2011)

Recent advances communication technology has created environments that are rich in blue light, mainly for office workers, school children and portable device users. Nighttime use of technological self-luminous devices such as smartphones and tablet computers is increasing, especially directly before bedtime. Excessive viewing of portable device displays before sleep might adversely impact psychiatric disorders and sleep problems, including restlessness, especially in school children (Cain and Gradisar , 2010).

2.3. Review of empirical literatures

Some studies have been conducted globally to show this emerging concern of light pollution. And the studies conducted elsewhere show high levels of light pollution (Fokus, 2020);(Faid *et al.*, 2016). In the context of our country, a rough indication of light pollution is implicated in an international map of light pollution (World light pollution map, 2015). Some studies indicate that excessive quantities of artificial light that can span more than hundreds of kilometers from the outskirts of the city is the major reasons to increase light pollution and are the causes of light pollution which may have a detrimental impact on the environment and its inhabitants (Karol *et al.*, 2010 ; Kyba, 2018); Crawford, 1996).

The other current concerning issue is blue light ray the other form of light pollution. Light is basic for life, but prolonged exposure to artificial light is a matter of increasing health concern. The blue light beaming from smartphones and tablets is changing cells in our eyes that could accelerate blindness (Billau, 2018). The university of Toledo in Ohio, United States of America additionally discovered blue light triggers "toxic" reactions in retinal molecules that experience light and signal the brain. The retinal used by photoreceptors in our eyes is what allows humans to watch. Results confirmed blue light enables generate toxic chemical reactions killing photoreceptors, which cannot be restored after they die out. Moreover, Personal electronic

devices cause massive negative impact on children which stimulate blue-light-sensitive ganglion cell photoreceptors that regulate circadian rhythm (Berson *et al.*, 2002) which is evening blue light exposure has been linked to circadian rhythm disorders including sleep disorders, and other conditions including cancer, obesity, hypertension, diabetes and depression (Ayaki *et al.*, 2016).

As a result, mobile telephone, tablet and personal laptop use earlier than bedtime can postpone sleep onset, degrade sleep quality and impair alertness the subsequent day (Chang *et al.*, 2015). Extended use of those devices has additionally been proven to reason symptoms of dry eyes, blurred vision and headaches (Klamm and KG., 2015).

People have recently become more aware of the effects of light pollution on their eyes. Short-wave blue light is linked to eye light damage in the visible range. This high-energy blue light penetrates through the cornea and lens to the retina, causing disorders like dry eye, cataracts, and age-related macular degeneration, as well as disrupting hormonal balance and negatively impacting sleep quality. (Zhao, Tan and Li, 2018). The impact of screen reading on schoolchildren's visual acuity was examined in a recent study. The findings suggest that screen reading can lead to the occurrence and development of poor eyesight in schoolchildren, and that the higher the incidence of nearsightedness, the longer the screen reading time (Czepita *et al.*, 2016). As a result, the impact of Blue-rays on vision is becoming a major worry in the near future.

Blue light ray is one form of light pollution (Lamphar and Kocifaj, 2013) however nowadays in Ethiopia parents without realizing the blue light ray effect, they unknowingly allowing their children to be expose to a variety of risks and expose them to the appearance of a variety of eye problems. Growing up with inside the digital age, today's children are in particular vulnerable to any negative health outcomes from blue light exposure. In the western countries health professionals and early childhood experts are warning parents that interacting with screens has become a real addiction and cause many problems.

A study found out that about 83% of the world's population is exposed to light pollution (Falchi *et al.*, 2016). On the basis of satellite data, a worldwide rise of approximately 2% per year in the region illuminated at night (Fokus, 2020). The developed countries are indicated to live under light-polluted skies and to be affected in comparatively greater extent. To mention few, a country with the most light-pollution is Singapore, where the whole population lives under skies so bright

that the eye cannot fully dark-adapt to night vision. United States (99 percent), Kuwait (98 percent), Qatar (97 percent), the United Arab Emirates (93 percent), Saudi Arabia (83 percent), South Korea (66 percent), Israel (61 percent), Argentina (58 percent), Libya (53 percent), and Trinidad and Tobago (50 percent) are among the countries with high level of light pollution. More than half of the people in each of these countries live under extremely bright skies. (Falchi *et al.*, 2016). The rise is also indicated to be above average in many rapidly developing countries in Africa, South America and Asia (Fokus, 2020).

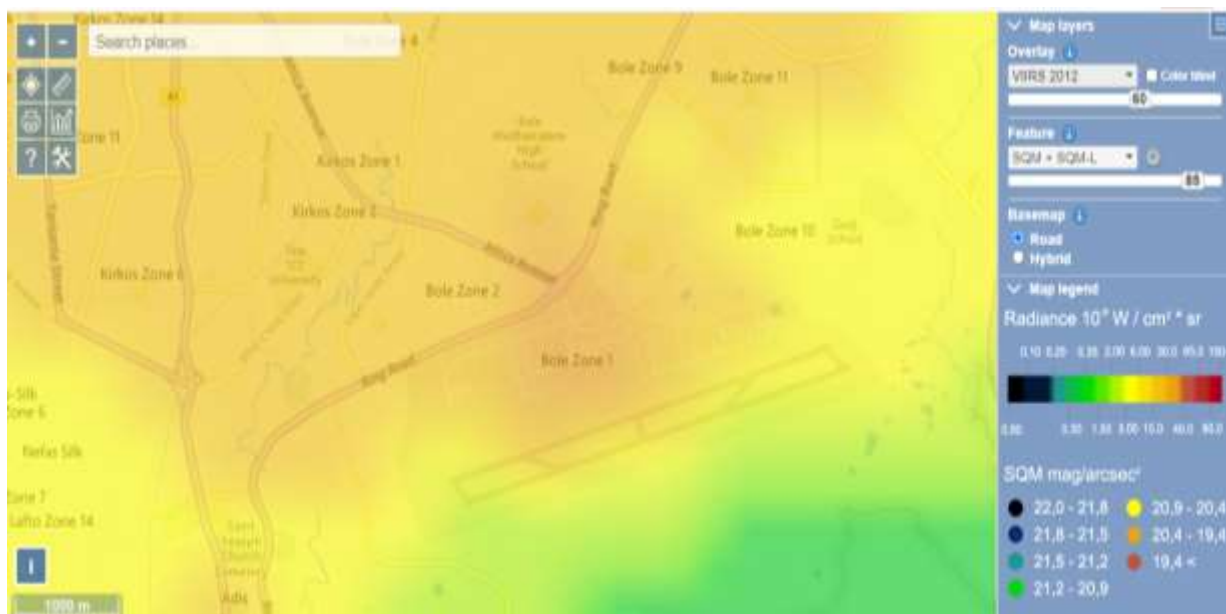


Figure 3. Light pollution map 2012

Source- www.lightpollutionmap.info

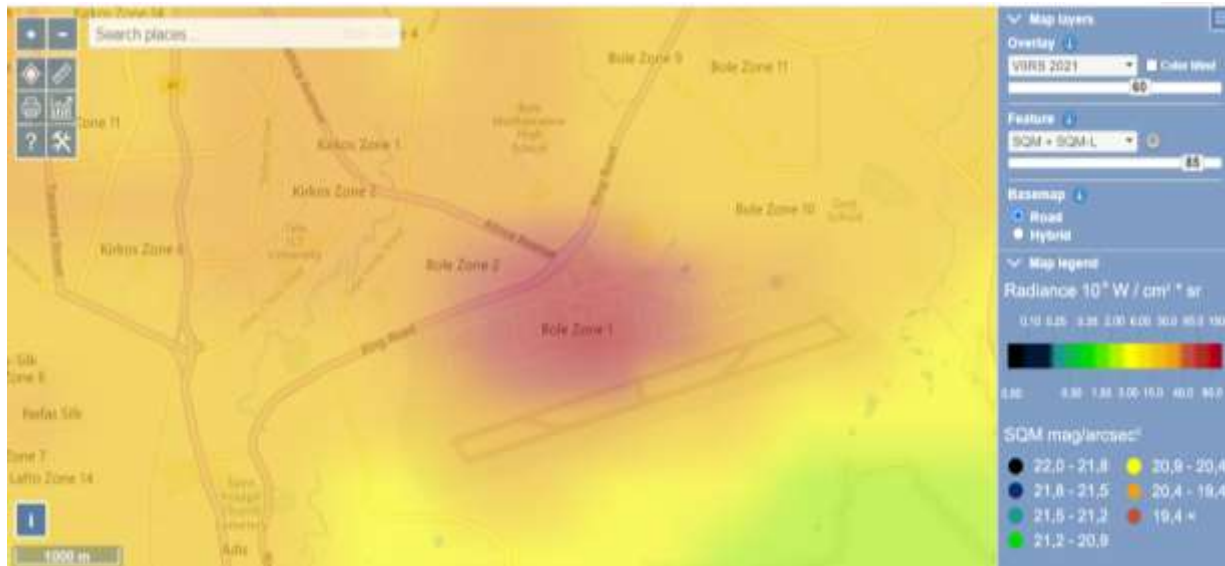


Figure 4. Light pollution map 2021

Source- www.lightpollutionmap.info

In Figure 4 the map shows that the area shaded red color indicated that the area of affecting area by light pollution in Bole area the city of Addis Ababa.

In economical point of view taking the instance of the U.S. alone, an annual total of 3,600 billion kilowatt-hours of energy for electrical consumption was generated in 2018, equivalent to the cost of USD 362 million. Considering that 30 percent of outdoor lighting was poorly illuminated, this meant that a total of 35 billion kilowatt hours of electricity was wastefully generated annually for outdoor lighting at a cost of USD 3.5 billion per year (Gallaway *et al.*, 2010).

Health related impacts for instance according to a study conducted in long-term night shift work among women increased the risk of cancer by 19 percent. Additionally, the researchers found that this vulnerable population had an increased risk of skin (41 %), breast (32 %), and gastrointestinal cancer (18 %) compared with women who did not perform long-term night shift work and when it comes to female nurses shift workers, those who worked the night shift had an increased risk of breast (58 %), gastrointestinal (35 %), and lung cancer (28 %) compared with those that did not work night shifts (AACR, 2021) the problem is becoming a current alarming issue. A number of published studies also indicate a correlation between night light exposure and breast cancer risk due to the suppression of normal nocturnal production of melatonin (Davis *et al.*, 2001). Additionally, a research showed that populations with the highest exposure to light

pollution at night had a higher risk of prostate cancer than populations with lower exposure to light pollution (Kyba, 2018).

A study conducted in Poland based on night shift work (exposed to light), a risk factor for breast cancer. The research instrument measured light exposure at night during shift work (for 15 years) and at home during shift work (for 5 years). Working at night and exposure to light at night causes a disturbance of circadian rhythms. The following are more common in people who work night shifts compared to those who work only during the day: cardiovascular diseases, gastrointestinal disorders, peptic ulcers, diabetes, obesity, chronic fatigue and anxiety, sleep disorders, depression, and reduced secretion of melatonin (through exposure to light at night). The study finally supported the hypothesis that night shift work is a significant risk factor for breast cancer. It is important to note that only night shift work increases this risk (shift work that is not at night has no effect on the risk). According to Eurostat statistics, 13.2 percent of Europeans and 17.5 percent of Poles work night shifts, exposing a significant number to an increased risk of cancer. (Szukiela *et al.*, 2020).

A research conducted on awareness of light pollution among college students using a descriptive cross-sectional study was conducted in India among 100 college students, the research created close-ended questionnaire and was distributed among college students to learn about their knowledge of light pollution. From the research through statistical analysis, it is found that, 73% of the students think that light pollution is harmful to the environment and only 20% has told it is not harmful. About 22% of the students have told that light pollution is causing injurious to health but 68% has been voted for no and 10% of the students did not have any idea. About 67% thinks light pollution is reversible and other 10% strongly say that it is not reversible and 23% do not have any idea about this. About 40% of the population who answered the survey thinks that the introduction of artificial light is the cause of light pollution. Purchase of IDA approved light fixtures is one of the major ways of reducing light pollution and this has been told by around 42% of the students (Vasishta *et al.*, 2019).

Concerning about light pollution problem, a research which focuses on the character of night sky brightness in selected areas in Malaysia using Sky Quality Meter (SQM) has been conducted. In the study the SQM was stationed at two different places, each with a varied population density

and close to the city center. These localities, Kuala Lumpur and Teluk Kemang, are categorized as urban and suburban sites, respectively. The study discovered that the sky in Kuala Lumpur, which has a higher population density and is located in the city center, is heavily polluted, with a magnitude of 17.59 mag/sec² and 3.78 naked-eye limiting magnitude, which is 5 times brighter than the sky in Teluk Kemang, which has a brightness of 19.28 mag/sec² and 4.98 naked-eye limiting magnitude (Faid *et al.*, 2016). Likewise, Indonesian preliminary report on light pollution, light pollution levels are moderate at most sites the values at Biak, Agam, Sumedang, and Pontianak are 20.0, 19.5, 19.6, and 17.7 mpsas, respectively and high at stations near or in cities Bandung and Pasuruan with 17.1 and 18.0 mpsas, respectively (Admiranto *et al.*, 2019)

A data measured in Portugal in to different areas which is in Alqueva and Peneda-Gerês National Park (PNPG). Some measurements also taken for the sake of comparison of the sky brightness in two locations inside the city of Porto (northern Portugal) were conducted on various occasions during the same period, giving values ranging from 17.63 mag/ arcsec² (NELM of 3.65, indicating that only the stars brighter than 3.65 are visible at the zenith) to 18.01 mag/arcsec² (NELM of 3.97) (Lima *et al.*, 2016), which this result shoes that this area of city of Portugal is very polluted.

A research conducted in Berlin, Germany focusing on artificial night-time sky glow decreased during COVID-19 lockdown found that a luminance (21.5 mag/arcsec²) was measured in 2017 and a value of (21.7 mag/arcsec²) was obtained in 2020. And in other place of the city, a luminance of (21.6 mag/arcsec²) was obtained in 2017, a value of (21.8 mag/arcsec²) was measured in 2020 (Jechow & Hölker, 2020).

A study conducted in Rzeszów, Poland a measurement value for the years 2015 and 2018 was collected, the numerical value of the measurement for the center of Rzeszów has been taken. In 2015, this value was 18.70 mag/arcsec², while in 2018, it was equal to 16.73 mag/arcsec² which makes Rzeszów light polluted area (Wesołowski, 2019).

Another study conducted in Australia night sky brightness as a function of distance from the Perth central business district (CBD) is 21.8 mag arcsec². The result of 21.8 mag arcsec², was located towards the end of the eastern track and the north track was 21.6 mag arcsec² (Biggs *et al.*, 2012).

2.1. Conceptual framework

As shown in figure 5, the conceptual framework of the study is illustrated below. Light pollution can be underestimated by society as well as government bodies, while it is an inevitable evolutionary by product akin to knowledge, and human technological progress. The government and society awareness is significant in contributing of light pollution when the negligence is high and controlling mechanism is low the probability of the problem light pollution occurrence is high. In addition, practical management of the government which include policy making and controlling mechanism has potential role increasing light pollution causing factor.

Light pollution has both direct and indirect negative influences on the environment, life style, astronomy, etc. (Kaushik, Nair and Ahamad, 2022). There are various factors and consequences linked to this pollution, stating that the situation will worsen over time. Despite the serious consequences of the unchecked and hazardous use of different forms of artificial lighting sources, whether indoor or outdoor, the general population may have little to no awareness about the type of pollution that they are being exposed to daily.

As shown in conceptual frame work exposure to artificial lighting has alarming consequences causing various harmful health impact which alters sleep deprivation and it also affects human physiology and circadian rhythms by causing vision loss, stress on the retina, cancer, etc. (Falchi *et al.*, 2011). Another consequence of excessive lighting poses a profound threat to astronomy (Riegel, 1973). Astronomical light pollution which is the difficulties in viewing the night sky and observing limited objects because of artificial inappropriate existing excessive illumination and light design, during nighttime.

This study assumed that awareness of society and practical management of stockholders aggravate the occurrence of light pollution and this consequence health and astrological problem which may led to environmental disaster risk as shown in conceptual framework presented hereunder (Figure 5).

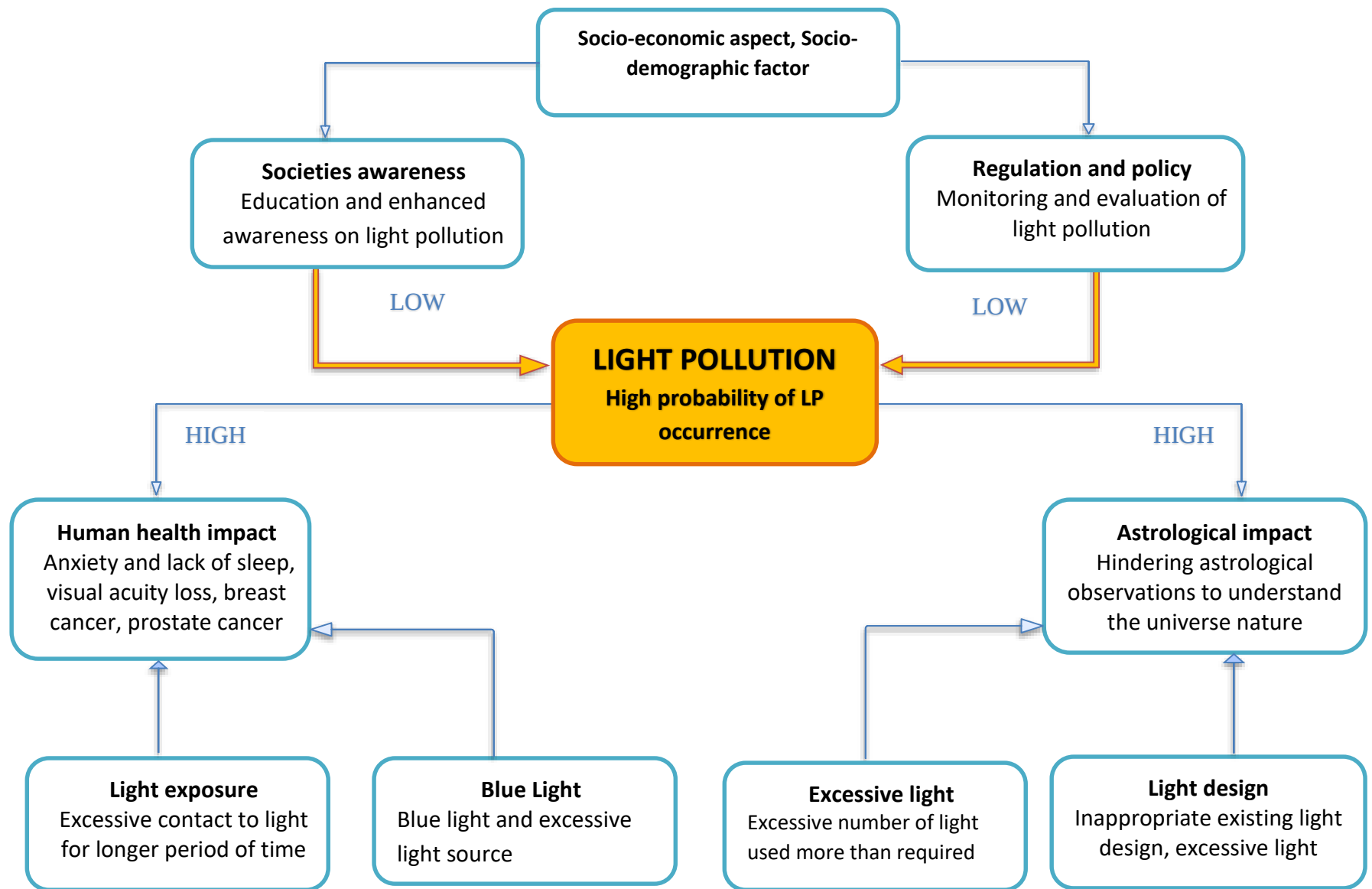


Figure 5. Conceptual framework of light pollution aggravating factors and impact

Chapter Three

Methods

3.1 Description of the study area

The study was undertaken in Bole, Addis Ababa starting from March 2021 up to June 2021. Bole, Addis Ababa was chosen as the study area because it is in the capital city of Ethiopia having the greater share (40%) of access to the national electricity supply as the difference between urban and rural access to electricity is huge in Ethiopia, as in most sub-Saharan African countries (Guta et al., 2015). This makes Addis Ababa a potential highest contributing city to the distribution of light pollution.

Another rationale for choosing Addis Ababa as the study area is taking account of the fact that it hosts main branches of national environmental government organizations, which makes it ideal to measure the awareness and management practices of concerned organizations that work on environmental pollution including policy making nationally.

As the map provided by light pollution map Bole sub city is selected as a study area considering the level of illumination of the area comparatively (World light pollution map, 2021), and taking into account the fact that Bole sub city accounts as the principal area of the city hosting big shopping malls, many business centers, recreational spots as well as a hub for many organizations.

3.2 Material and Methods

3.2.1 Material and methods on magnitude of light pollution

To measure magnitude of light pollution sky brightness measures were implemented by internationally recognized and approved (IDA, 2020) Germany's Cosalux GmbH owned digital measurement software called Loss of the Night version 2.1.7. The digital software was developed to help scientists measure and recognize the effects of light pollution. This software allows robust

measurement of the night sky brightness and evaluates the sky brightness which can be converted into the unit of magnitude per square arc second ($\text{mag}/\text{arcsec}^2$) which is the unit of light pollution.

The phrase magnitudes per square arc second means that the brightness in magnitudes is spread out over a square arc-second of the sky and an arc-second of longitude approximately equals an arc-second of latitude, which is 101.27 feet or 30.87 meters. For example, if a measurement provides a reading of 19.00 that would be like saying that a light of a 19th magnitude star brightness was spread over one square arc-second of the sky (Teikari , 2007).

3.2.1.1 Study design

A cross-sectional study design was used to measure level of light pollution in Bole, Addis Ababa.

3.2.1.2 Method of data collection

In the process of measuring the sky brightness, the range of scale is between the numbers of 16.00-22.00. The lowest number 16.00 the sky is the brightest. This class would transpire in urbanized areas. A value of 22.00 represents the least pollution. This reading would occur mostly in rural areas (Miguel *et al.*, 2017).

To increase the quality of data during measurement of night sky brightness using Loss of the Night software some recommended measurement cautions were taken. This includes avoiding near lights like streetlights and areas that are shaded by trees or buildings. Positioning as far from these objects while taking measurement, if possible, for streetlights for example standing at least 7.5 meters away were employed (Walker *et al.*, 2019). While taking measurement of sky, the brightness observations were taken on whether it is clear night which is when the moon is not up and when the sun has set for at least an hour as the sun and moon will have negative contribution to the measurement of sky brightness reading (Bará *et al.*, 2019).



Figure 6. Dates recommended for night time sky brightness measure

Source: - www.globeatnight.org

According to IDA's recommendation, due to the moon appearance time frame used for measuring in this research were as per the pre-specified dates as can be seen from the above image, i.e., from April 3, 2021 up to April 12, 2021 and from May 2, 2021 up to May 11, 2021, June 1 up to June 10 and June 30 up to July 9.

After measuring the brightness of the sky we get a value ranging from maximum of $7.9 \approx 8$ and minimum of up to 2.2 and then this values were converted using: -

$$21.58 - 5 \log(10^{(1.586 - \text{NELM}/5)} - 1) \quad (\text{Schaefer et al., 1990}).$$

Where, NELM is Naked Eye Limiting Magnitude

After converting the measured value, a consistent standard for comparing observations with light pollution and interpreting the darkness and quality of a night sky is the Bortle Scale, developed in 2001 by J. Bortle (Bortle, 2001). The Bortle scale is a method of assessing the quality (brightness) of a given location's night sky. This scale has nine categories, with 1 being a dark sky area excellent in every way and 9 being the absolute worst indicating the most severe light pollution. To assure the current sky brightness this research uses comparison with the standard value and appearance with respect to the given value using Table 1.

Class	Title	NELM	Approx. mag/arcsec ²	Description	Color of the Sky
1	Excellent dark-sky site	7.6–8.0	21.99–22.0	Zodiacal light, zodiacal band visible; M33 direct vision naked-eye object; Scorpius and Sagittarius regions of the Milky Way cast obvious shadows on the ground; Airglow is readily visible; Jupiter and Venus affect dark adaptation; surroundings basically invisible.	Black
2	Typical truly dark site	7.1–7.5	21.89–21.99	Airglow weakly visible near horizon; M33 easily seen with naked eye; highly structured Summer Milky Way; distinctly yellowish zodiacal light bright enough to cast shadows at dusk and dawn; clouds only visible as dark holes; surroundings still only barely visible silhouetted against the sky; many Messier globular clusters still distinct naked-eye objects.	Gray
3	Rural sky	6.6–7.0	21.69–21.89	Some light pollution evident at the horizon; clouds illuminated near horizon, dark overhead; Milky Way still appears complex; M15, M4, M5, M22 distinct naked-eye objects; M33 easily visible with averted vision; zodiacal light striking in spring and autumn, color still visible; nearer surroundings vaguely visible.	Blue
4	Rural/suburban transition	6.1–6.5	20.49–21.69	Light pollution domes visible in various directions over the horizon; zodiacal light is still visible, but not even halfway extending to the zenith at dusk or dawn; Milky Way above the horizon still impressive, but lacks most of the finer details; M33 a difficult averted vision object, only visible when higher than 55°; clouds illuminated in the directions of the light sources, but still dark overhead; surroundings clearly visible, even at a distance.	Green/Yellow
5	Suburban sky	5.6–6.0	19.50–20.49	Only hints of zodiacal light are seen on the best nights in autumn and spring; Milky Way is very weak or invisible near the horizon and looks washed out overhead; light sources visible in most, if not all,	Orange

				directions; clouds are noticeably brighter than the sky.	
6	Bright suburban sky	5.1–5.5	18.94–19.50	Zodiacal light is invisible; Milky Way only visible near the zenith; sky within 35° from the horizon glows grayish white; clouds anywhere in the sky appear fairly bright; surroundings easily visible; M33 is impossible to see without at least binoculars, M31 is modestly apparent to the unaided eye.	Red
7	Suburban/urban transition	4.6–5.0	18.38–18.94	Entire sky has a grayish-white hue; strong light sources evident in all directions; Milky Way invisible; M31 and M44 may be glimpsed with the naked eye, but are very indistinct; clouds are brightly lit; even in moderate-sized telescopes the brightest Messier objects are only ghosts of their true selves.	Red
8	City sky	4.1–4.5	<18.38	Sky glows white or orange—you can easily read; M31 and M44 are barely glimpsed by an experienced observer on good nights; even with telescope, only bright Messier objects can be detected; stars forming familiar constellation patterns may be weak or completely invisible.	White
9	Inner-city sky	4.0		Sky is brilliantly lit with many stars forming constellations invisible and many weaker constellations invisible; aside from Pleiades, no Messier object is visible to the naked eye; only objects to provide fairly pleasant views are the Moon, the Planets, and a few of the brightest star clusters.	White

Table 1. The Bortle Scale: Measuring Light Pollution

Bortle (2001)

3.2.2 Measurement and observation of light pollution

Personal observation was carried out on the purposefully selected places by comparing the nature of street light position, and the scatterings of the lights. These factors indicate contribution towards light pollution, for instance, streetlights often use high-pressure sodium (detected by bright yellow light), mercury lamps or LED light (detected by white or blue color of the mercury vapor). In terms of spectral energy distribution, mercury lamp and LED light compared to that of high-pressure sodium lamp, the spectrum of mercury and LED light is approximately 10 times stronger than those in the sodium spectrum indicating that virtually small light is emitted by sodium lamps relatively (Fletcher and Crampton, 1973).

Food and Drug Administration (FDA) also reported that if the outer bulb of mercury vapor lamps breaks, and the inner tube continues to produce unshielded light, intense UV radiation will be emitted which is a concern for health through light pollution. This unshielded emissions and breakages as well as type of fixtures were also thus be one element of observation (FDA, 2020). The position of the lights was also observed as it also dictates if light is spilled in unwanted directions, resulting in glare, non-uniform light patterns, upward-reflected light and wasted energy (Lechner and Arns, 2013).

For the focus of our study. It holds multiple small observational studies to fulfill how the existing light design, color of lighting and the arrangement of lighting effects play a key role in activities and cognition. In the time of observation, taking a record of the current state of lighting, by taking pictures of the arrangement of light practice in Bole sub-city. Our research observed the current lighting designs and additional factors in the area of light pollution anticipated areas in Bole sub-city in the time frame of measurement record which is similar to the date of measurement taken from April 3-12, May 2-11, June 1-10 and June 30- July 9 of 2021. The surrounding of buildings light source and advertisement light were included for the observation and it involves one and half one-hour sessions to see how concentrated are existing light under different lighting type and color temperatures consideration.



Figure 7. Picture on bortle scale

Source: Bortle Dark-Sky Scale by Skyglowproject

The above figure is comparison image that helped to identify the sky brightness level according to Bortle measurement scale. Notes was taken concerning what were observed immediately after each session.

3.2.3 Methods on awareness and management of light pollution

3.2.3.1 Study design

To assess awareness and management practices among purposively selected relevant organizations and vulnerable dwellers in Bole, Addis Ababa.

3.2.3.2 Populations and sampling procedures

Among the eleven sub-cities in Addis Ababa, Bole sub-city was purposively selected considering the level of light access distribution. The sub-city is known to be relatively urbanized with a night vision covered with very high light emission and according to the world light pollution map (Fig 2) the area is clearly indicated as light pollution risk area (World light pollution map,

2021). Vulnerable dwellers and respondents in relevant government organizations which are directly or indirectly responsible with environment pollution were also purposively selected.

For the data collection process from governmental organizations, staffs working related to environment was included for the awareness and management assessment, it was ensured that key informants currently working on pollution including department heads are included. In EFCCC two main departments who are responsible in pollution control were targeted which are Environmental Pollution Monitoring Directorate and Solid and Hazardous Waste Compliance and Control Directorate and for EPGDC three main departments were focused the first department is Energy Technology Expansion Team, the second is Energy Technology Promotion and Dissemination Unit and the third one is Environmental Pollution and Climate Change Directorate.

3.2.3.3 Sample size determination

Sample size was determined according to Yemane, (1967) simplified formula as follows:

$$n = \frac{N}{1 + N(e)^2}$$

(Yemane, 1967).

Where n is the sample size, N is the population size, and e is the level of precision.

Using the principle of (Fowler, 2009) stated as *"For a population, the level of precision increases steadily up to sample sizes of 150 to 200. After that point there is much more modest gain to increasing sample size."* Accordingly, this research selected a total of 150 sample size out of the total population size of Bole Sub-City dwellers. Furthermore, 10 percent (15) of the sample respondents were taken as contingency in order to achieve a high response rate and assure the representativeness of the sample keeping in mind the reasons for survey failure thus total sample size for dwellers is 165.

Number of populations of interest which are susceptible surrounding dwellers and government staff of study organizations are described in the Table below (Table 1).

Name of Government Organizations	Description	No. of population
Environmental Protection and Green Development Commission (EPGDC)	Responsible to ensure the societies safety and protect from any environmental negative consequence.	605
Environmental Forest and Climate Change Commission (EFCCC)	Major responsibility on policy formulation regarding on environment	370
Total Number of Population for (EPGDC and EFCCC)		975
Dwellers on areas exposed to light pollution sample size	High vulnerability to the effect of light pollution	165

Table 2. Number of study population

Accordingly,

$$n = \frac{(605+370)}{1+975(0.05)^2} = \frac{975}{3.43} = 284.2 \approx 284$$

The total sample size computed were thus 449 respondents. Consequently, 176 respondents were selected from Environmental Protection and Green Development Commission (EPGDC), 108 respondents from Environmental Forest and Climate Change Commission (EFCCC), 165 respondents from dwellers on areas exposed to light pollution proportional to size of population in each group.

3.2.1.4. Method of data collection

Data were collected through sky brightness measurement digital technique, observation, and survey questionnaire. For the purpose of improving quality for analysis, this triangulation approach was important to obtain information from different data sources. The details given in the observation were verified by cross-checking with the measurement of sky brightness. The data collection methods which were used are described as follows:

Survey questionnaire

The questionnaire was designed to assess the awareness among the area inhabitants and the awareness and practice of the concerned governmental bodies about light pollution. Considering relative heterogeneity of respondents, i.e., respondents who are vulnerable to the effect of light pollution and from government offices controlling and monitoring environmental threats; similar as well as specific questions related to awareness were asked to the groups while practical management related questions were developed for respondents from the government organizations. Data on socio-demographic factors of the respondents as well as questions related to awareness level related to different factors concerning light pollution including knowledge, perception of risk as well as management and control practices including consideration of light pollution on current practice and policy formulations like design of infrastructure facilities; consideration of less light pollutant materials and fixing of light fitting materials; and willingness to change the current routine development trend by considering light pollution and related data were collected.

3.3. Method of data analysis

Data were analyzed using Statistical Packages for Social Sciences (SPSS) for statistical analysis. Descriptive summary was employed for describing characteristics of study participants for relevant study variables. The analysis of the collected outcome data was based on both simple descriptive statistics (such as frequency and percentage) and elaborative cross-tabulation associative techniques. For sky brightness measurement, after getting the value of sky brightness measurement conversion from naked eye limiting magnitude (NELM) to magnitudes per squared arc second (mag/arcsec^2), was implemented and the results were also compared to the Bortle (2001) classification scale, which has nine levels, with class 1 being the best on Earth's surface and class 9 being a strongly light-polluted region. Class 3 corresponds to a NELM value of 6.6 to 7.0 (rural sky); class 4 corresponds to a NELM value of 6.1 to 6.5 (rural/ suburban transition); and class 5 corresponds to a NELM value of 5.6 to 6.0 (rural/ suburban transition) (suburban sky). Class 9 corresponds to a NELM value of 4. (inner-city sky).

3.4. Ethical considerations

Ethical approval was obtained from the research ethics committee of the department of Environmental and Sustainable Development and Institutional Review Board of the College of Development Studies, Addis Ababa University. The purpose of the study was explained to the study subjects and participation was on voluntary basis. Participant was informed that participating in the study was based on voluntary and as refusal to participate would be possible. Study participants were clearly informed that they can withdraw from the study at any time if they need to do so. The right of each respondent to refuse or answer for few or all questions was respected. Names of study participants were not mentioned in the study report to ensure confidentiality. The data was collected according to the recommended institutional research ethics and guideline. In general, the study was conducted according to AAU ethical policy.

Chapter Four

Result and Discussion

4.1 Magnitude of light pollution in Bole sub-city

As nighttime brightness increases globally, well-distributed data collection is required to analyze its impact and determine the thresholds between beneficial to damaging impacts of lighting. In this study, we evaluate urban night lights within Bole the city of Addis Ababa. Ground measurements were carried out within the city open area using loss of the night software and change it to sky quality sky measurement. Loss of the night is recognized by International Dark-Sky Association which is founded to create awareness and works for light pollution. As per the IDA listed data collection information given this research covers from April 3-12, May 2-11, June 1-10 and June 30- July 9 of 2021.

As Figure 8 depicts the measurement the average value of NELM value 5.17 which converted using the formula $21.58 - 5 \log(10^{(1.586 - \text{NELM}/5)} - 1)$ get to amount of 19.54 mag/arcsec². Figure 13 monthly measurement result shows that the average value of 19.54 resided in the Bortle scale classification of 5 this refer the color is nearly orange and the Milky Way is very weak or invisible near the horizon and looks washed out overhead, light sources visible in most, clouds are noticeably brighter than the sky.

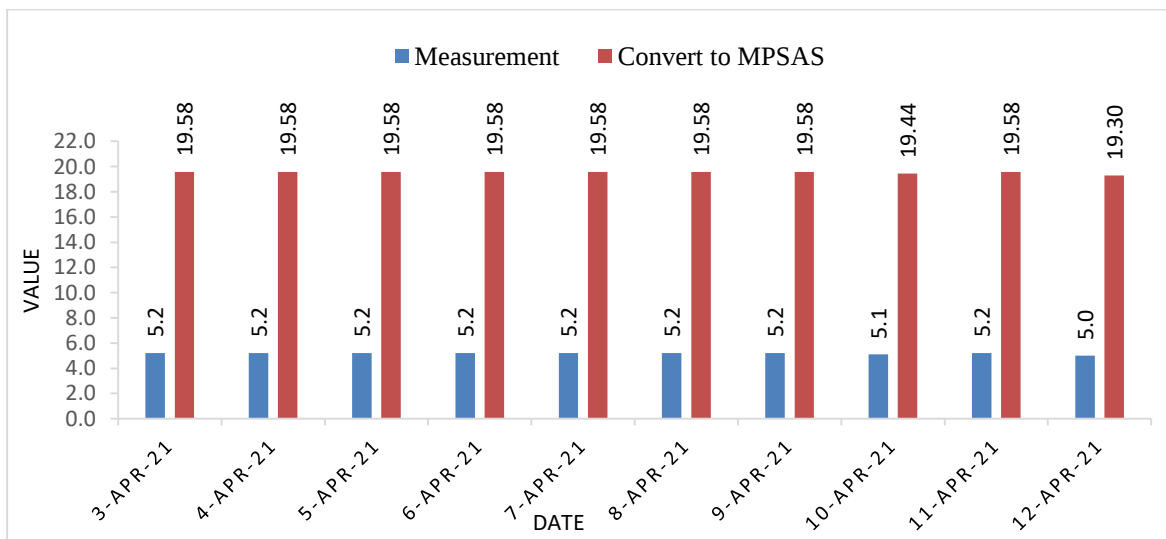


Figure 8. Measurement from April 3-April 12

The measurement in Figure 8 chart shows that the average value of NELM value 5.16 which converted by using the formula $21.58 - 5 \log(10^{(1.586 - \text{NELM}/5)} - 1)$ get a value of 19.52 mag/arcsec². On the above reading May 4,2021 there was foggy cloud weather which has negative effect on the reading and lower the quality of reading process for that reason no reading was taken. The measured value for month of May the average value of 19.52 resided in the Bortle scale classification of 5 this refer the color is nearly orange and the Milky Way is very weak or invisible near the horizon and looks washed out overhead, light sources visible in most, clouds are noticeably brighter than the sky.

Values of 21.3 and greater (darker) fall within "natural" skies (Bortle Class 1-3), 19.5-21.3 considered significantly degraded skies (Bortle Class 4-6), while values less than 19.5 may be considered severely degraded (Bortle Class 7-9). Hence in our research case the average measurement value on April which is 19.54 and May's measurement value 19.52 resided in significantly degraded skies.

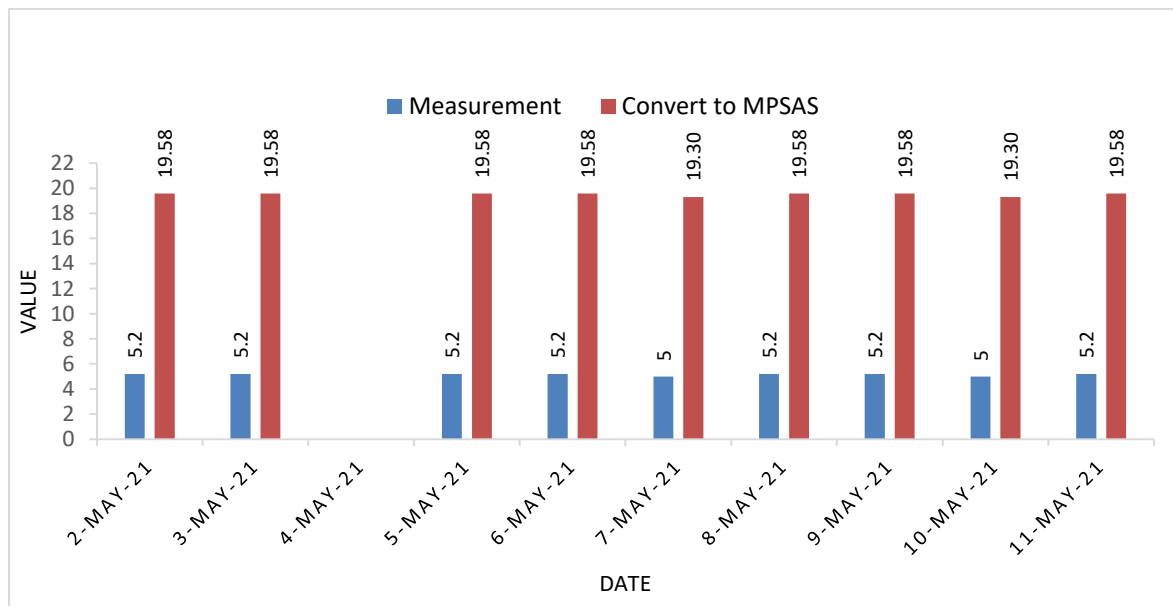


Figure 9. Measurement from May 2- May 11

In the Figure 9 chart measurements, the average value of NELM value 5.14 which converted in to amount of 19.49 mag/arcsec². Like the previous reading on June 3,2021 and June 8, 2021 there was foggy cloud weather which has negative effect on the reading and lower the quality of reading process for that reason no reading was taken. Similarly, the measured value for month of June the average value of 19.49 resided in the Bortle scale classification of 5 this refer the color is nearly orange and the Milky Way is very weak or invisible near the horizon and looks washed out overhead, light sources visible in most, clouds are noticeably brighter than the sky.

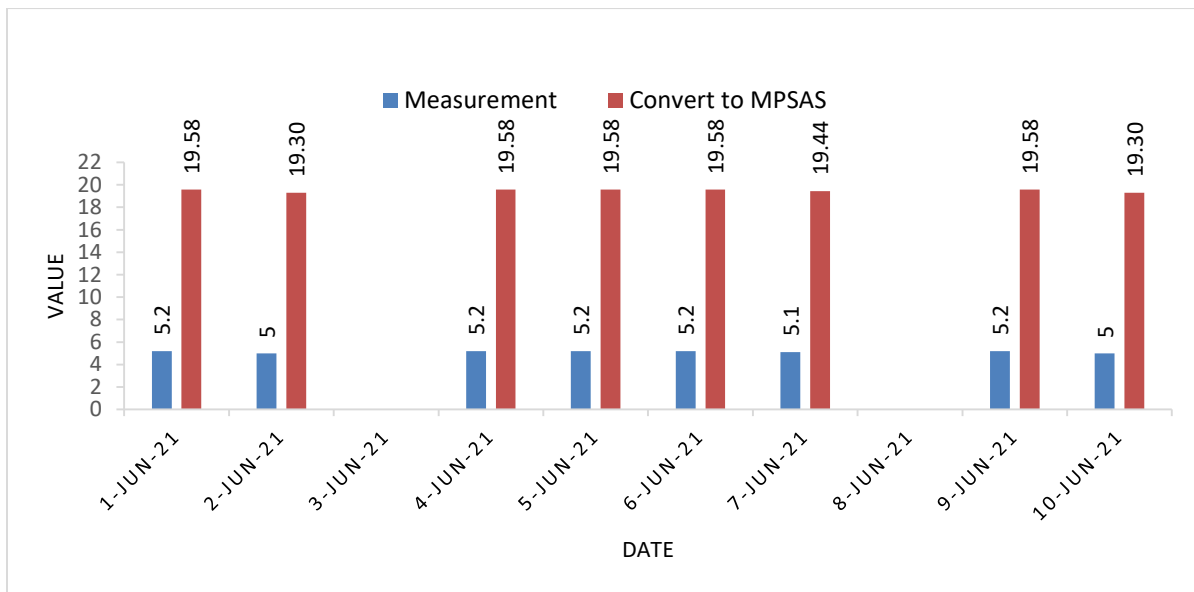


Figure 10. Measurement from June 1- June 10

As Figure 10 chart measurement illustrations, the average value of NELM value 5.13 which converted in to amount of 19.48 mag/arcsec². Like the previous reading on July 3,2021, July 6, 2021 and July 8, 2021 there was foggy cloud weather which has negative effect on the reading and lower the quality of reading process for that reason no reading was taken. The measured value for month of June/July the average value of 19.48 also resided in the Bortle scale classification of 5 this refer the color is nearly orange and the Milky Way is very weak or invisible near the horizon and looks washed out overhead, light sources visible in most, clouds are noticeably brighter than the sky

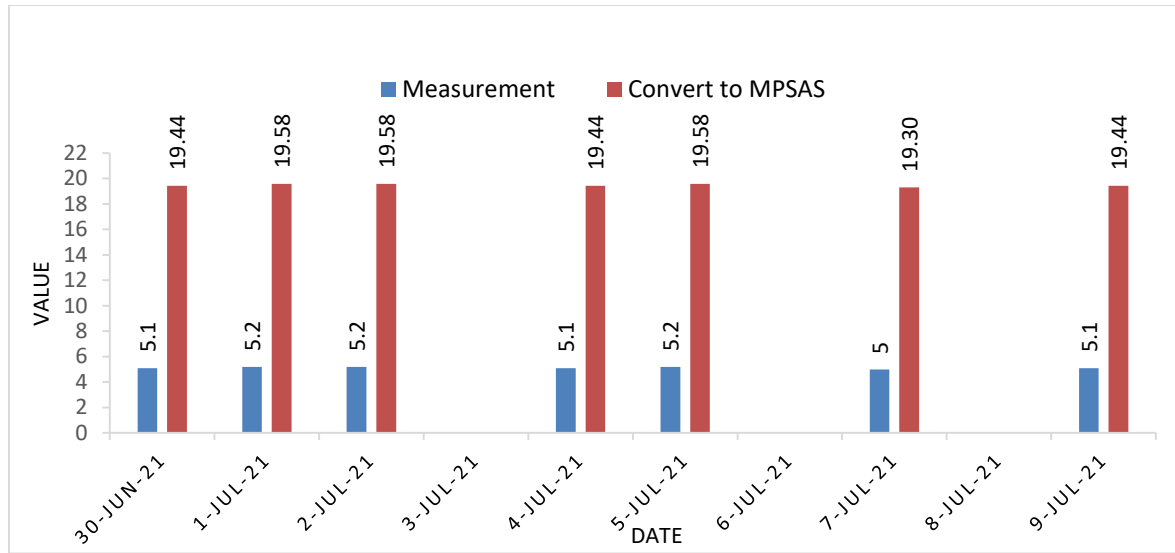


Figure 11. Measurement from June 30- July 9

The measurement result of our study revealed that the average value of current Addis Ababa City, Bole area sky brightness is $(19.54+19.52+19.49+19.48) = 19.51 \text{ mag/arcsec}^2$. Which make Bole, Addis Ababa suburban sky according to the Bortle classification scale in a range of class 5 this means the milky way very faint or invisible near the horizon and washed out overhead, light source visible in most directions, clouds are noticeably brighter than the sky.

Similar to our findings a study conducted in Italy present the implementation of a monitoring network for artificial light at night (ALAN), in seven locations of the Veneto region. The study presents the results of some elaborations for the 2018 dataset for seven monitoring sites. The result for this research is as shown.

Monthly sky brightness value (mag/arcsec^2) of different places of Veneto region in Italy (Bertolo *et al.*, 2019). From this research finding the annual night sky brightness value varied from 18.0 to 21.3 mag/arcsec^2 , confirming great variability of light pollution depending on the place and urbanization activates. And according to Bortle scale Passo Valles, Cima Ekar, Monte Baldo and Pennar having 21.3, 20.9, 20.7 and 20.8 mag/arcsec^2 average value respectively between April to July exist in the range of Rural/suburban transition with class 4, whereas Montebello, Nove and Padova with sky brightness average value of 19.7, 19.6 and 18 mag/arcsec^2 respectively like in this study Bole area it belongs in a range of Suburban sky with class 5.

Likewise, a study conducted in Malaysia, Selangor observatory a ground-based measurement of night sky brightness detector was performed. The study was performed from May to October 2018. The results show that it has a night sky within Bortle scale Class 4 to 5 based on average value of 20.04 mag/arcsec². During the measurement period, the maximum recorded value is 21.1 mag/arcsec² and 21.03 mag/arcsec² in average (Ngadiman *et al.*, 2021). .

The above two researcher's conducted in Italy and Malaysia main objective is to inspect suitable place for selection of astrological observatory places and the results are more of class 5 and 4 which is similar to our research findings and this show that Bole, Addis Ababa are on the boarder side which does not mean that results are useless for measurements of skies darker more than 20.49 mag/arcsec², it just means that they need be interpreted with caution. For example, such observations are valuable in the context of a long-term monitoring and estimation. Observations taken at the same time in multiple years can also be compared in the context of a long-term observing.

However, a study conducted in Rzeszów, Poland presents measurement results for the years 2015 and 2018, from which it is clear that the quality of the night sky has been declined in terms of the finding. As an example, the numerical value of the measurement for the center of Rzeszów has been taken. In 2015, this value was 18.70 mag/arcsec², while in 2018, it was equal to 16.73 mag/arcsec² which makes Rzeszów in a range of Bortle class 9 and light polluted area. The results obtained shows increasing light pollution of the night sky. Additionally, in neighboring villages have also experienced a change in the sky quality from Bortle Class 5 to Class 7 with in three-year period (Wesołowski, 2019).

The results of measurements presented in Poland research is clearly demonstrate that the surface brightness of the night sky in Rzeszów and its surrounding area has greatly increased during three-year period of time. No doubt, the sky light pollution has a huge impact on the visibility of astronomical objects in the night sky and the Poland is starting to face the down side of this drastically change.

When it comes to most bright cities for instance Portugal a data collected based on Bortle scale shows that measurements of the sky brightness undertaken in selected locations inside the city of Porto (northern Portugal) and Peneda-Gerês National Park (PNPG) and Alqueva which

conducted on various times, giving values ranging from 17.63 mag/ arcsec² (NELM of 3.65) to 18.01 mag/arcsec² (NELM of 3.97), and the result corresponding to class 9 on the Bortle scale (Lima *et al.*, 2016).

Unlike to our study result a sky brightness measurement conducted in Berlin, Germany, indicated that the luminance of the artificial night-time sky light reduced during COVID-19 lockdown, with a value of (21.5 mag/arcsec²) in 2017 and (21.7 mag/arcsec²) in 2020. A brightness of (21.6 mag/arcsec²) was measured in another part of the city in 2017, while a value of (21.8 mag/arcsec²) was measured in 2020 (Jechow & Hölker, 2020). Similar to Germany Result a study conducted in Australia night sky brightness as a function of distance from the Perth central business district (CBD) is 21.8 mag arcsec². The result of 21.8 mag arcsec², was located towards the end of the eastern track and the north track was 21.6 mag arcsec² (Biggs *et al.*, 2012).

Supporting the previous study another study focused on the world atlas of artificial sky luminance, which was computed using light pollution propagation software and new high-resolution satellite data and precision sky brightness measurements identifies among the G20 countries Germany and Australia are the least polluted (Falchi *et al.*, 2016).

Comparable to our study a research conducted in Burkina Faso, light pollution has increased by 20% in big cities such as Ouagadougou. In the heart of Ouagadougou, only the brightest stars and planets can be seen with the naked eye. Light pollution hampered the advancement of space science for health and the environment (Kam *et al.*, 2020).

The brightness values measured in the Germany and Australia region for clear sky conditions is very low and when we compare the data with our countries measured and Burkina Faso findings considering the developmental standard Germany and Australia are very developed country with a probability of higher artificial light exercise however due to the country rigorous rule and regulation practices the country manage to lower the level of light pollution.

Multiple factors contribute to the level of sky glow (light pollution) produced in any location, and the level likely changes with the combination of those factors. A related consideration is that street and advertisement lighting is one of many sources of light at night in urban areas. The findings in this study consequently represent only the estimated contributions to sky glow from

the street and advertisement lighting system under the conditions considered, and may address the primary sources of sky glow contribution in locations like urban areas.

In this research, the city of Addis Ababa especially in Bole sub-city have adopted a tendency to transfer from the up-to-now, high-pressure, and non-shielded, sodium vapour lamps (with a high polluting level, due to the not being covered factor), and LEDs with blue/white color bulbs with a higher health and environmental impact due to their warm color. Although most of the literature and reports share a common view agreeing that white/blue light is the most harmful light (Behar-Cohen *et al.*, 2011) thus affecting negatively both humans, animals, plants, and virtually all imaginable ecosystems exposed to it.

In the current urbanization transformation endeavors LED lightings have replaced the traditional high-pressure, however, there are neither specifics nor information on the kind of LEDs used by their respective organizations. White LED lights have five times greater impact on circadian rhythms than conventional street lamps (Hobkirk, 2020) and white LED lamps have the potential to increase the impacts of light pollution dramatically (Pawson and Bader, 2014) meaning that the possible outcome with the newest implemented solution -white/blue LEDs- causes greater damage on humankind and the environment than the already or soon-to-be-replaced high-pressure sodium vapor lamps.

In the current situation of Bole sub-city, Addis Ababa there are practices that most rapidly increase light pollution environmental degradation. According to our observation several damaging practices have been defined: there is no use of shielding on lighting fixture to prevent direct upward light, particularly at low angles above the horizon; there is over lighting, i.e. using higher lighting levels than strictly needed for the task, no constraining illumination to the area where it is needed and the time it will be used.

Limiting the number of light sources is one of the measures listed by the International Dark-Sky Association (2015) for reducing the detrimental impacts of light pollution. According to our findings, the number of light sources is the most important factor contributing to light pollution among the light characteristics considered.

Fixture designs and practical preventative measures, have an impact on how much artificial light is available locally at night. Within the city, both appropriate and ineffective lighting fixtures were discovered. Because the city of Bole, Addis Ababa has seen such a wide range of fixture types, comparable results may be drawn in other places. According to the findings of this research, there is a problem in urban area with obsolete, uncontrolled infrastructure. The US National Park Service estimates that nearly half of the light from outside structures is wasted because it is focused upward (Chepesiuk, 2009). Only 40% of the time is the right target. Glare is created by the remaining 10%. Because of poor infrastructure, 60–70% of the energy utilized for outdoor lighting is wasted. When we come to Bole, Addis Ababa city for our observation, we found it to be true.

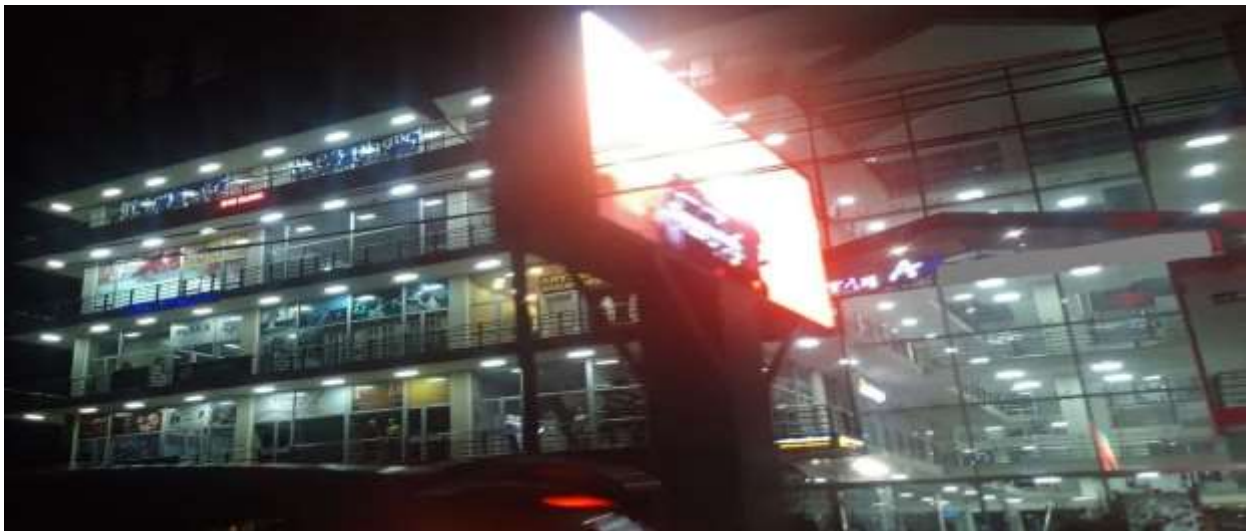


Figure 12. Excessive number of light used more than required



Figure 13. Extreme illumination of light for advertisement

Fully shielded lighting is crucial, however the color of the light is also important. The color temperature of lights in the city was also evaluated, as white LED lighting emits high amounts of potentially dangerous blue light, which harms human health and puts wildlife in danger. Lower color temperatures have less blue in their spectrum, according to IDA, and are referred to as "warm" lighting. Blue light is predominant in higher color temperature light sources. As a result, according to our research, the majority of the city lights in Bole, Addis Ababa are LED lights with white and blue color temperatures, while there are certain sites that utilize warm color temperature lighting.



Figure 14. Market lights fittings considering shield protection and excessive glare energy waste



Figure 15. LED blue and white light source



Figure 16. LED blue and white light and excessive source

From the Figure 17 we can observe that the value we get from measurement having a Bortle scale value of 5 is nearly similar to the night brightness of the sky picture taken. Figure 17 result shows that we are in the scale of 5 which implies light pollution will be visible in most and only hints of the zodiacal light are seen on the best spring and autumn nights. The Milky Way is very weak or invisible near the horizon and looks rather washed out overhead. Light sources are evident in most if not all directions. Over most or all of the sky, clouds are quite noticeably brighter than the sky itself.

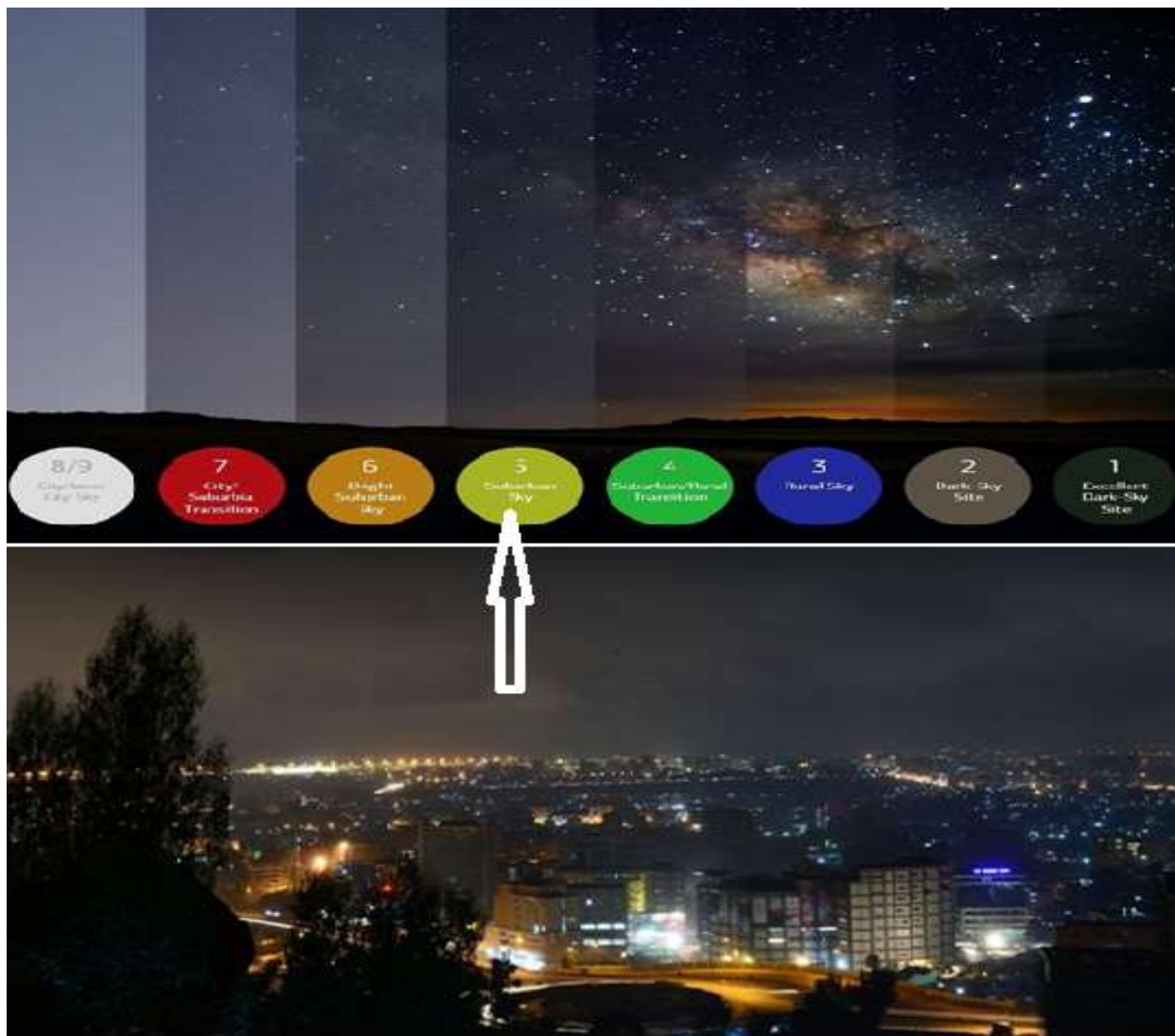


Figure 17. Comparison of Addis Ababa sky brightness with the Bortle scale classification

Source- TomDe Motz

According to (IDA) and illuminating engineering society which serves as a set of standards for preventing light pollution outdoor lighting that is properly protected should be utilized at all times, according to the requirements (Joint, 2010). It also recommends that outdoor light fixtures include a control device or system that switches off the light automatically when sufficient daylight is available. Furthermore, the different types of fixtures used in outdoor lighting, both good and harmful, in order to minimize the consequences of light pollution. Some of them conserve energy, direct light where it's required, and enhance the ambiance of our nighttime environment. However, in our observation finding light fixtures are waste energy, spill light in all directions, produce glare, and ruin the beauty of the night.

Similar to our findings a study conducted in Beijing, China focusing on evaluating light pollution in residential zones states that although Beijing's lighting project has brought some economic benefits, and it has created a series of new landscapes there are problems in the selection of light sources, their layout, and so on. Excessive pursuit of economic benefits, blind comparisons of brightness, a lack of scientific guidance, and lack of attention for human wellbeing have all contributed to light pollution in Beijing, resulting in a significant waste of energy, harm to civilians, and demonstrating the legislative system's vulnerability (Jin *et al.*, 2017).

Likewise, the Korean government spent a period of 4 years, assessing all possible actions to prevent light pollution caused by excessive artificial lighting. As a result, the prevention act observed a number of light radiating from advertisement boards, streetlights, etc., trespassing into people's homes at night and disrupting their sleep patterns. This shows that the levels of artificial lighting are not equally rigorous in all areas (Lim *et al.*, 2018).

Unlike to our study a study conducted in America almost all lighting on the Island of Kauai is fully shielded, despite there being no observatories on that island. In terms of shielding and spectral energy distribution, the lighting requirements for preserving endangered species and protecting observatories are aligned (Green *et al.*, 2022). Lighting ordinance did require full shielding of all lights (Luginbuhl *et al.*, 2009). One of the most significant techniques for conserving the night sky is complete shielding of light sources. Light that is aimed at small angles above the horizontal is very harmful. All artificial light sources on the island of Hawaii are fully shielded and emit no light above the horizontal plane.

4.2 Survey data analysis

Out of the total 449, survey questionnaires distributed, 9 questionnaires which is 2.04% were not responded. 440 questionnaires were considered for analysis of the study. The questionnaires collected from the respondents were entered and analyzed using SPSS and the results of the data analyses that consists of frequency and cross tabulation.

Table 3. Educational status of Respondent

Level of education	Frequency
High School	56
Undergraduate	308
Masters	76
Total	440

Table 3 indicates that the sample mainly comprises of education level that hold Undergraduate (n= 308 or 70%), followed by respondents that hold Master's Degree (n=76 or 17.2%) and by respondents that hold high school certificate (n=56 or 12.8%). The result indicates that undergraduate and above respondents holds (n=384 or 87.2%) qualified personnel have an ability to identify and evaluate easily what is happening in the community residential area in a knowledgeable manner.

Relevant stakeholders and dwellers awareness on light pollution

First, it is important to know about the basic concept and definition of light pollution and my survey. Light pollution is known as excessive, misdirected, or obstructive artificial light which is usually outdoor. Light pollution is the presence of anthropogenic and artificial light in the night environment, but even carefully used light fundamentally alters natural conditions also. The major side to know is the effect of urbanization. This is also blamed from compromising health, disrupting ecosystems, and also spoiling esthetic environments. Light pollution has also a side effect of industrial civilization. Even sources of light pollution are important to be known such as building exterior and interior lighting, advertising, and outdoor lighting such as car parks, offices, factories, streetlight such, and illuminated sporting venues.

Table 4. depicts the accessibility of light which has direct relationship with light pollution vulnerability. As clearly seen from the table out of total 440 respondents from governmental institutions only (n=8 or 2.8%) get no enough street light and none form vulnerable dwellers whereas (n=270 or 97.1%) and dwellers (n=162 or 100%) which has access to street light and it is one of many sources of light at night in urban areas which makes it a major input for cause of light pollution and this makes 98.3 % of the respondent can experience the effect of light pollution.

Table 4. Presence of street lighting in the surrounding

Question	Category	Frequency of responses		
		Yes	No	Total
Do you have street lighting in your town?	EFCCC	103	2	105
	EPGDC	167	6	173
	Total	270	8	278
	Vulnerable Society			
	Dwellers	162	0	162
	Total	162	0	162

Table 5. indicates that ability to identify and evaluate easily what is happening in the community residential area out of a total of 440 respondents (24 high school certificate, 163 undergraduates and 39 master's level) said the street light is on all night long and no part night lighting. On the other hand, (5 high school certificate, 52 undergraduates and 24 master's level) respondent said there is timing switch which turn off after some hour and the remaining (27 high school certificate, 94 undergraduates and 12 master's level) said that they have no idea about light timing.

Table 5. Period of street/advertisement lighting

Question	Category	Frequency of responses			
		Yes	No	I am not sure	Total
Are your street lights on all night (dusk to dawn) or no operate on a timing switch (part night lighting)?	High Schools	24	5	27	56
	Undergraduate	163	52	94	309
	Master's	39	24	12	75
	Total	226	81	133	440

Too much outdoor lighting used at night is inefficient, overly bright, poorly targeted, improperly shielded, and, in many cases, completely unnecessary and let to be exposed to the pollution effect (IDA). In total of respondent (n=226 or 51.36%) street light is turned on all night long this makes half of the respondent is facing the effect and the other (n=133 or 30.2%) answered they don't know about the light timing and the rest said (n=81 or 18.41%) that they notice that it is controlled on a scheduled timing.

In the Table 5 findings we can articulate a higher level of vigilant attention toward lighting of the surrounding area as a result light pollution is associated with limitation of the duration of lighting and when events appear to be random, literate people looking for explanations, including experts in their fields, have a tendency to see meaning. When the higher the literacy rates the probability of being vigilant to the surrounding will also increase, this highly displayed in our finding that in total of 69.7% respondent most of higher educational level pay enough attention on the period of street lighting which is the main cause of light pollution.

From Table 6. we can easily understand that the respondents were asked that if they heard about light pollution in government organization which is in Environmental Forest and Climate Change Commission and from Addis Ababa Environmental Protection Authority (EPGDC) In total of governmental institution of (n=221 or 79.4%) whereas with in dwellers (n=146 or 90 %) never heard about light pollution.

Table 6. Knowledge about light pollution

Question	Category	Frequency of responses		
		Yes	No	Total
Have you heard about light pollution?	EFCCC	21	84	105
	EPGDC	36	137	173
	Total	57	221	278
	Vulnerable Society			
	Dwellers	16	146	162
	Total	16	146	162

According to Lyytimäki *et al.*, (2012), research stated that environmental information's unintentionally left with insufficient attention or purposefully neglected. The reasons for this lack of recognition are recognized, false awareness, deliberate unawareness and concealed awareness. In a similar way, from the total respondents of 81.0 % percent never heard about light pollution and 18.9% percent heard about the subject. we can see a broad consensus from Table 6 that there is a problematic and general unawareness of the problem. More than two-thirds of the respondents have never heard about night light of light pollution by the fact that people are not aware

Similarly, a study conducted in Lima, Peru aimed to measure the level of knowledge of the light pollution, data collected revealed that only 4% of those interviewed had a good understanding of what light pollution is, while 20% had a medium understanding and a high 76 % of persons interviewed had a poor understanding about light pollution (Grijalva-Salazar *et al.*, 2020).

Table 7 indicates awareness of the cause of light pollution in governmental institutions respondents (n=211 or 75.89%) answered and dwellers (n=162 or 100%) responds that no perception about the cause and on the other hand, n= 67 or 24.1 % of the respondents from government institution responded they are aware of artificial light source as a cause of light pollution. Lighting is experienced as natural, and darkness as unnatural and unpleasant, even dangerous. streets, parking lots, parks, squares and other areas without bright lighting are therefore usually taken unsafe (Koskela and Pain, 2000). This easily increases demands for

stronger brightness although it is the main cause of light pollution. In this research more than 80% of respondent are unaware of the cause of light pollution.

Table 7. Understanding the causes of light pollution

Question	Category	Frequency of responses		
		Yes	No	Total
Are you aware of the causes of light pollution?	EFCCC	26	79	105
	EPGDC	41	132	173
	Total	67	211	278
	Vulnerable Society			
	Dwellers	0	162	162
	Total	0	162	162

Similar to our findings a study conducted in Korea empirically analyzed with high risk perception of light pollution causes and type compared to the group with low-risk perception, the risk perception group classification criteria gave: for light trespass, group included low-risk perception (61.7 %), and (38.3 %) high-risk perception. For over-illumination, the low-risk perception group included (60.4 %), and the high-risk perception group included (39.6 %). For glare, the low-risk perception group included (34.4 %), and the high-risk perception group included (65.6 %). For sky glow, the low-risk perception group included (34.6 %), and the high-risk perception group included (65.4 %) (Kim et al., 2015). In total an average value of 52.22% of the respondent is in a range of low perception about the cause of light pollution while 47.77% of the respondent have knowhow about the cause of the incident.

Unlike experts, naturally the public is known to perceive risk based on personal knowledge and experience. However, this study also showed that the perception of the respondent on cause of light pollution was significantly very low. Public perception about relevant causes of light pollution and its effective is critical to understand the way the public thinks and feels. In addition, the analyses indicated that level showing the acquisition of information of the public is very low.

The question was distributed to respondents on the Table 8, to identify if they know about light pollution health problems, and those government institutions respondents (n=112 or 40.28 %) and dwellers responds (n=19 or 11.72%) answered yes and since this question is an open end

questionnaire in which the research gave an opportunity to the respondents in order to express their opinion the respondents mention how it can damage to eye vision. The other (n=166 or 59.71%) of the government institutions and dwellers (n=143 or 88.2%) respondents have no knowhow about health case to express their opinion about the problem. Especially respondents who are very susceptible to artificial light in our case dwellers with respect to their respondent number respondent not aware to health effects of light pollution.

Table 8. Awareness of light pollution significant health problem

Question	Category	Frequency of responses		
		Yes	No	Total
Do you know light pollution cause significant health problem?	EFCCC	44	61	105
	EPGDC	68	105	173
	Total	112	166	178
	Vulnerable Society			
	Dwellers	19	143	162
	Total	19	143	162

The current results resonate these findings that a study conducted among college students in India about 22% of the students have told that light pollution is causing injurious to health but 68% has been voted for no and 10% of the students did not have any idea (Vasishta *et al.*, 2019). And another study conducted in Barcelona among people living in large Catalan cities and towns asked the reason the care about environmental issues (light pollution) the great majority of respondents asserted that it was because it affected human lives -40.7%, raising concerns either about their health or their communities -16.7% (Hobkirk, 2020). This study and other conducted researches based on the existing technological and scientific research papers indicates that citizens have seemingly been undergoing a set of poorly-addressed and insufficient artificial lighting awareness continually endangering their health and optimal well-being.

Table 9 depicts that out of the total respondents (n=104 or 37.41 %) from government institutions and dwellers respondents (n=17 or 10.49%) believe that light pollution has effect on nature and respondents from government institution which accounts (n=174 or 62.59 %) and dwellers (n=145 or 89.5%) believe that nature will not face significant problem due to exposure to light

pollution. As we can see from this result higher number in vulnerable society awareness about light pollution is low when we compare to governmental institutions.

Table 9. Awareness of light pollution problem to nature

Question	Category	Frequency of responses		
		Yes	No	Total
Do you know light pollution cause significant problem to nature?	EFCCC	45	60	105
	EPGDC	59	114	173
	Total	104	174	278
	Vulnerable Society			
	Dwellers	17	145	162
	Total	17	145	162

Unlike this research finding a study conducted on college students in India indicated that 73% of them are aware that light pollution does cause harm to the nature and only 20% has told it is not harmful (Vasishta *et al.*, 2019). Related to Indian finding a study conducted in Germany also indicate that over 90% of all respondents agreed that the negative effects of lighting on animals and ecosystems are important or very important reasons to tackle the problem (Schulte-Römer *et al.*, 2019).

Our findings show that on negative non-visual effects of artificial light at night on ecosystems that institutional employees and dwellers approaches were useful in gaining insight into public of man-made lighting effect. Further, this study indicates that there were low perceptions of the presence and impact of light pollution. While other countries like India and Germany research showed that the on the condition that respondent have significant understanding about the effect of light pollution on nature.

As Table 10 reveals the respondents requested whether they avoid unnecessary use of light has shown the following, some 310 (or 70.4%) of the respondents avoid unnecessary light and the rest of respondents (n=130 or 29.6 %) said that they do not avoid unnecessary use of light.

Table 10. Avoiding the unnecessary use of lights

Question	Level of education	Frequency of responses		
		Yes	No	Total
I always avoid the unnecessary use of lights?	High School	48	8	56
	Undergraduate	218	90	308
	Masters	44	32	76
	Total	310	130	440

A study conducted on Oklahoma State University indicates that approximately 50% of the visitors to the national parks were willing to contribute something to preserve dark skies and support to maximize the light pollution measurements (Mitchell *et al.*, 2008). And another study in New York among students in the Rochester Institute of Technology community indicate that students were willing to contribute approximately the same amount for the small light pollution improvement as they were willing to contribute for the prevention of the worsening of the light pollution by the same amount (Simpson , 2007). Even though this studies show the willingness to contribute for the idea of light pollution this indirectly shows that they are willing to take action against any factor that can aggravate the effect of light pollution and both this studies and our study shows an average of half or more than half percent of the people is willing to avoid unnecessary use.

In addition to the negative ecological and health effect of light pollution Reducing energy consumption and avoiding unnecessary utilization of lighting systems is very crucial for the reason that power cannot be stored completely which is produced, hence arise a need to make efficient utilization of power by avoiding unnecessary light usage (Mohandas et al., 2019). There are numerous things to consider when it comes to lighting systems, including power consumption and power use. The economy of a country is influenced by its lighting system, which is especially relevant in developing countries where street lighting is widely used and to save energy as individual and national level is simply turning off lights is a start.

From Table 11, we can easily understand that the respondents are concerned about in Addis Ababa's a light pollution situation, totally (n=174 or 62.59%) of the respondents from government institution and (n=30 or 18.51%) of dwellers respondents express that they are concerned, whereas (n=104 or 37.41%) from government institution and (n=132 or 81.48%) from dwellers answered they are concerned about light pollution. In this survey governmental institutions respondents higher number responded that the light pollution concerned them while society vulnerable groups who are exposed for excessive building artificial light and advertising light in their day to day activity replied not concerned about the issue.

Table 11. Concern of light pollution in Addis Ababa

Question	Category	Frequency of responses		
		Yes	No	Total
Do levels of light pollution in Addis Ababa concerns you?	EFCCC	54	51	105
	EPGDC	120	53	173
	Total	174	104	278
	Vulnerable Society			
	Dwellers	30	132	162
	Total	30	132	162

According to IDA, concern about light pollution is rising dramatically in developed countries, an increasing number of scientists, homeowners, environmental groups and civic leaders are taking action to restore the natural night. Unlike to this higher number of vulnerable dwellers respondent in our case are not concerned and lower number of respondent are concerned about Light Pollution. On the other side environmental government organizations are concerned about light pollution in Addis Ababa which shows positive attitude of the organization. However inevitable amount of respondents is not concerned which this shows additional efforts are needed on creating awareness.

On the Table 12, the respondents had been requested whether light pollution is reversible/correctable, and (n=9 or 3.23%) from governmental institution and none dwellers respondents said that it is reversible and the other respondents (n=77 or 27.69%) from governmental institution and (n=24 or 14.81%) dwellers respondents said that light pollution is not reversible

the rest (n=192 or 69.0%) from government institution and dwellers (n=138 or 85.18%) of the respondents do not have any idea about the reversibility.

Table 12. Reversability/correctability of light pollution

Question	Category	Frequency of responses			
		Yes	No	I don't know	Total
Do you think light pollution is reversible/correctable?	EFCCC	0	34	62	105
	EPGDC	9	43	130	173
	Total	9	77	192	278
	Vulnerable Society				
	Dwellers	0	24	138	162
	Total	0	24	138	162

Different from our findings a study conducted in India among college students show that about 67% thinks light pollution is reversible and other 10% strongly say that it is not reversible and 23% do not have any idea about the correct ability of LP (Vasishta *et al.*, 2019). Unlike this study our result shows that from the total respondent's answer (n=207 or 71.1%) have no knowhow about the probability of reversing light pollution.

Light pollution, unlike other types of pollution, is reversible, according to IDA, which indicates that the days of stargazing under dark skies are far from over and that problems caused by artificial lighting can still be mitigated. Another way to assist restore the natural night sky, according to IDA, is to raise awareness about light pollution. A lot of individuals don't know or understand a lot about light pollution and the harmful effects of artificial light at night.

As light pollution becomes more of a problem, some countries have started to reduce excessive illumination and reverse their natural sky appearance. Some countries have recently passed national legislation to combat light pollution. In other places, outdated bulbous street lamps that spread light in all directions are being replaced with modern, more efficient street lamps that only send light downward. As a result of the reduced glare, the skies above appear to be noticeably darker (Stone, 2017). There are other lighting technologies cities could adopt to reverse and correct light pollution.

5.1.2 Practical management of stakeholders on light pollution

Excessive artificial light is not always necessary. It is likely to become what is termed ‘light pollution’, and not all modern lighting is suitable in all locations. It can be a source of annoyance to people, harmful to wildlife and undermine enjoyment of the countryside or the night sky, especially in areas with naturally dark landscapes. Naturally dark landscapes are those entirely, or largely, undisturbed by artificial light. To preserve the desirable natural darkness, this research survey anticipated to assess the practical management of governmental institute in Addis Ababa.

On the Table 13, the respondents have been asked if they have ever seen any regulatory action like lamp figments/protection thus (n=22 or 7.91 %) respondents affirm that they realize protection practice nevertheless (n=139 or 50%) of the respondents said there is no protection/figment on lamp accessories and (n=105 or 42.09%) the rest stated they have no idea about the protection mechanism.

Table 13. Practice of protection for street lamps

Question	Work Place	Frequency of responses			
		Yes	No	I don't Know	Total
Do street lamps use fitment /protections?	EFCCC	4	53	51	108
	EPGDC	18	86	66	170
	Total	22	139	117	278

A study conducted on the effect of shading solution apparently support its applications that the light shade/protection can significantly reduce the light flux emitting from the interior, which can make contribution to the protection of light trespass and sky glow (Dua *et al.*, 2018). According to the result found we can conclude that aligning with the idea of deliberate unawareness, which is the most obvious reason for an environmental issue to gain only limited attention is that the subject is not considered to be important (Lyytimäki *et al.*, 2012).

From the Table 14, the respondents answered that if they heard or experience construction consultant offices or importers regulation or law to consider important factors when approving and importing light fittings (n=2 or 0.8%) of respondent give affirmative answer however no specific law or measurement techniques was described, on the other hand (n=276 or 99.2%) of

respondents never heard previously on importers or construction consultant office regulatory mechanism. To supporting the regulator measurement evaluation a second question is prepared

Table 14. Existence of regulation considering LP light materials

Question	Work place	Frequency of responses		
		Yes	No	Total
Have you heard or experience construction consultant offices or importers regulation or law to consider important factors when approving and importing lighting?	EFCCC	2	105	107
	EPGDC	0	171	171
	Total	2	276	278

Table 15 to investigate whether regulatory body taken any action against property owners, landowners or businesses that have caused a lighting nuisance and (n=276 or 99.2%) respondents never experienced any measurement taken due to light pollution causing stalk holders.

Table 15. Action against Owners caused lighting nuisance

Question	Work place	Frequency of responses		
		Yes	No	Total
Has your town pollution regulatory body taken any action against property owners, landowners or businesses that have caused a lighting nuisance?	EFCCC	2	105	107
	EPGDC	0	171	171
	Total	2	276	278

For question related to early recommendation on the design stage of planning Table 16, (n=278 or 100 %) of respondent answered no early direction or recommendation is implemented.

Table 16. Regulatory body recommendations on light pollution considering designing of buildings

Question	Work place	Frequency of responses		
		Yes	No	Total
Does your town pollution regulatory body make recommendations on light pollution when considering planning/designing applications?	EFCCC	0	107	107
	EPGDC	0	171	171
	Total	0	278	278

Unlike to the above findings concerned institutions such as the International Commission on Illumination (CIE) offer general lighting recommendations for proper and sustainable usage of artificial lighting (Lim *et al.*, 2018). A number of countries including Korea, France and Italy have begun dictating lighting level limits through regulations in order to decrease the amount of light pollution (Ho and Lin , 2015). Additionally, a study conducted in Hong Kong better indicate that design of light shielding implemented to reduces light pollution not only to avoid direct up light effectively but also means reduction of electrical energy consumption, regulations for turn-off time, pointing direction, and timing pattern (no rapidly flashing lights) of external lightings can also contribute to relieve the problem (Jason and So, 2010).

From the Table 17, the respondents answered that if they know any regulatory standard or law that design to control light pollution and (n=278 or 100%) all of respondents agree that there is no guideline to regulate the effect of light pollution in the country.

Table 17. Existence of standard/law or policy related to light pollution

Question	Work Place	Frequency of responses		
		Yes	No	Total
Is there a standard you know which helps to regulate light pollution?	EFCCC	0	109	109
	EPGDC	0	169	169
	Total	0	278	278

For question Table 18 (n=84 or 30.22%) respondents they believe if they complain related to light pollution their voice will be heard and (n=194 or 69.7%) respondents believe that their complaint will not be heard.

Table 18. Perception of complianes being heard

Question	Work Place	Frequency of responses		
		Yes	No	Total
If you have made complaints on lighting to the governmental body, do you feel your voice has been listened to?	EFCCC	18	90	108
	EPGDC	66	104	170
	Total	84	194	278

Unlike to the above findings, at least 17 states, the District of Columbia and Puerto Rico have laws in place to reduce light pollution (Schultz, 2016) countries such as France, Slovenia and South Korea have national level legislation aiming to reduce energy consumption caused by unnecessary use of lighting and to prevent nuisances caused by light spill, glare or over-illumination. In places like Taiwan, light pollution research and policy is also becoming prevalent (Ho and Lin, 2015). Additionally, concerned institutions such as the International Commission on Illumination (CIE) also offer general lighting recommendations for proper and sustainable usage of artificial lighting (Lim *et al.*, 2018). Many countries are acknowledging light pollution as serious environmental problem that need proper attention like any other environmental problems which has a potential to affect human health, animal sustainability and ecosystem hence they establish controlling mechanism while some other countries are waiting the consequence to get worse.

Countries with serious regulatory guideline for instance like Australian standard AS 4282-1997 (Standards Association of Australia, 1997) establishes rules for limiting the obtrusive impacts of artificial outdoor lighting, as well as recommended limitations for the relevant lighting parameters, in order to keep these effects tolerable. Outdoor lighting's obtrusive effects are controlled by appropriate design; the advice provided is primarily for new installations. As regulation is done on a state level in the United States of America, several separate regulations and laws exist. In addition, there is a standard EN 12464(2) (British Standards Institution, 2011) in the European Union that provides specific guidelines for light pollution. In terms of lighting levels and uniformities, this document lays out the lighting requirements for various outdoor workplaces ranging from power stations to railway yards. Similarly, countries namely Canada, Chile, Czech Republic, Finland, Italy, Spain, New Zealand and United Kingdom are exemplary countries with light pollution regulatory rule.

In South Africa a strong legislative and regulatory framework has been designed and implemented to protect astronomy observation and scientific operations. Dust and light pollution are protected at the national level for the Southern African Largest Telescope (SALT) and Square Kilometer Array (SKA) optical telescope astronomical projects (Statement by The Republic of South Africa, 2021).

In our country there is environmental pollution control proclamation (No. 300/2002) which states that *‘no person shall pollute ... the environment’ but also includes provisions for prevention and penalties if pollution does occur. It follows the ‘polluter pays principle’ and requires the person who causes pollution to pay for any clean up. Specific articles detail the need for proper management of hazardous and municipal waste and the adoption of environmental standards with reference to wastewater effluents, air, soil, noise and waste.* Related to this pollution is defined in this proclamation as: *‘any condition which is hazardous or potentially hazardous to human health, safety, or welfare or to living things created by altering any physical, radioactive, thermal, chemical, biological or other property of any part of the environment in contravention of any condition, limitation or restriction made under this Proclamation or under any other relevant law’* (FDRE, 2002). However, as our study indicate that this proclamation has no specific regulatory mechanism targeting on light pollution. In future specific legal guideline focusing on light pollution is required to advance the regulation process and ease to monitor and evaluate.

On Table 19 responses indicated that people face prejudices when raising attention towards the issue of light pollution. The majority of the respondents (n=228 or 82 %) concluded that light pollution management is not important.

Table 19. Importance of light pollution management

Question	Work Place	Frequency of responses		
		Yes	No	Total
Do you think light pollution management is more or less important than other environmental issues?	EFCCC	23	84	107
	EPGDC	27	144	171
	Total	50	228	278

From the table 19 outcome, better lighting is considered a key factor for enhancing outdoor exercising and recreation (Lyytimäki and Rinne , 2013) and improving the quality of residential areas. These preferences reflect some commonly held misconceptions that complicate the management of light pollution (Schwartz, 2003). Our results corroborated that these misconceptions i.e. more light is always better, regulating excessive lighting is unnecessary and not important also present in our survey.

Our results show that the problems caused by light pollution are recognized as a factor decreasing the quality of life by certain groups of people. However, the problem is not recognized more generally and even among concerned citizens, awareness of the environmental and health effects of artificial light at night remains low (Lyytimäki and Rinne, 2013), similarly a study conducted in Barcelona among people living in large Catalan cities and towns asked to choose the option which is less important right now, from all options (air pollution, plastics in oceans-rivers-lakes, noise pollution, light pollution, forbidding single-use plastics, and pushing for renewable energy sources instead of fossil fuels), light pollution has been chosen as the least important option according to their criteria (Hobkirk, 2020). Including our city respondents and abroad evidenced that large number of respondents did not respond to questions about the environmental or health implications of light pollution.

From the Table 20, the respondents answered that if they use blue light filter to control the light pollution and (n=394 or 89.5%) all of respondents answered they use no filter. And the rest of respondent (n=46 or 10.45%) respondents they use blue light filter in order to protect their health.

Table 20. Practice of blue light filter on mobile/computer

Question	Category	Frequency of responses		
		Yes	No	Total
Do you use blue light filter on your mobile/computer?	EFCCC	10	95	105
	EPGDC	12	161	173
	Dwellers	24	138	162
	Total	46	394	440

Similar to the above findings a study conducted in Hangzhou, china about the blue light who had used blue light-proof phone protection or not, the data showed that 64.40% of the respondents had never known the principle of blue light-proof phone protection, 29.32% knew a little about the attitude and 6.28% had a rough understanding of the principle (Shen *et al.*, 2020). Both results showed that most people were not aware of the dangers of blue light, and some people had more or less limited knowledge about blue light ray. At the same time, the use of blue light mobile phone/computer protection is not popular. The community still must to increase their awareness of the risk of blue light as well as the awareness of blue light prevention.

Chapter Five

Conclusions

In this study, assessment of light pollution was conducted by determining the current level of light pollution in Bole, Addis Ababa, as well as emphasizing on the current awareness and management practices.

Data from our measurement survey allowed us to articulate Bole, Addis Ababa is found to be as one of the cities with an average value of 19.51 mag/arcsec² of sky brightness. When we compare the finding with respect to current and future developmental prospect of our country it makes it is an alarming issue, as light pollution is usually indicated to proportionally match to the developmental standing of a country. This is because it rapidly changes with the expansion of lighting infrastructure, which is strongly associated with economic development. Lesson thus can be drawn early on from some well-developed countries like Germany and Australia which have less light pollution measurement irrespective of their development status.

Our data also show that most of our respondents have no sufficient knowledge about light pollution and its effect towards nature and human health. Awareness level of concerned government officials and staffs was also not satisfactory. When it comes to formulating policies, light pollution reducing policies focusing on monitoring and evaluation are also lacking. This research is a tip of the iceberg to draw attention on an environmental subject which seems to be given lesser consideration. Ethiopia or any other citizen living in a global city who wants to live a healthier tomorrow need to give adequate regard starting from individual level up to governmental organization.

Recommendation

Artificial light at night has many positive attributes. It can increase human safety and provide for longer periods of work or recreation. However, it also has a negative effect. The simple logic in reducing LP is to efficiently light the needed space, and leaving the rest naturally dark as it is. This will be realized in broader terms via improving awareness, better lighting design and implementing standard lighting guidelines and regulations. In terms of raising public awareness, it is important to call attention from governmental pollution concerned organizations through public outreach campaigns and collaborating with technological material importers with Ethiopian Standard Agency on LP issues and encouraging more public-participatory research.

Additionally, it is also worth mentioning that new lighting technology don't always provide better options for light pollution mitigation. Traditional street lamps and general building lighting are being rapidly replaced by LEDS by governments and communities. This is partly due to LEDs' shown ability to save energy. White LEDs, on the other hand, are more likely to harm natural ecosystems than high-pressure sodium (HPS) vapor lamps. As a result, the environmental pollution concerned government regulatory agency must pay attention on raising awareness and Ethiopian Standard Agency joint with construction material importers must monitor the types of materials inclusive of light pollution minimization techniques. Furthermore, it is important from the environmental pollution concerned governmental organization side to strengthening the administrative system and environmental monitoring system in legislation, creating a light pollution prevention legislation system, establishing strong civil liability for light pollution further developing a single law in light pollution control.

Considering that many Ethiopians are at the verge of beyond fulfilling the daily consumption of electricity and has poured its resources into a slew of megaproject, Grand Ethiopian Renaissance Dam for a glorious future to a brightened country, hence, From Ethiopian Power Energy Authority light pollution prevention standards and regulations should receive equal weight for the effective eradication of the detrimental effects of artificial lighting at night to ensure sustainable lighting which goes hand in hand with health and wellbeing considerations.

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Annex

Dear respondent, the main objectives of this questionnaire is to obtain data on the awareness and management practice of light pollution in selected area and in government institution in Addis Ababa city. The data will be analyzed to inspect for better improvement of awareness and the management practice of the city. The quality of the research work highly depends on your genuine responses. Thank you in advance for your commitment and truthful responses.

ውድ የመጠይቁ ተሳታፊ ፣ የዚህ መጠይቅ ዋና ዓላማ በአዲስ አበባ ከተማ በተመረጡ አካባቢዎች ስለ ብርሃን ብክለት የግንዛቤ እና የቁጥጥር አሰራር ላይ መረጃ ማግኘት ነው። መረጃው የብርሃን ብክለት ግንዛቤ እንዲሻሻል እና የከተማዋን የቁጥጥር አሰራር ለመመርመር ይጠቅማል። የምርምር ሥራው ጥራት በእውነተኛ ምላሾች ላይ የተመሠረተ ነው። ለሚሰጡት እውነተኛ ምላሾችዎ አስቀድሜ አመሰግናለሁ።

- ❖ Please fill the mark on the appropriate answer you choose (እባክዎን በመረጡት ተገቢ መልስ ላይ ምልክቱን ይጽሱ)

I. Age(እድሜ): _____

II. Educational background (የትምህርት ደረጃ): _____

☐ High school graduate (ሁለተኛ ደረጃ የጨረሰ)

☐ Undergraduate level (የመጀመሪያ ዲግሪ)

☐ Master's level (ሁለተኛ ዲግሪ)

III. Working place (የስራ ቦታ): _____

☐ የአካባቢ ፣ የደን እና የአየር ንብረት ለውጥ ኮሚሽን (EFCCC)

☐ የአዲስ አበባ አካባቢ ጥበቃና አረንጓዴ ልማት ኮሚሽን (EPGDC)

☐ ሌላ _____

Awareness measurement questions (የግንዛቤ መለኪያ ጥያቄዎች)

- 1) Do you have street lighting in your town/village? (በከተማዎ ውስጥ የመንገድ መብራት አለዎት?)

☐ Yes (አዎ)

☐ No (የለም)

2) Are your street lights on dusk to dawn or do they operate on part night lighting? (የጎዳና ላይ መብራቶች ሌሊቱን በሙሉ (ከጠዋት እስከ ንጋት) ነው ወይም በጊዜ ማብሪያ (በከፊል ማታ መብራት) ላይ ይሰራሉ?)

☐ Yes, all night (አዎ ለሌሊቱ ሙሉ ይበራል)

☐ No when it is necessary (አይ በሚያስፈልግበት ጊዜ ይበራል)

☐ I don't pay attention (ትኩረት አልሰጥም)

3) Have you heard about light pollution? (ከዚህ በፊት ስለ ብርሃን ብክለት ሰምተዋል?)

☐ Yes (አዎ)

☐ No (የለም)

☐ መልሱ አዎ ከሆነ ቢገልፁልን _____

4) Are you aware of the causes of light pollution? (የብርሃን ብክለት መንስኤዎችን ያውቃሉ?)

☐ Yes (አዎ)

☐ No (የለም)

☐ መልሱ አዎ ከሆነ ቢገልፁልን _____

5) Do you know light pollution cause significant health problem? (የብርሃን ብክለት ከፍተኛ የጤና ችግር እንደሚያስከትል ያውቃሉ?)

☐ Yes (አዎ)

☐ No (የለም)

☐ መልሱ አዎ ከሆነ ቢገልፁልን _____

6) Do you know light pollution cause significant problem to nature? (የብርሃን ብክለት በተፈጥሮ ላይ ከፍተኛ ችግር እንደሚፈጥር ያውቃሉ?)

☐ Yes (አዎ)

☐ No (የለም)

☐ መልሱ አዎ ከሆነ ቢገልፁልን _____

7) I always avoid the unnecessary use of lights (ሁልጊዜ አለስፈላጊ መብራቶችን ከመጠቀም እቆጠባለሁ)

☐ Yes (አዎ)

☐ No (የለም)

8) Do levels of light pollution in Addis Ababa concerns you? (በአዲስ አበባ ውስጥ የብርሃን ብክለት ደረጃዎች ያሳስቡዎታል?)

☐ Yes (አዎ)

☐ No (የለም)

9) Do you think light pollution is reversible/correctable? (የብርሃን ብክለት ሊስተካከል ይችላል ብለው ያስባሉ?)

☐ Yes (አዎ)

☐ No (የለም)

Practical management questions (ተግባራዊ አስተዳደር ጥያቄዎች)

- 1) Do street lamps use fitment/protections? (የጎዳና ላይ መብራቶች ተስማሚ / የብርሀን ብክለት መከላከያዎችን ይጠቀማሉ?)

☐ Yes (አዎ)

☐ No (የለም)

- 2) Have you heard or experience construction consultant offices or importers regulation or law to consider important factors when approving and importing lighting? የኮንስትራክሽን አማካሪ ቢሮዎች ወይም አስመጪዎች መብራትን ሲያፀድቁ እና ሲያስገቡ አስፈላጊ የብርሀን ብክለት መከላከያ ከግምት ውስጥ እንዲያስገቡ የሚደረግ ቁጥጥር አለ?)

☐ Yes (አዎ)

☐ No (የለም)

☐ If your answer is yes, please Specify መልሶት አዎ ከሆነ

ይግለፁልን _____

- 3) Has your town pollution regulatory body taken any action against property owners, landowners or businesses that have caused a lighting nuisance? (የከተማዎ ብክለት ተቆጣጣሪ አካል በንብረት ባለቤቶች ፣ በመሬት ባለቤቶች ወይም በመብራት ችግር ምክንያት በሆኑ የንግድ ድርጅቶች ላይ ማንኛውንም እርምጃ ወስዷል?)

☐ Yes (አዎ)

☐ No (የለም)

☐ If your answer is yes, please Specify መልሶት አዎ ከሆነ

ይግለፁልን _____

- 4) Does your town pollution regulatory body make recommendations on light pollution when considering planning/designing applications? (የከተማዎን ብክለት ተቆጣጣሪ አካል ሲታቀድ / ዲዛይን ለማድረግ ሲያስቡ በብርሃን ብክለት ላይ ምክሮችን ይሰጣል?)

☐ Yes (አዎ)

☐ No (የለም)

- 5) If you have made complaints on lighting to the governmental body, do you feel your voice would have been listened to? (ለመንግስት አካል በመብራት ላይ ቅሬታ ካቀረቡ ድምጽዎ እንደተደመጠ ይሰማዎታል?)

☐ Yes (አዎ)

☐ No (የለም)

6) Are you willing to change the light fitting if you are causing the light pollution? (የብርሃን ብክለት የሚያስከትሉት እርስዎ ከሆኑ የብርሃን መግጠሚያውን ለመለወጥ ፈቃደኛ ነዎት?)

☐ Yes (አዎ)

☐ No (የለም)

7) Is there a standard you know which helps to regulate light pollution? (የብርሃን ብክለትን ለማስተካከል የሚረዳ የምታውቀው የመቆጣጠሪያ ደንብ አለ?)

☐ Yes (አዎ)

☐ No (የለም)

☐ If your answer is yes, please Specify መልሱን አዎ ከሆነ

ይግለጹልን _____

8) Do you think light pollution management is more or less important than other environmental issues? (የብርሃን ብክለት አያያዝ/ ቁጥጥር ከሌሎች የአካባቢ ጉዳዮች ባልተናነሰ አስፈላጊ ነው ብለው ያስባሉ?)

☐ Yes (አዎ)

☐ No (የለም)

9) Do you use blue light filter on your mobile/computer? (የሰማያዊ ብርሃን ማጣሪያ ከሞባይሎ ወይም ከኮምፒውተሮች ይጠቀማሉ?)

☐ Yes (አዎ)

☐ No (የለም)