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Regulation of Light Pollution in IIT Mandi

DP301P: Interactive Socio-Technical Project Report

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(Abstract) *Light pollution, which is characterized by excessive or poorly focused artificial illumination, presents serious threats to the environment, animals, and public health. This initiative aims to combat light pollution on the Indian Institute of Technology (IIT) Mandi campus by increasing awareness, recommending lighting guidelines, and reducing environmental effects. The detrimental consequences of light pollution were emphasized by a literature study. A lack of understanding and divergent illumination requirements were found through surveys and interviews with the college population and surrounding village inhabitants. Long-term fixes, energy efficiency improvements, a balanced lighting environment, as well as quick fixes to lessen the existing light pollution, were all suggested. The campus community and the local environment will benefit from this project's efforts to increase awareness, offer guidelines, and provide practical recommendations for a sustainable lighting environment at IIT Mandi.*

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Chapter 1

Executive Summary

1.1 Defining light pollution

Light pollution, which obstructs the night sky's natural darkness, is a phrase used to describe excessive or poorly targeted artificial illumination. It is detrimental for the ecological system as a whole, animal behavior, and human health.

1.2 Objectives of the study

The major objectives of this study includes informing the IIT Mandi community about the significance of light pollution and the negative consequences it has on the environment, wildlife, and people's health. We also aim to suggest the formulation of specific guidelines and standards that will limit the use of artificial lighting on our campuses. And lastly, we hope to lessen campus lighting's negative effects on the environment.

1.3 Approach of the study

We began our project by performing extensive literature review on existing studies and research to understand the significance of light pollution and its harmful effects. This review also enabled us to understand the existing practices in place, differences in regulation of light pollution in India as opposed to other countries and how light

relates to safety.

Further, since our study was focused on our campus community, we set out to conduct a survey of all campus residents to identify the level of awareness as well as their views on existing lighting on campus and willingness to take further steps to mitigate the effects. We also took in-person interviews of campus staff to understand the differences between campus lighting and where they live.

In addition to this, in-person interviews were conducted in nearby villages to majorly understand the effect of campus lighting on them. Interviews were conducted in Mandi town and a survey was conducted in areas independent of campus light to identify the general perception regarding the problem and to acknowledge steps, if any, being taken to mitigate the effects of light pollution.

Lastly, we worked towards creating a zonation map which quantitatively depicted regions on campus requiring urgent consideration.Real time changes in light intensity (lux) were measured to depict changes and comparisons where needed.

1.4 Results and Recommendations

The results of both our surveys and interviews pointed towards a lack of awareness in the general public regarding light pollution and its impact. Additionally, the campus survey and in-campus interviews helped us recognize the respondent identified pain points on campus which may require urgent attention. It also enabled us to understand the stark contrast between the lighting on-campus and in nearby villages, with an actual local need for lighting in the villages.

Based on our results and conclusions, we drafted a list of conclusions and recommendations to the campus administration. Our recommendations were divided into two main sub-groups, long-term and immediate recommendations wherein long-term recommendations focused on ensuring how the campuses can eventually become pollution-free with a balanced lighting environment and optimized electricity consumption. The immediate recommendations involved suggestions about steps that can be taken immediately to mitigate the current campus light pollution.

Chapter 2

Introduction

The Indian Institute of Technology, Mandi is renowned for being situated in the very heart of the Himalayas, in an environmentally friendly location. IIT Mandi has never had to deal with worries about a number of issues more pertinent to cities due to its ecologically pleasant setting. However, a recent incident involving an animal seen close to the north campus's main gate raised concerns about student safety and anxiety. In response, a number of street lights were put in place, with the hope that the lights would deter animals from the area. However, this incident raised questions about the effectiveness of such measures and the potential negative consequences of excessive lighting.

These instances spurred debates among students over the issue of excessive lighting on campus and its effects on the environment, animals, and people's health. Light pollution is the term for excessive or poorly focused artificial illumination that obstructs the night sky's inherent blackness. It is harmful to many facets of life, including human health, animal behavior, and the ecological system as a whole. In addition to disrupting circadian rhythms and affecting sleep patterns, excessive artificial illumination has been linked to a number of health problems, including chronic illness risk and weariness [3]. In addition, wildlife is impacted by light pollution, which alters their natural behaviors, interferes with migratory patterns, and damages ecosystems [4]. The energy waste brought on by superfluous illumination increases environmental problems and adds to carbon emissions [5].

In light of these concerns, our project aims to address the regulation of light pollution specifically within the premises of IIT Mandi. These objectives have been determined by us:

1. **Raising Awareness**: We aim to educate the people of IIT Mandi about its meaning and the damaging effects that light pollution has on the environment, animals, and human health.

2. **Regulating Light Pollution**: The goal of our project is to recommend creation of detailed rules and regulations that will control the use of artificial lighting on campuses. Reducing irrational and excessive illumination, making sure lighting fixtures are positioned and built to minimize skyglow, and encouraging the use of energy-efficient lighting technology are all part of this. We work to provide a sustainable and ecologically friendly lighting environment on campus by putting in place efficient policies.

3. **Reducing Environmental Impacts**: Our objective is to reduce the environmental impact of campus lighting. This entails coming up with recommendations to reduce energy consumption, including using shielded lighting, motion sensors, and timers. Additionally, we will evaluate and suggest solutions to any problems that particular lighting installations which directly impact student hostels and common areas have caused.

By working towards these goals, we hope to improve IIT Mandi's lighting environment in a way that will benefit both the campus community and the local ecology. We want to lessen light pollution and contribute to the preservation of dark sky, reduction of energy waste, and promotion of ecological balance on campus through awareness, regulation, and customized solutions.

Chapter 3

Literature Review

3.1 Objective of the literature review

A literature review is a systematic and critical evaluation of the scholarly literature and current research on a certain subject or research question. It entails a thorough investigation and evaluation of pertinent literature, including books, papers, and other published sources. The objective is to summarize and assess the existing research on a particular subject in order to find knowledge gaps, pinpoint areas that require more research, and improve understanding of the theories, concepts, and procedures already in use by reviewing the literature.

3.2 Introduction to Light Pollution

3.2.1 Definition and Scope

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Light pollution is the term used to describe the excessive and inappropriately directed artificial light that obstructs the night sky's inherent darkness. It is brought about by the excessive and improper use of outdoor lighting, which wastes energy, obstructs the ability to see the stars and conduct astronomical studies, and is bad for the environment and people's health [6]. The goal of the literature review with respect to light pollution was to gather and analyze the existing research present on the topic. A literature

review can specifically be used to determine the scope and nature of the light pollution problem, the effects of light pollution on the environment and human health, and the available light pollution reduction strategies. A review of the available research can assist in determining the methods and tools that have proven to be most successful in reducing light pollution and promoting dark skies. A critical assessment of the current approaches and techniques for minimizing light pollution may be found in the literature review. It can also reveal any obstacles to putting these strategies into practice, such as political, societal, or economic considerations. In conclusion, the purpose of a literature review on the subject of light pollution is to provide a thorough grasp of the present state of knowledge on the subject, identify research gaps, and provide a foundation for further analysis of the problem so as to learn more about the best methods for lowering light pollution and promoting the preservation of the night sky's natural blackness by synthesizing and examining the body of existing knowledge.

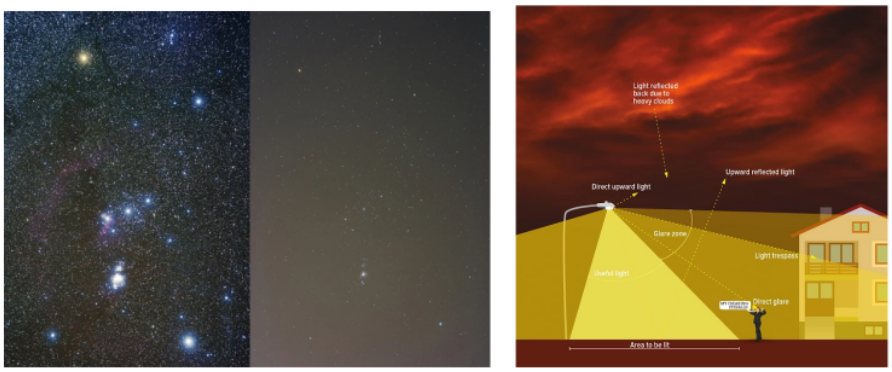
The various forms of light pollution include the following [7]:

1. Skyglow: The brightening of the night sky brought on by the atmospheric particles scattering artificial light is known as skyglow. It is the most prevalent type of light pollution, obstructing the night sky's inherent darkness and interfering with astronomical observations and stargazing. Using outdoor lighting that is intended to minimize upward light emission will help to lessen skyglow.

2. Glare: The harsh, bright light that a light source emits is referred to as glare. As it can result in eye discomfort, impairment, and even accidents, it can be an issue for vehicles, pedestrians, and wildlife. Utilizing lighting equipment that minimizes intensity and directs light to the desired region will help prevent glare.

3. Light Trespass: When artificial light intrudes into places it was not intended to, such as private residences or natural habitats, this is known as light trespass. It may disturb nature and alter the routines of creatures, including nocturnal creatures, marine life, and migrating birds. By employing targeted lighting and shields to stop the light from leaking into unauthorized areas, light trespass can be minimized.

4. Over-illumination: It is the excessive use of artificial light, which uses energy inefficiently and has a negative effect on the environment. By using illumination only when essential and energy-efficient fixtures, it can be decreased.



(a) Celestial Objects Visibility reduced due to Sky-Glow, Jeremy Stanley

(b) Types of light pollution, International Dark Sky Association

Fig. 3.1: Effects of Light Pollution

The brightness of the night sky is measured by its luminance value. The brightness value of a clear sky on a moonless night is approximately 1.7 10-4 lux [1]. However, depending on whether or not the moon is present, this value can change. The brightness value can range from 0.27 to 1 lux when the moon is present. This occurs as a result of the moon reflecting sunlight and brightening the night sky. A rising issue is how artificial light affects the night sky since it may harm the environment, wildlife, and people. By interfering with the circadian rhythm, excessive artificial light can sabotage the normal cycles of many species, including humans. Additionally, exposure to artificial light at night raises the risk of depression, other health issues, and sleep disturbances. Researchers have produced maps of the brightness of artificial night lights using high-resolution satellite data to determine the amount of night light pollution. A global overview of the spread of night light pollution is provided by these maps. More than 66% and over 80% of the world's population, respectively, reside in areas with above-threshold night light pollution, according to the first and updated globe maps of artificial night light brightness.

A global 6% annual increase in Artificial night light pollution (ANLP) is being attributed to an increase in the use of artificial light (AL) sources [8]. These findings show that artificial light sources need to be effectively managed in order to lessen light pollution and its detrimental impacts on the environment and human health.

3.2.2 Importance of the Issue

The literature review helped in establishing the importance and urgency of dealing with the issue of light pollution. According to a recent study, anthropogenic light pollution wastes over 23.5 billion kg of carbon dioxide annually in India, making it one of the countries with the worst light pollution problems [8]. The survey also discovered that India has about 27 million street lamps, which use between 30 and 35 percent of the nation's total energy output and are responsible for 43 percent of all light pollution. The sleep-wake cycle, bodily functioning, starlight visibility, astronomical studies, and ecosystems can all be negatively impacted by light pollution. Modernization drives it to spread quickly by consuming natural resources, producing carbon dioxide emissions that cause global warming, and altering weather patterns. The difficulty of Astro-tourism is one of the most severe effects of light pollution in India. Many suitable locations for astronomical observations and stargazing may be found in India. However, light pollution prevents the growth of astro-tourism and thus hinders a great source of revenue in these regions.

India's light pollution increased between 2013 and 2020, according to radiance data from the NASA Suomi satellite's Visible Infrared Imaging Radiometer Suite (VIIRS) [9].

The Indian government has launched many programs, including Unnat Jyoti by Affordable LEDs for All (UJALA), to address the issues of light pollution and energy waste. With the help of this program, outdated streetlights will be swapped out for LED models that use less energy [8]. To ensure that streetlights are on continuously, solar-powered sensors have also been placed. The benefits of switching to energy-efficient lighting over conventional streetlights were demonstrated via a case study done in Mumbai. T5 fluorescent tube lights were installed in place of 11,500 streetlights in

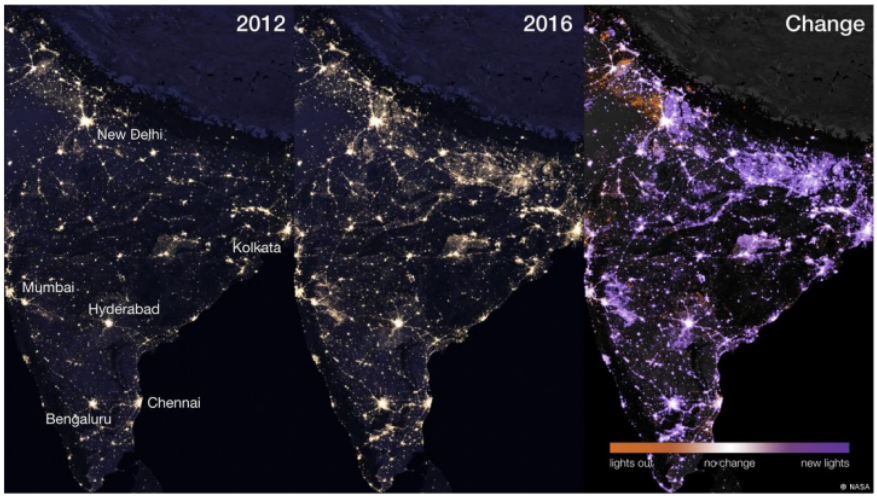


Fig. 3.2: Increase in India's Light Pollution, NASA

2007, resulting in an energy reduction of 2.1 million kWh, or 56%. The annual cost of electricity was reduced by INR 6.4 million ($133,000).

The negative consequences of light pollution are being acknowledged as an issue in contemporary society more frequently. More research must be done on the consequences of light pollution so that people are aware of how it affects the environment and public health. It has been shown through the case studies that reducing light pollution is doable without sacrificing other crucial elements like work and safety. This shows that reducing light pollution can be a win-win situation for both the environment and people. We can create a more sustainable and healthy future for everyone by raising awareness of the problem and taking action to eliminate light pollution.

3.3 Supporting the impact of Light Pollution

3.3.1 Scientific Studies on Ecological and Environmental Effects

Light has been one of the most fundamental factors that helped in the development and sustenance of life on the planet. Nearly all living things derive their energy mostly

from sunlight, and plants and some microorganisms employ the process of photosynthesis to transform light energy into chemical energy in order to produce food. The effect of light pollution on living organisms is referred to by the term "photopollution" which can be defined as the "adverse effect of artificial light on living organisms" [10]. Artificial night light pollution is considered a major factor in the deterioration of ecosystem maintenance. While remote sensing areas are impacted by scattered AL in the atmosphere (skylight), other natural ecosystems are directly impacted by continuous or blinking AL. Greater magnitude than moonlight is present in localized direct AL from streetlights or car headlights. Nighttime AL illumination of many natural or semi-natural settings has the potential to alter the physiological and ecological responses of plant systems [11]. The physiological and behavioral processes of plants may be significantly altered, which may affect living things' predator-prey interactions, plant-animal interactions, insect courtship, seasonal oestrus cycle, eating habits, and sleeping patterns. A stable ecosystem's food webs could be altered by ANLP, and it could have an impact on how nocturnal insects like moths pollinate plants. ANLP also has the potential to eliminate biodiversity. It could also result in enormous energy and financial waste and harm the environment and the general public's health. Light and dark periods have far-reaching consequences on the growth and development process of plants affecting the seedling development, flowering, photosynthetic procedure, and other activities like mineral absorption, transpiration, etc. Plants have photoreceptors. Artificial light can lead to premature start and end of flowering, DNA damage, delaying or advancing the circadian cycle of plants, and altering the food web by changes in abundance of parasites and predators [1].

Researchers conducted studies to analyze the eco-physiological response of artificial light night pollution in planes. To investigate the impact of artificial light at night (ALAN) on plant growth, development, and photosynthetic activities, the researchers conducted tests on six distinct plant species. At night, they subjected the plants to various light conditions, from low to high intensities and brief to lengthy durations. The outcomes demonstrated that ALAN significantly affected the growth and development of plants. The morphology of the plants exposed to ALAN changed, showing

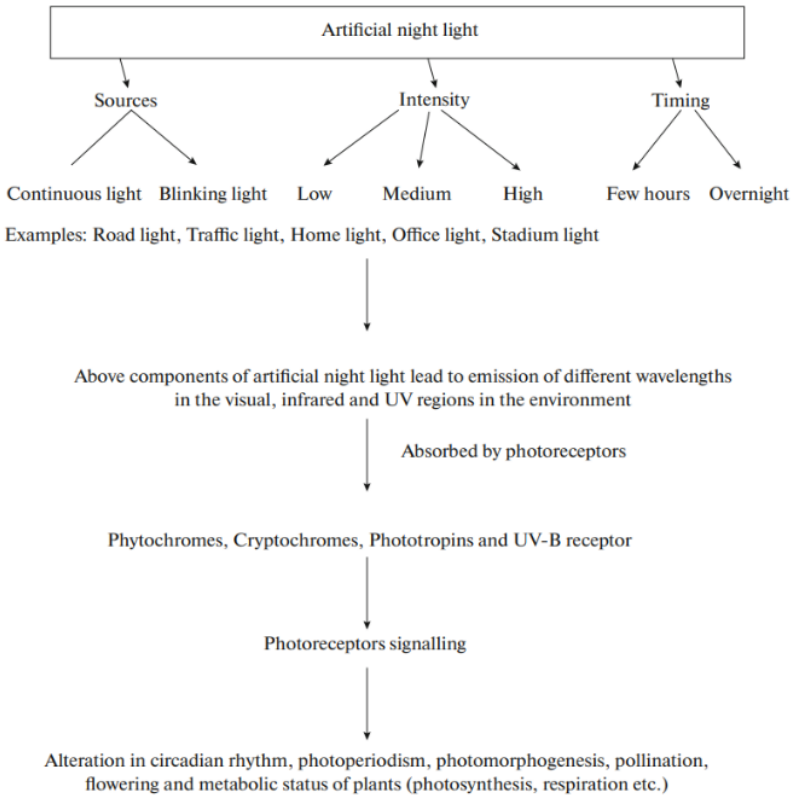


Fig. 3.3: "Effects of Artificial Light on Plants" [1]

altered stem elongation, leaf size, and biomass accumulation. Reduced chlorophyll concentration and reduced photosynthetic efficiency also impacted the plants' rate of photosynthetic activity. ALAN has an impact on plant physiological functions, including changes in gene expression and hormone levels, according to the study. The amounts of auxins, cytokinins, and abscisic acid, which are all significant hormones that control plant growth and development, were specifically altered, the researchers found [1]. According to the research, light pollution levels may need to be lowered to protect plant populations' productivity and health, which are vital parts of the world's ecosystems.

3.3.2 Health Effects on Humans and Wildlife

It has been established that artificial night light pollution (ALAN) harms both people and wildlife. According to study publications, the following are a few of ALAN's negative consequences on health:

1. Circadian rhythm disruption: Exposure to ALAN can alter the body's normal circadian rhythms, which can cause sleep disorders and other health issues [12]. In a study conducted in 2017 by Hale and colleagues[13], it was discovered that women's sleep duration and quality were both shortened when they were exposed to more outdoor artificial light at night.

2. Developing Cancer: Exposure to ALAN has been associated with an increased risk of developing some cancers, particularly breast cancer. According to research, Women who had greater levels of ALAN had a higher chance of developing breast cancer [14].

3. Disturbance in wildlife behavior: ALAN can harm wildlife, including alterations in behavior, migratory patterns, and reproductive success. According to a, ALAN from streetlights interfered with migratory birds' behavior, increasing their fatality rates [15].

4. Ecosystem disruption: ALAN has the ability to alter ecosystems, changing species relationships and nutrient cycling completely. ALAN from streetlights affected bats' feeding behavior, changing insect populations and plant communities [16].

Overall, ALAN's detrimental impacts on health emphasize the need for efficient light pollution reduction techniques. Using lower-intensity lighting, shining light downward, and shutting off lights while not in use are a few of these techniques.

3.3.3 Disruption of Natural Cycles and Behaviors

Artificial lighting, arising from municipal or street lighting, significantly impacts the behaviors of animals, insects and birds. Specifically, it affects species interactions -

detection of resources, mate selection and navigation. It is important to note that the behaviors of organisms have "evolved under the intensities, timings and spectral composition of light emitted from the sun and stars, and reflected from the moon" [2]. From an evolutionary standpoint, this implies that stimulation from natural lights governs the natural cycles of these organisms and any changes in the quantity or quality of light is bound to disturb the natural cycles. Then, the questions that arise are: to what extent are these organisms affected? And, what types of lighting are the most disturbing? We look at the four most commonly used street lighting lamps namely, Low Pressure Sodium (LPS), High Pressure Sodium (HPS), Light Emitting Diode (LED) and Metal Halide (MH) lamps, and discuss how they might affect wildlife and insects following the analysis done in [2].

The absorbance properties of the visual pigments present in the photoreceptors of animals and humans can provide information about how sensitive they are to different types of street lamps. From [2], we learn that "LPS lamps emit light over a narrow region of the light spectrum to which human photoreceptors are sensitive", while as, " HPS, LED and MH lamps emit light over a greater proportion of the light spectrum to which humans are sensitive". Therefore, switching to LPS type lamps, which have a warmer orange tone, over the other three lamps could potentially reduce health problems associated with artificial lights in humans. [2]

Further, based on the range and types of wavelengths emitted by the lamps, we can group them into three categories: narrow-spectrum lamps with no UV emission (LPS), broad-spectrum lamps with no UV emission (HPS and LED), and broad-spectrum lamps with UV light emission (MH). Now, we refer to Fig. 3.5 that shows the degree to which each type of street lamp stimulates the visual range of five taxonomic groups of animal species. In the figure, $\lambda_{0.5}$ range means the range of spectrum over which the pigments in the eyes of the animals absorb more than half of the light incident on them. Clearly, the first category of lamps (LPS) affects the five taxonomic groups of organisms the least, while the third category of lamps (MH) affects them the most. [2]

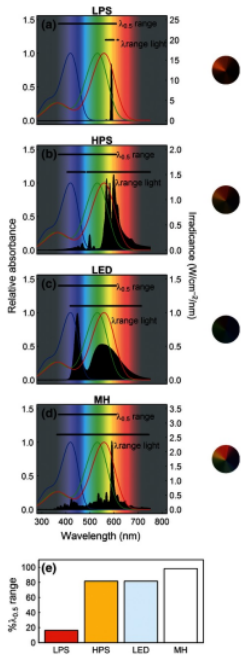


Fig. 3.4: Human color vision under different street lighting technologies: (a) LPS lamps: Emit light over a narrow region of the spectrum (λ_{range}). They stimulate a smaller proportion of human visual pigments' half maximally sensitive range ($\lambda_{0.5}$ range), making objects outside that range appear less bright (shown by the color wheel insert). (b, c, d) Broad spectrum street lighting technologies (HPS, LED, MH): Emit light across a wider spectrum that matches human sensitivity, enabling identification of objects reflecting light across various wavelengths. (e) Visual performance comparison: An index (% $\lambda_{0.5}$ range stimulated) measures the overlap between the λ_{range} light and the $\lambda_{0.5}$ range. (a-d): Solid black lines represent absorbance curves for visual pigments. Filled curves depict emission spectra of each street light, with the plot background approximating human color perception. Color wheel inserts show photographic images captured under each street lighting type, using a standard digital SLR camera sensitive to wavelengths similar to human visual pigments. [2]

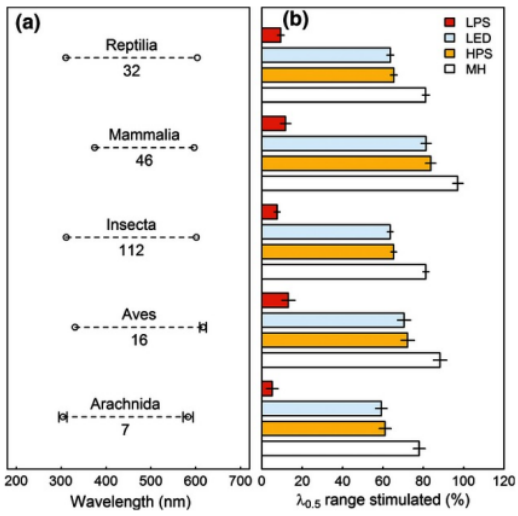


Fig. 3.5: Percentage of visual range stimulated by contrasting street lighting technologies in five animal classes: (a) $\lambda_{0.5}$ range estimation: The average minimum and maximum wavelengths of half maximum visual pigment absorbance for five classes of animals. Points with error bars represent 95% credibility intervals derived from Markov Chain Monte Carlo (MCMC) regression. The values quoted under dashed lines indicate the number of species used for the calculations. (b) Percentage of visual range stimulation: Each street light's stimulation of the visual range above half maximum absorbance in the five animal classes. Means and 95% credibility intervals (error bars) were estimated using MCMC regression. [2]

Moreover, we see that mammals and birds are more adept at detecting objects under the narrow spectrum of LPS lighting as compared to arachnids, reptiles, and insects. For broad spectrum lighting lamps, we observe that a larger proportion of the $\lambda_{0.5}$ range is stimulated in birds and animals as compared to other taxonomic groups due to the former's relatively limited vision range. This means that broad spectrum lighting affects mammal and bird interactions more adversely. For instance, LED lighting is seen to cause increased feeding rates among Great Tits (Parus Major), and bats (Rhinolophus Hipposideros) are observed to avoid HPS and LED lit areas. Lastly, among the broad spectrum lights, MH lights stimulate the UV spectral range.

Therefore, non-UV alternatives should be considered, as many species of wildlife have evolved to follow certain behaviors under natural UV lighting that would otherwise be disrupted. [2]

3.4 Opposition of the Impact of Light Pollution

3.4.1 Counter Arguments and Debates

While the majority of research supports the negative impacts of light pollution, it is important to acknowledge the existence of counterarguments and debates surrounding its effects. Some studies argue that the detrimental effects of light pollution may be overstated or have limited significance in certain contexts. These perspectives raise questions about the strength of the evidence linking light pollution to specific health outcomes and the potential role of methodological limitations and confounding factors.

Kyba et al. (2017) [17] emphasize the need for a subtle approach to assessing the impact of light pollution on ecosystems. They argue that while light pollution can have negative effects on certain species, it can also provide benefits to others, such as urban-adapted species that thrive in illuminated environments. They advocate for considering the ecological context and the potential trade-offs associated with light pollution mitigation efforts.

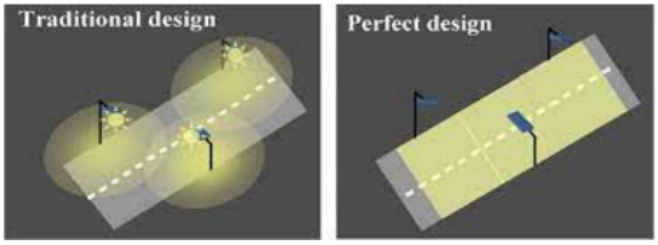


Fig. 3.6: "Traditional lighting vs Proper Lighting"

3.4.2 Studies Challenging the Severity of Effects

In addition to counterarguments, some studies challenge the severity of the effects of light pollution, suggesting that its impact may be less significant than previously believed. For example, in a study [18] conducted examining the relationship between outdoor artificial light at night and breast cancer incidence. Their findings indicate that while there may be an association between light at night and breast cancer, the effect size is relatively small compared to other established risk factors.

Furthermore, Navara and Nelson (2007) [19] argue that the ecological effects of light pollution may be context-dependent and vary across different species and ecosystems. They suggest that some organisms can adapt to or tolerate artificial lighting to a certain extent, and that the overall ecological impact may be more complex and nuanced than a straightforward negative relationship.

3.5 Different Perspectives on Light Pollution

3.5.1 Cultural and Aesthetic Considerations

In addition to the scientific and ecological perspectives, it is important to explore the cultural and aesthetic considerations surrounding light pollution. Some researchers argue that artificial lighting plays a crucial role in enhancing safety, promoting urban development, and creating visually appealing cityscapes. They highlight the positive aspects of well-designed lighting schemes that contribute to the cultural heritage, architectural beauty, and social activities of urban areas[20].

On the other hand, authors such as Meier [21] emphasize the importance of preserving natural darkness and the cultural value of starry skies. They argue that excessive artificial lighting not only obscures our view of the night sky but also diminishes the cultural and spiritual significance associated with stargazing. They advocate for a balance between the need for functional lighting and the preservation of natural darkness to maintain cultural connections with the night sky.

3.5.2 Urban Planning and Lighting Design Approaches

The field of urban planning and lighting design offers different perspectives on addressing light pollution. Some urban planners and designers advocate for implementing innovative lighting strategies that reduce light spillage and glare while maintaining sufficient illumination for safety and security. They emphasize the importance of considering lighting design as an integral part of urban planning processes to minimize the negative impacts of light pollution on ecosystems and human well-being.

Additionally, sustainable lighting initiatives and technologies are being explored to mitigate light pollution. For example, the use of shielded fixtures, motion sensors, and dimming systems can help reduce unnecessary light emissions while maintaining appropriate lighting levels [22]. Such approaches promote energy efficiency and minimize light pollution in urban environments.

3.5.3 Social and Psychological Effects

The social and psychological effects of light pollution have gained attention in recent years. Researchers have examined how excessive artificial lighting impacts human well-being and quality of life. For instance, Kloog et al. (2015) [23] conducted a study on the association between light pollution and sleep quality in urban populations. Their findings revealed a negative correlation, suggesting that exposure to artificial light at night can disrupt sleep patterns and lead to sleep disturbances.

Moreover, the aesthetic and psychological implications of light pollution have been explored. Some studies highlight the loss of a natural connection to the night sky and the diminishing sense of wonder and awe that starry nights evoke. The overabundance of artificial lighting in urban areas can also impact people's perception of space and their overall psychological well-being.

3.6 Historical Perspective on Light Pollution

The historical analysis of light pollution offers valuable insights into the development of artificial lighting and the initial concerns and awareness regarding its environmental

and societal impacts.

The origins of artificial lighting can be traced back to Thomas Edison's invention of the incandescent light bulb in the late 1800s. This breakthrough revolutionized our approach to illuminating our surroundings and extended human activities into the nighttime hours. As electric lighting became more widely adopted, urban areas experienced a substantial increase in light emissions, leading to the emergence of light pollution as a significant concern.

In the early 1900s, early apprehensions about the adverse consequences of excessive artificial lighting started to emerge. Astronomers were among the first to raise awareness about the effects of artificial lighting on their observations of celestial objects. They expressed concerns about the challenges they faced in studying the night sky due to the glare and skyglow resulting from urban lighting.

Furthermore, environmentalists of the time also voiced their worries about the ecological implications of light pollution. They identified the disruption of natural light-dark cycles and the disorientation of nocturnal animals as potential consequences of excessive nighttime illumination. Researchers acknowledged that artificial lighting could interfere with the behavior, reproduction, and migration patterns of various species.

Moreover, the health effects of light pollution began to receive attention. Medical professionals and scientists started investigating the impact of artificial lighting on human health, particularly its potential to disrupt sleep-wake cycles and melatonin production. The understanding of the importance of darkness and natural light for maintaining circadian rhythms and overall well-being gradually gained recognition.

As the 20th century progressed and extended into the 21st century, our understanding and awareness of light pollution continued to develop. Scientists conducted research to quantify and measure light pollution levels, establish lighting standards, and propose strategies for mitigating its effects. International organizations, such as the International Dark-Sky Association, were founded to promote responsible lighting practices and raise public awareness about light pollution.

The historical perspective on light pollution emphasizes the progression of our un-

derstanding of its ecological, astronomical, and health impacts. It underscores the significance of historical context in shaping current policies, practices, and scientific advancements aimed at addressing light pollution. By examining the historical trajectory of artificial lighting and the initial concerns and awareness surrounding light pollution, we can gain a deeper appreciation of the importance of this issue and the ongoing need for efforts to minimize its negative effects.

3.7 Comparison of India and European countries like Germany

India and Germany, one of the leading European countries, can be compared in terms of light pollution along the following lines:

1. Magnitude: The size of the issue is one of the main variations between the trend in light pollution seen in Germany and India. Compared to India, where light pollution is more severe, Germany has a significantly lower amount of light pollution.

2. Urbanization: Germany is a highly urbanised nation, yet the stricter laws it has on light pollution have managed to lower the quantity of light pollution there. India, on the other hand, is quickly urbanizing, which has caused a noticeable rise in light pollution.

3. Economic Development: The state of the economies in the two nations has a big impact on the trajectory of light pollution. Germans can afford to invest in high-quality lighting that is energy-efficient and reduces light pollution because their nation is well-developed and has a strong economy. But because India is still a developing nation, many individuals continue to use poor lighting systems that add to light pollution.

4. Lighting system: To lessen light pollution, Germany has a well-designed and efficiently operated lighting system. India, on the other hand, has a less ad-

vanced lighting infrastructure that is frequently inadequately built, managed, and maintained, which results in a higher amount of light pollution.

5. Cultural Disparities: The trend in light pollution may also be influenced by differences in culture between the two nations. During festivals and celebrations, India's culture favors bright and colorful lighting, which can add to light pollution. In contrast, energy-saving and environmentally friendly lighting are prioritized more in Germany.

6. Climate: The climates in Germany and India are dissimilar, which may also have an effect on the rise of light pollution. In Germany, the days are shorter in the winter, therefore lighting is given more importance during this time. In India, however, the summer months have longer days and more lighting is needed, which raises the amount of light pollution there.

7. Light Sources: The types of lighting employed in the two nations may also be a factor in the rise in light pollution. LED lights are more frequently used in Germany because they are more energy-efficient and create less light pollution. India, on the other hand, continues to rely on conventional lighting, such as incandescent bulbs, which are less effective and increase light pollution.

8. Population Density: Another important aspect in the rise of light pollution is the population density of both nations. Germany has lower population density than Indai, which means that it has less need for light as well. India, in comparison, has a significantly higher population density, which necessitates more light and increases light pollution.

9. Government Policies: The trend in light pollution can also be impacted by government policies and laws. Germany has stricter lighting and light pollution restrictions, which have assisted in lowering the level of light pollution. India, on the other hand, has less stringent laws, which has led to more light pollution there.

10. Population Awareness: The trend in light pollution can also be influenced by how much the general population is aware of its effects. In Germany, there is a growing emphasis on minimizing light pollution as a result of a deeper understanding of the effects of light pollution on the environment and human health. Contrarily, India has a higher level of light pollution because there is less knowledge on how light pollution affects people there.

German regulations on light pollution control:

1. German lighting regulations: In order to reduce light pollution, this law establishes limits for outdoor lighting, including light intensity and direction.

2. Germany has designated a number of locations as "Dark Sky Parks," where artificial lighting is absolutely prohibited in order to prevent light pollution and protect the nocturnal sky.

3. Street lighting: In order to reduce light pollution, street lighting in Germany is controlled. This includes the use of LED lighting, motion sensors, and shields that aim light downward and reduce glare.

4. Building Lighting: In order to prevent light pollution, the German lighting legislation places restrictions on building lighting as well. These restrictions include the usage of dimmers and motion sensors.

5. Lighting displays for advertisements are restricted in terms of their frequency, duration, and intensity in order to lessen light pollution.

6. Energy efficiency requirements: Germany strictly enforces energy efficiency requirements for lighting, which promotes the adoption of energy-efficient lighting options like LEDs, which create less light pollution than conventional lighting sources. Germany's laws generally seek to lessen light pollution while supplying safe and reliable lighting for buildings and public areas.

3.8 Conclusions from Literature Review

Light pollution is a serious problem that impacts the environment, wildlife, and public health. The literature on this subject sheds information on both the origins and consequences of light pollution. In India, there is still a lack of awareness regarding light pollution despite the numerous issues it causes. The fact that the majority of the current study on light pollution is concentrated on big cities is one of its drawbacks. Because of this, conclusions are hard to extrapolate to smaller towns and villages. Further research is necessary because there is a sizable research vacuum for Himachal Pradesh. Lack of data on the impacts of light pollution over the long term is another drawback. To fully comprehend the issue and create workable solutions, these investigations are required. To create efficient policies and technical solutions to alleviate light pollution, interdisciplinary research involving scholars and policymakers is also essential. It is crucial to carry out studies to ascertain the existing state of knowledge on light pollution in Himachal Pradesh and the precise effects it has on humans and wildlife. This will shed light on how much has changed and what steps must be taken to properly address the issue. All interested parties, including policymakers, researchers, and the general public, should be considered when developing recommendations for dealing with light pollution. These suggestions can involve the creation of laws governing outdoor lighting, the promotion of energy-efficient lighting systems, and educational initiatives to raise public awareness of light pollution. The unique effects of institutions like IIT Mandi on the areas in which they are located should also be studied, and strategies to lessen the consequences of light pollution should be developed. This could entail collaborating with the institution to encourage appropriate lighting practises and putting in place solutions that lessen the environmental effects of light pollution.

Chapter 4

Methodology

We divided our target population into three major zones:

1. Campus residents: People living on campus
2. Buffer zone residents: People living in nearby villages that have a possibility of being affected by campus light
3. Non-buffer zone residents: People living in areas independent of campus lighting

4.1 Course of Action

The following course of action was adopted for our project:

1. Review of related literature based on impact, effects of light pollution and laws and other regulations in place regarding light pollution.
2. Survey of campus residents to understand awareness and pain points.
3. Survey of non-buffer zone residents to gauge awareness and ideas about regulations already in place. This also included students from other IITs.
4. Interviews of buffer zone residents to understand the effect of campus lighting on their town.

5. Interviews of campus residents and staff to understand the effects (if any) of highly lit areas on campus.

6. Creation of a campus zonation map to visually represent areas more severely affected by light pollution.

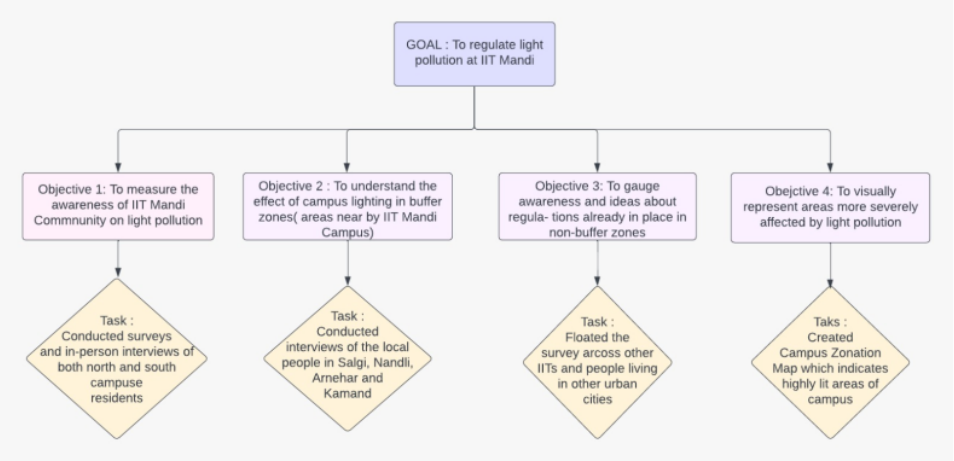


Fig. 4.1: Overview of the Methodology employed

4.2 Surveys

We conducted two different types of surveys, with 212 respondents for campus residents survey and 28 responses for non-buffer survey. The standard set of questions used as a part of the questionnaire is added in the Appendix I.

4.2.1 Campus Residents

The questions included in the questionnaire for campus residents focused on the awareness related to light pollution, its effects and impacts, along with questions based on steps or measures that are (or can be) taken to mitigate the effects, correlation of light pollution with electricity consumption and some final questions based on the campus, such as areas which the respondents feel is (are) over-illuminated.

4.2.2 Non-Buffer zone Residents

The questionnaire for survey among the non-buffer zone also included questions based on awareness, effects and impacts, steps and measures, correlation of light pollution and electricity consumption, however, instead of campus based questions it emphasized more on questions towards laws/regulations already in place to mitigate the effects of light pollution.

4.3 Interviews

4.3.1 Campus Residents

The purpose of on-campus interviews was to qualitatively and quantitatively analyse the effects of overlit areas (identified through survey results) on individuals who are always exposed to them. Interviews were conducted of the following individuals:

1. Ram Sharan (Guard of the sports complex, North Campus)
2. Paras Kanwar (Owner, Drongo Canteen)

Snippets have been added in Appendix II.

4.3.2 Buffer zone Residents

Interviews were conducted in the villages of Salgi, Nandli, Arnehar, and Kamand to understand the impact of IIT Mandi Campus lighting on their community and explore potential strategies to reduce the negative effects. Snippets added in Appendix II.

4.3.3 Non-buffer zone Residents

Interviews were conducted in Mandi town to analyse the response in a town/city completely independent of our campus lighting. It also helped us understand the level of awareness and perception of the general public regarding light pollution and its effects.

4.4 Zonation Map

The team worked towards curating a zonation map to visually represent the distribution of light pollution on campus, and identify the pain points that required immediate consideration. The team identified specific locations based on the survey results and calculated the real-time light intensity in those locations with the help of a mobile application that measured the intensity in the unit LUX with the help of mobile light sensors.

Chapter 5

Results

5.1 Survey Analysis

5.1.1 Campus Survey Analysis

The Campus Light Pollution Survey received 212 responses, categorized into North and South campus data. The survey aimed to raise awareness and understanding about light pollution, including its environmental impact and how to mitigate its harmful effects. Results showed that 74.9% of respondents had heard the term "light pollu-

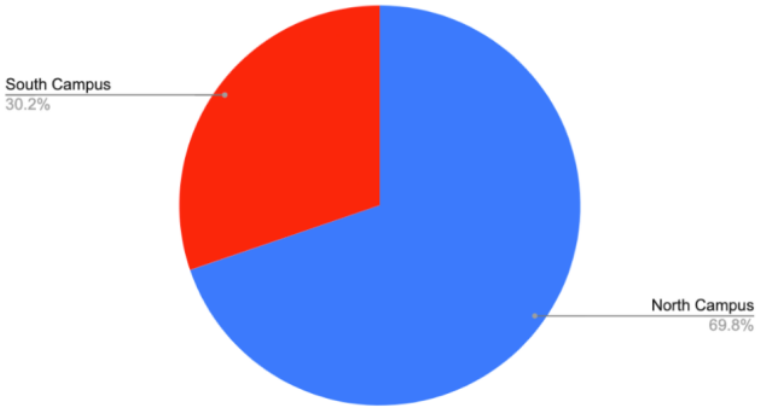


Fig. 5.1: "Count of which campus you reside in?"

tion" before, indicating increasing awareness among the public. However, 17.3% had not heard the term before, suggesting that there is still room for improvement in educating the public about this issue. A small percentage (7.9%) were unsure if they had heard the term, indicating a need for further clarification or explanation.

Most respondents (94.7%) correctly identified light pollution as excessive artificial light in the environment, demonstrating a good level of awareness of the issue. However, only 75.4% believed that the general public was aware of the threat posed by light pollution, highlighting a significant gap in public knowledge and understanding of the impact of excessive artificial lighting on the environment and human health.

Most respondents believed that light pollution can have negative health effects on humans, with increased headache incidence, stress, and anxiety being the most commonly selected options (89.8%) and increased worker fatigue due to disruption of circadian rhythm (65.2%) following closely. A smaller percentage (18.2%) also believed that light pollution could lead to decreased sexual function.

However, a small minority of respondents (7%) believed that light pollution does not affect humans. Research has shown that exposure to artificial light at night can disrupt sleep and have a range of negative health effects, including an increased risk of obesity, diabetes, and cancer. Therefore, it is crucial to continue educating the public about the potential impacts of light pollution on human health.

Most of the respondents (95.2%) believed that light pollution disrupts the natural sleep and feeding patterns of wildlife, indicating a good level of awareness among the public. However, only about 46% of the respondents believe that it causes wildlife to become more active at night, and 34.2% think it attracts more wildlife to urban areas, suggesting a need for more education and awareness-raising about this issue.

The results also suggest that light pollution delays or disrupts the blooming of flowers, according to 79.1% of respondents. Almost half of the respondents (47.1%) believe that light pollution inhibits the pollination rate of these flowers. The survey also indicates that light entering the bedroom at night often affects the sleep cycle (65.2%), highlighting the impact of light pollution on human health. The survey results also

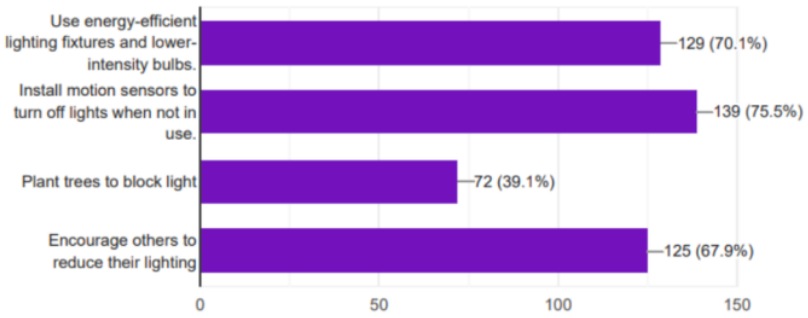


Fig. 5.2: "What steps do you think can be taken to reduce light pollution?"

suggest that respondents believe that several steps can be taken to reduce light pollution. The most popular options selected were installing motion sensors to turn off lights when not in use (75.5%) and using energy-efficient lighting fixtures with lower-intensity bulbs (70.1%). Encouraging others to reduce their lighting was also a popular option (67.9%). Interestingly, planting trees to block light was selected by only 39.1% of respondents, indicating that this may not be considered a top priority in reducing light pollution in the area.

The survey indicates that a significant proportion of respondents (33.2%) were willing to make changes to reduce light pollution in their room/office/home, while 34.8% had already taken personal steps. However, a considerable number of respondents (32.1%) reported not having taken any action or being unsure about it, suggesting a need for more awareness-raising and education about the issue.

The results also suggest that respondents believe that better-designed lighting fixtures can help reduce light pollution. The majority of the respondents (71.9%) believe that better-designed lighting fixtures that direct light where it is needed, reduce light spillage into the night sky, and reduce glare, can help reduce light pollution. Interestingly, planting trees to block light was selected by only 39.1% of respondents, suggesting that this may not be considered a top priority in reducing light pollution in the area. This highlights the importance of designing and implementing lighting fixtures that are efficient and effective in reducing light pollution in and around IIT

Mandi to minimize the adverse effects of light pollution on the environment, wildlife, and human health. Results of the survey suggest that there is a good level of awareness

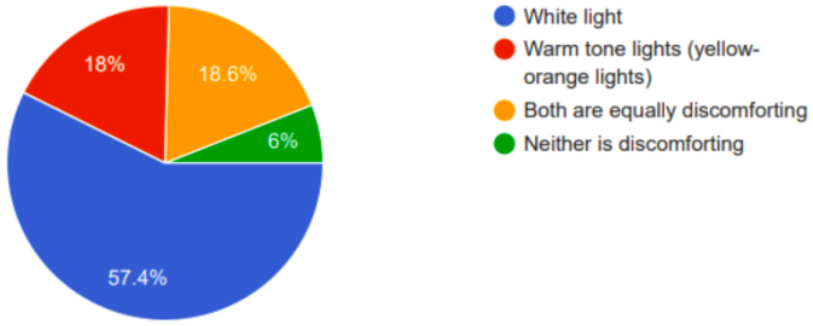


Fig. 5.3: "Which color in your opinion is most discomforting to your eyes"

among the respondents about the harmful effects of artificial lighting on human health. However, there is still a need for more education and awareness about the potential risks of blue light exposure, particularly in the evening and at night when melatonin levels are naturally higher. The survey shows that reducing the use of bright white lights in public areas or replacing them with warmer, less intense lighting options may be beneficial for reducing the effects of light pollution on individuals' comfort and well-being.

Moreover, the survey analysis indicates a high interest in sustainable energy solutions among the campus community, with most respondents preferring to use solar-powered appliances. However, it's important to compare the costs and feasibility before switching to solar-powered appliances because it might not be financially feasible.

The survey responses also suggest that more than half of the respondents believe that there are areas on campus with excessive lighting, indicating a concern about light pollution. The respondents have proposed solutions such as installing sensor-based lights, using directed street lamps, and providing separate switches to turn off lights during stargazing events or telescope sessions. The survey highlights the need to address the issue of light pollution on campus and implement measures to reduce it. It

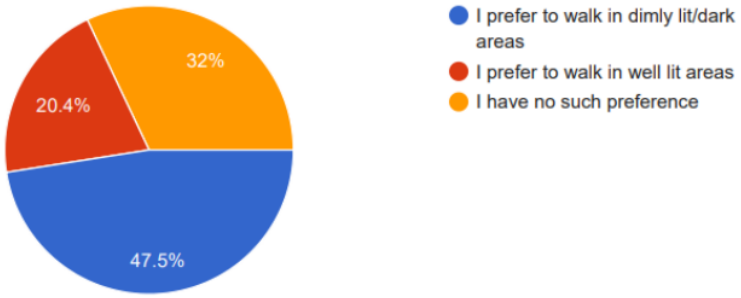


Fig. 5.4: "Do you prefer walking around certain areas on campus at night in regards to how dark/lit up the places are?"

is important to note that personal preference for lighting can vary among people, and there could be reasons why a sizable minority of respondents do not think that there are any areas that have excessive lighting. The light pollution survey results suggest a good level of awareness among respondents about the potential of solar-powered appliances to reduce reliance on traditional energy sources that contribute to light pollution. However, a small fraction of people believe that solar energy contributes to light pollution.

The survey also shows that most respondents believe that reducing light pollution can help reduce electricity, but it's important to consider potential drawbacks, such as compensatory indoor lighting or other energy-consuming devices.

The results also indicate a need to consider the reasons behind preferences for lighting in certain areas, such as personal experiences or cultural background, when designing lighting policies on campus.

The survey highlights a need for sustainable and efficient lighting solutions to reduce light pollution on the IIT Mandi campus. Additionally, there is a need for more education and awareness about the harmful effects of artificial lighting on human health and the potential risks of blue light exposure. The survey also emphasizes the importance of considering the needs and preferences of all stakeholders when designing lighting policies. Overall, the survey responses provide valuable insights into the attitudes of the IIT Mandi community towards light pollution and indicate a growing concern

about the issue.

5.1.2 Non-buffer zone Survey Analysis (Steps taken by other IITs)

There have been several steps which have been taken by other IITs, especially older IITs to combat the problem of light pollution in their campuses.

1. Optimized street lighting: A rough comparision was done for the number of street lights used to light up a certain region in IIT Mandi and IIT Madras. Both campuses are in isolated regions and so safety from animals is also a concern for both the campuses. It was observed that everything is well lit in both the campuses, however for every 1 street light in IIT Madras, IIT Mandi has approximately 2.5 street lights for the same area. Better planning could be done, including relocation of street lights so that over-illumination does not occur.

2. Utilisation of LED Lights: IIT Madras has LED lights in place of all the conventional street lights. To lessen light pollution, IIT Bombay and IIT Delhi have also put LED lights on their campuses.

3. Timers and Sensors: The street lights at IIT Kharagpur use timers and sensors. Automatically, the lights come on at dusk and go out at dawn. By doing this, it is made sure that the lights are not left on throughout the day.

4. Shielded lighting: The campus of IIT Kanpur now features shielded lighting. Since the light from these lights is directed downward, there is less light trespassing and light pollution.

5. Timers and Dimmers: IITs have also installed timers and dimmers for outdoor lighting, which automatically change the brightness of lights based on the time of day and the amount of activity in the area.

6. Dark sky observatory: IIT Indore has established a dark sky observatory on its campus for the purpose of astronomical research. Students can explore the night

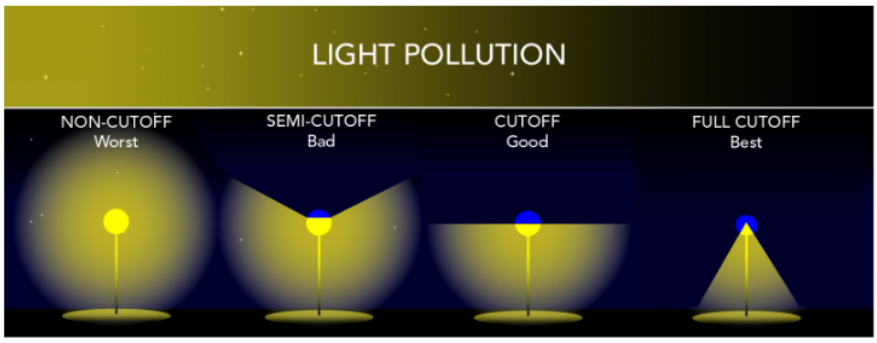


Fig. 5.5: Shielded Lighting and different amount of pollution

sky at the observatory using telescopes and other tools without contributing to light pollution.

7. Awareness Programmes: To inform students and staff about light pollution, certain IITs have also run awareness programmes. The objectives of these campaigns are to encourage sensible outdoor lighting use and lessen light pollution on their campuses.

5.2 Interview Analysis

In person interviews were conducted to better understand and analyze the awareness about the problem of light pollution and people's views. Interviews were conducted in the campus, of campus workers and security guards. INterviews were also conducted in the buffer zone, which is the neighboring villages of Kamand, Nandli, Arnehar and Saalgi. To understand the effect and awareness about light pollution in a more populous city of Himachal Pradesh, not being affected by the IIT Mandi campus, was also required, for which interviews were also conducted in Mandi town.

5.2.1 Campus Interview Analysis

Multiple interviews were conducted in the North campus including some security officers, guards of sports complex and people working in canteens, basically people working

near highly lit areas of the campus. There was a common consensus that there were extra lights in the campus at night time and turning them off would be better for the health, especially the eyes, and would help in saving energy. Considering the high amount of lights lighting up the campus, many lights could be found to be necessary and turning them off will not have a negative impact on the safety of campus residents. Lights in Over lit regions in both North and South campus can be better managed.

The sports complex's security guard, Mr. Ram Sharan, voiced his concerns about the very bright lighting on campus. He emphasized the need to turn off extra lights in particular places, like the village square and the CnP board, in order to lessen light pollution, reduce eye strain, and save on electricity. The responsibility of individuals in maintaining the natural beauty of the surroundings was emphasized by Paras Kanwar from the Drongo Canteen. Having grasped the idea of light pollution, he offered doable solutions to combat it, such as the use of energy-efficient lighting, shutting off superfluous lights, and directing lights in the appropriate directions.

The significance of using ethical lighting practices to support a cleaner and healthier environment was emphasized in both interviews. IIT Mandi can effectively combat light pollution, improve visual appeal, and lessen the negative ecological effects of excessive artificial lighting by lowering the amount of lights and their brightness. The interviews show how the IIT Mandi community is becoming more aware of and concerned about light pollution. In order to reduce light pollution on the campus, they emphasize the need for a coordinated effort to implement sustainable lighting solutions, encourage energy efficiency, and make sure that lighting fixtures are utilized wisely.

5.2.2 Buffer zone Interview Analysis

The findings of interviews conducted in the neighboring villages of Kamand, Nandli, Arnehar and Saalgi, were as follows:

1. It was discovered that the inhabitants did not know what "light pollution" meant. Only one person in twenty has heard the phrase and that too is used in relation

to cities. The need for programmes to educate people about light pollution and raise their awareness is highlighted by this.

2. The locals agreed that while light pollution may exist in cities, it is not present in the mountains since the light is contained in a valley region after the team described what it is and how it affects the environment. This impression is not totally true because mountainous areas can still be affected by light pollution.

3. Locals said that the light from the campus had little impact on Kamand, Nandli, and Arnehar, which do not directly face the college because of mountains in the way. This discovery supports the idea that the mountains in the area can serve as a natural shield against light pollution.

4. One participant in Saalgi mentioned how the illumination had changed over the last 10 years and how the campus lighting had an impact on the adjacent communities. They agreed that the visibility of the night sky had decreased drastically. This observation emphasizes how crucial it is to use ethical lighting techniques, particularly in regions where there are both human populations and wildlife.

5. Villagers also claimed that the majority of light during nighttime came from passing by vehicles.

6. The assessment found a glaring contrast between the many facilities present in IIT Mandi and how several villages were operating with very little light. This discrepancy highlights the need to close the gap between lighting infrastructure and facilities.

7. Contrary to what the team had initially believed, the residents demanded appropriate street illumination for safety reasons. This result demonstrates the importance of lighting as a service in rural locations, particularly in terms of protecting residents' safety.

8. Before IIT Mandi, there used to be a very big animal farm in the region, as per

a few locals of Kamand and Saalgi who had been living here for more than 50 years. The animal farm was also lit up at night and so IIT Mand's lights were not entirely new.

9. Finally, the possibility of IIT Mandi addressing their issues with the lack of adequate lighting facilities in the streets and villages excited the residents. This passion highlights the necessity for institutions and local communities to work together to address the problem of lighting infrastructure.

Difference in perspective: The viewpoints of people on the IIT Mandi campus and those outside of the institution differ dramatically. In contrast to the surrounding areas, where there is a shortage of lighting and no access to basic safety lighting, the campus appears to have an excess of unnecessary lights. This is a perfect example of how access to resources can vary significantly between communities and how it can produce a striking disparity in the standard of living. The observations of the people in Nandli, who calculated that only six street lights would be necessary to light up two entire villages, illustrate the glaring contrast between the excessive lighting within the campus and the absence of fundamental lighting in the neighboring villages. It is obvious that resources are being spent on the campus when even a small portion of these resources might tremendously assist the neighboring villages. On campus people have problems from excessive lighting but in nearby villages people are devoid of even the basic lighting. A redistribution and judicial use of resources is a must in such a situation.

5.2.3 Non-buffer zone Interview analysis (Mandi town)

The findings in Mandi town were similar to those in the buffer zone.The interviews with residents of Mandi town demonstrated a lack of awareness about light pollution and its threats. The residents had not heard of the term before, They did, however, recollect that as a result of development, there was more lights in the area. The people had no problem with streetlights at night as the streetlights increased the safety of the town, from thefts and crimes, as well as from wild animals. The people had no

(a) Overly lit campus area (b) Saalgi at night

Fig. 5.6: Difference between Inside the IIT Mandi campus and outside at night time.

problem with street lights as they said the street lights were very high up, if the light was directly entering their windows then it would be a problem, but that is not the case. The people were also aware that LED lights are used in most street lights, thus making them energy efficient as compared to traditional bulbs. There was a common consensus that some basic lighting should be there for safety reasons. They did add, though, that excessive brightness, like that found in cities, is undesirable. This shows that the inhabitants of Mandi town are more cognizant of the necessity for appropriate illumination as well as the negative consequences of excessive lighting on the environment and public health. They recognise that little illumination is required but also that excessive lighting can have undesirable effects. In order to encourage a balanced approach to lighting, the interviews conducted in Mandi town generally indicate that there is a need for increased awareness and education regarding light pollution in the area.

5.3 Zonation Map

To pinpoint the locations with excessive lighting, a detailed zonation map of the IIT Mandi campus was made. This map will serve as a reference for the placement of street lights and other lighting equipment in the future, ensuring that the level of illumination employed is suitable for each particular region. The team used a mobile application that makes use of the light sensor found in smartphones to record the light intensity of various areas of the North campus in order to build the map. The software offers real-time data in SI units of LUX on changes in light intensity. This strategy will assist in lowering resource waste and light pollution while maintaining the proper illumination levels for security and safety.

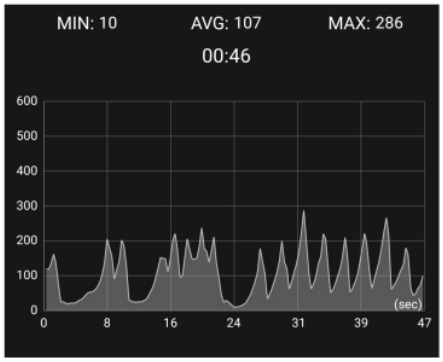


Fig. 5.7: Light Intensity (lux) vs time (s) for hostel corridors

Figure 5.6 shows how bright the hallways of a hostel are, with each peak denoting an overhead light. The graph clearly demonstrates how close together the lights are since the time difference between two successive peaks is very less. The intensity and closeness of peaks demonstrates that there is excessive lighting inside the hostels as the range of illumination for overhead lights is much more and so lights in such close proximity are not a requirement.

Figure 5.7 shows the amount of light in the village square, which serves as the main gathering place for the campus community. Except for the very first peak, which is the CnP logo and the Audi complex region, the area has a generally modest light

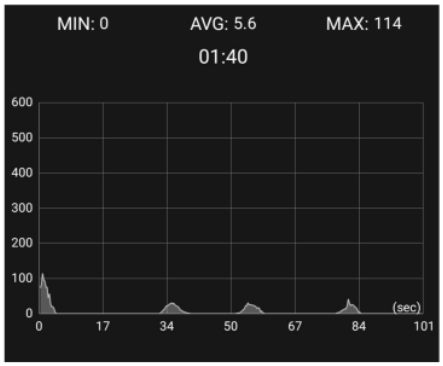


Fig. 5.8: Light Intensity (lux) vs time (s) for Village Square

intensity. The village square's brightest spot is located near the CnP Logo. The following peaks represent several locations, including the guest house, SAC building complex, and sports facility. The graph identifies the primary problem areas where there are excessive lighting resources, which can subsequently be taken into account when installing future street lighting or other lights.

The fountain region (figure 5.8) is mostly dimly lit at night and adequate illumination

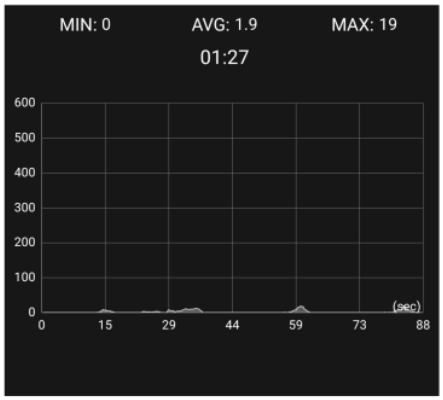


Fig. 5.9: Light Intensity (lux) vs time (s) for Fountain area

is present there throughout, which is why this region was used for astro-photography by the space and technology club of the college earlier. The elongated peak in the graph represents the CnP logo which lights up at night, after the installation of the CnP logo on the backside of the building, stargazing is no longer possible even when

all street lights are turned off in the region, due to the extensive bright light of the logo. Sometimes when the fountain is turned on, its colorful light also adds to the overall light intensity of the region.

The most surprising finding while collecting data for the zonation map was inside the

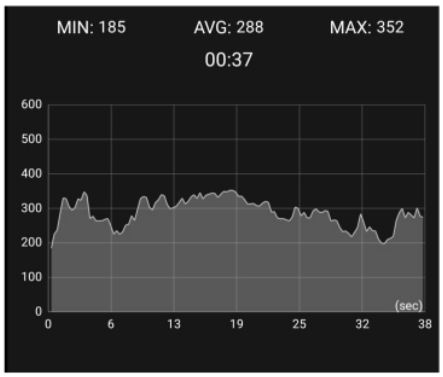


Fig. 5.10: Light Intensity (lux) vs time (s) for classrooms

classrooms (figure 5.9). As can be seen from the light intensity map, the inside of classrooms are heavily lit. This data was collected during night, when no external light was present. The classrooms are in use mostly during the day time for classes during which they are similarly illuminated. This shows the wastage of energy and resources during the daytime when natural light can be used for illumination and such a high amount of indoor lighting is not required.

The analysis and mapping of the light intensity on the Academic Road (figure 5.10) has produced some intriguing results. The graph's peaks, which are primarily caused by street lights, show how intense the light is along the road in various locations. The first peak originates from the vicinity of the bus stop, and the second peak is located close to the A9 building. The area illuminated by the School of Management sign is represented by the final elongated peak.

Figure 5.11 shows two hostels separated by the Pine Mess. The top one, B14, has brilliantly lit walls due to the presence of the School of Management sign, which is just in front of it, as can be seen from the graph. The light intensity on the walls

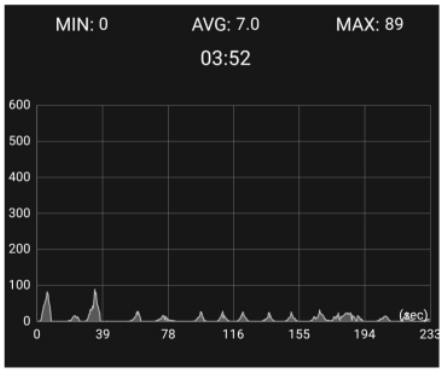


Fig. 5.11: Light Intensity (lux) vs time (s) for Academic road

of the following dormitory, B15, differs significantly from that of B14 since they are not as brightly lit. This clearly shows the amount of lighting difference one sign can make. It emphasizes the necessity of strategically placing lights only when there is a dire need or requirement.

The team's creation of a campus map (figure 5.12) reveals many locations that are overly illuminated and making people uncomfortable. They are often referred to as "pain points" in this context. The academic road and areas close to canteens are clearly lit up on the map. This indicates that people are experiencing discomfort because the lighting in these locations is brighter than is required. The School of Management and CnP sign lights, as well as other logo lights, are also highlighted on the map as being problematic for individuals. The village square and the hostel buildings are also noted for their bright lighting. Overly bright lighting in the hostels could disrupt students' sleep and lead to other issues. According to the team's study and campus interviews, many people have complained about these pain points. There may be discomfort, eye strain, headaches, or other health issues raised as a result of the extreme lighting. The zonation map aids in identifying campus locations that need to be improved in order to address the issue of excessive lighting and its effects on people's health and wellbeing. These issues can be resolved to make everyone feel more at home and welcome on campus.

Fig. 5.12: Comparison between hostel B14 (top) and B15 (bottom)

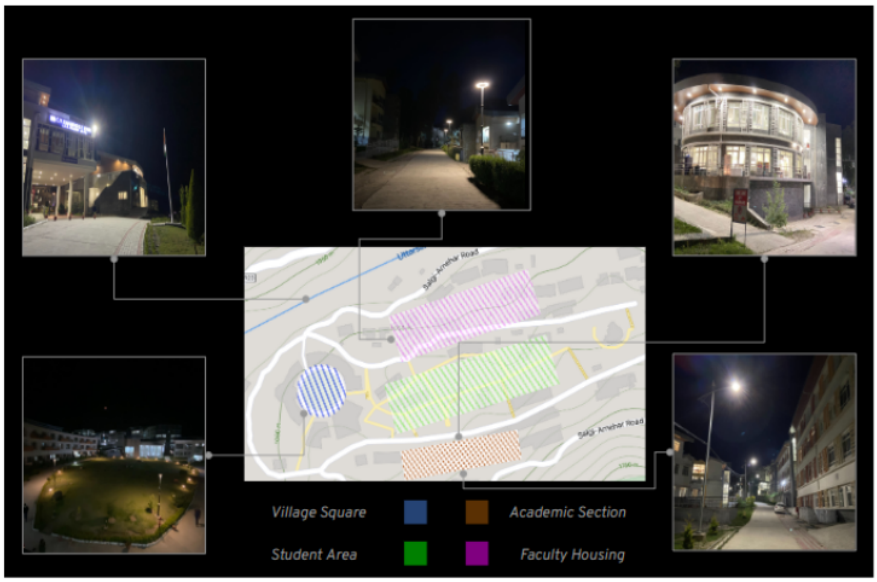


Fig. 5.13: Campus Zonation Map

Chapter 6

Recommendations and Conclusions

The results of the report underscore the severity of the issue of light pollution and its impact on various aspects of life. The findings highlight that excessive artificial light has far-reaching negative consequences, ranging from disrupted natural sleep and feeding patterns of wildlife to increased worker fatigue and risks of obesity, diabetes, and cancer in humans. This emphasizes the urgent need for immediate action to address the problem, with a focus on promoting education and awareness among the public, implementing measures to reduce light pollution, and designing efficient lighting fixtures that direct light where it is needed and reduce glare. Failure to take swift action to combat light pollution could result in irreversible damage to the environment, wildlife, and human health.

6.1 Recommendations

To address the issue effectively, we propose a set of recommendations that can be divided into two key categories: immediate and long-term measures.

6.1.1 Immediate recommendations:

1. **Identifying Overlit Areas:**Identify areas on campus that are overlit, such as the road next to CV Raman Guest House, the area near Drongo canteen and Pine mess, academic road, fountain area, and inside hostel areas. Evaluate the

lighting requirements in these areas and consider reducing the number of lights per area where possible. For instance, if three lights are not necessary and one is sufficient, reduce the number accordingly. This will significantly reduce light pollution and energy consumption.

2. **Analysing overlight areas and optimizing lighting patterns:** Assess and adjust lighting in overlit areas on campus, including the road near CV Raman Guest House, Drongo canteen, Pine mess, academic road, fountain area, and hostels. Determine the lighting requirements for each area and reduce the number of lights if possible, prioritizing energy efficiency and reducing light pollution. Additionally, review lighting patterns for banners like CNP and School of Management, considering lower-intensity bulbs, improved light direction, and timers for controlled lighting duration to mitigate negative environmental impacts.

3. **Collaborative Policy Revisions for Energy-Efficient Lighting Technologies:** Foster collaboration with authorities to revise lighting control policies, establish new guidelines, and adopt energy-efficient lighting technologies. This includes replacing high-intensity light sources with energy-efficient alternatives, and reducing energy consumption while maintaining effective illumination standards.

4. **Light Shielding with Curtains:** An efficient solution for combating light pollution, particularly in urban settings abundant with artificial illumination. Utilizing curtains effectively mitigates the environmental impact of excessive light, fostering improved sleep, relaxation, and creating a conducive atmosphere for both humans and wildlife. By effectively shielding rooms from external light sources, curtains contribute to reducing light pollution and promoting a healthier, more harmonious environment.

5. **Preserve Dark Sky Areas:** Identify and preserve designated dark sky areas on campus, such as the open-air theatre area in the south campus, which was once an excellent spot for stargazing. Implement measures to reduce artificial lighting

in these areas, allowing for better observation of the night sky and preserving the natural darkness.

6. **Collaborative Awareness Campaigns to Combat Light Pollution:** Collaborate with local authorities and student clubs, like STAC, to conduct awareness campaigns aimed at educating the public about the negative impacts of light pollution and promoting responsible lighting practices.

6.1.2 Long-term recommendations

1. **Implementing Smart Lighting Systems for Efficient Nighttime Illumination:** Excess light during the night can be mitigated by implementing a smart lighting system equipped with timers and motion trackers. This technology ensures that lights are only active when necessary, conserving energy and reducing light pollution. Additionally, the system can automatically adjust brightness and tones, providing optimal illumination while minimizing unnecessary light sources.

2. **Shielded and Directed Lighting for Minimal Light Spillage and Glare:** Utilize shielded and directed lighting techniques to minimize light spillage and glare, effectively reducing light pollution and improving visibility. By carefully controlling the direction and placement of light sources, we can enhance lighting efficiency while ensuring a more comfortable and safer nighttime environment.

3. **Optimize Classroom Lighting:** Evaluate the lighting systems in classrooms and identify opportunities to reduce unnecessary lighting. Since some classrooms receive natural sunlight, consider adjusting the number of lights turned on at a time to avoid excessive lighting overlap. Additionally, replace traditional bulbs with energy-efficient options to save electricity and reduce light pollution.

4. **Sustainable Lighting Management for Campus:** Implement regular monitoring and recording of light levels to maintain optimal ranges and address significant deviations. Establish a comprehensive lighting plan prioritizing the

reduction of light pollution while ensuring adequate safety and security lighting. Emphasize energy-efficient fixtures, glare-minimizing shielding, downward-directed lighting, motion sensors, timers, and warm-colored illumination. This holistic approach promotes environmental sustainability, preserves dark skies, and minimizes energy consumption.

5. **Promoting Sustainable Building Practices:** In the long run, encouraging sustainable development involves advocating for the use of building materials that reflect less light, such as dark-colored roofing materials and building facades. By incorporating these materials, the amount of light reflected into the sky can be reduced, contributing to the mitigation of light pollution. This proactive approach aligns with long-term efforts to preserve dark skies and minimize the environmental impact of artificial lighting.

6. **Utilize Solar-Powered Lights:** Consider the installation of solar-powered lights in suitable areas around the campus. Since the survey indicates a willingness among respondents to use solar energy, this renewable energy source can be leveraged to reduce reliance on traditional electricity and minimize light pollution.

6.2 Conclusion

Light pollution is a pressing issue that adversely affects the environment, wildlife, and human health. Through our study, we aimed to raise awareness among the IIT Mandi community about the significance of light pollution and its detrimental consequences. Our objectives included informing the community about the negative impacts, proposing guidelines and standards to limit artificial lighting on campus, and reducing the campus lighting's negative effects on the environment.

To achieve these objectives, we conducted an extensive literature review to understand the significance of light pollution and the existing practices and regulations

in place. We also surveyed the campus residents to gauge their level of awareness, views on existing lighting, and willingness to contribute to mitigating the effects of light pollution. Additionally, we interviewed campus staff to gain insights into the differences between campus lighting and residential lighting, and we conducted interviews in nearby villages to understand the impact of campus lighting on the local community.

Our findings revealed a lack of awareness among the general public regarding light pollution and its consequences. The survey and interviews on campus highlighted areas requiring immediate attention and showcased the contrast between campus lighting and lighting in nearby villages, where there was a genuine need for lighting.

Based on our results and conclusions, we developed a list of recommendations for the campus administration. Our long-term recommendations focused on creating a pollution-free campus with a balanced lighting environment and optimizing electricity consumption. These recommendations aimed to address the issue comprehensively and promote sustainable lighting practices. Additionally, we provided immediate recommendations for mitigating the current light pollution on campus, suggesting practical steps that can be taken in the short term. By implementing our recommendations, the campus can make significant strides toward reducing light pollution and its negative impacts. This would not only benefit the environment and wildlife but also enhance the well-being and health of the campus community. Furthermore, adopting sustainable lighting practices would contribute to energy conservation and promote a more harmonious relationship between human activities and the natural world.

In conclusion, light pollution poses a significant threat that requires urgent attention. Our study sheds light on the issue and provides valuable insights and recommendations for the campus administration to tackle light pollution effectively. By raising awareness, implementing sustainable lighting practices, and considering the needs of the local community, IIT Mandi can take a proactive

role in mitigating light pollution and setting an example for other institutions and communities to follow. Together, we can create a brighter future with a healthier environment for all.

Appendix A

Survey Questionnaire

The following questions were used as the survey questionnaire:

1. I understand the purpose and nature of this study and I am participating voluntarily. I grant permission for the data generated from this survey to be used in the researcher's publications on this topic
   - Yes
   - No
2. Which campus do you reside in?
   - North Campus
   - South Campus
3. Have you heard the term light pollution?
   - Yes
   - No
   - Maybe
4. What do you think light pollution is?
   - Pollution which is not very harmful
   - Light energy from the stars

- Excessive artificial light in the environment
- No clue at all

5. Do you think the general public is aware of the threat posed by light pollution?
    - Yes
    - No
    - Somewhat
    - Light Pollution is not a threat
6. What could be the health effects of light pollution on humans? (select all that apply)
    - It has no effect on humans.
    - Increased headache incidence, stress and anxiety
    - Increased worker fatigue (disruption of circadian rhythm)
    - Decreased sexual function
7. How does light pollution affect wildlife? (select all that apply)
    - It has no effect on wildlife
    - It disrupts their natural sleep and feeding patterns
    - It causes them to become more active at night
    - It attracts more wildlife to urban areas
8. What is the effect of light pollution on night blooming flowers? (select all that apply)
    - It has no effect on them
    - It improves their pollination rate
    - It inhibits their pollination rate
    - It delays or disrupts their blooming

9. Does light entering your bedroom at night affect your sleep?
    - Light does not enter my bedroom
    - Yes, it often affects my sleep
    - No, it does not affect my sleep
10. What steps do you think can be taken to reduce light pollution? (select all that apply)
    - Use energy-efficient lighting fixtures and lower-intensity bulbs.
    - Install motion sensors to turn off lights when not in use.
    - Plant trees to block light
    - Encourage others to reduce their lighting
11. Have you taken any personal steps to reduce light pollution in your room/office/home?
    - Yes, I have
    - No, I have not
    - I'm not sure
    - I would be willing to make changes
12. How, in your opinion, can better-designed lighting fixtures help reduce light pollution?
    - By directing light where it is needed
    - By reducing light spillage into the night sky
    - By reducing glare
    - All of the above
13. Are you aware that exposure to blue light, commonly found in cell phones, computer devices, and LEDs, can reduce melatonin levels in humans?
    - Yes

- No
- I don't accept this statement

14. Which light color, in your opinion, is the most discomforting to your eye?

    - White light
    - Warm tone lights (yellow-orange lights)
    - Both are equally discomforting
    - Neither is discomforting

15. What do you think is the relationship between reducing light pollution and reducing electricity consumption?

    - Reducing light pollution has no impact on reducing electricity consumption
    - Reducing light pollution can help reduce electricity consumption and energy waste
    - Reducing light pollution can increase electricity consumption
    - Reducing light pollution can only be achieved by increasing electricity consumption.

16. According to you, how can reducing light pollution help reduce greenhouse gas emissions?

    - By reducing the amount of electricity used for lighting
    - By reducing the amount of heat trapped in the atmosphere
    - By reducing the amount of greenhouse gases emitted by light fixtures
    - All of the above

17. What do you think is the relationship between solar energy, solar-powered appliances, and light pollution?

    - They are unrelated

- Solar energy contributes to light pollution
- Solar-powered appliances reduce the need for traditional energy sources that contribute to light pollution
- Solar energy and solar-powered appliances have no impact on light pollution

18. Would you prefer to use solar powered appliances on campus?
    - Yes
    - No
    - Maybe
19. Are there any areas on IIT Mandi campus that you think have excessive lighting?
    - Yes
    - No
    - If yes, please specify
20. Do you feel the village square is over illuminated at night?
    - Yes
    - No
    - Maybe
21. Do you prefer walking around certain areas on campus at night in regards to how dark/lit up the places are?
    - I prefer to walk in dimly lit/dark areas
    - I prefer to walk in well lit areas
    - I have no such preference
22. Would you approve if the hostel corridor lights are switched off during the day?
    - Yes

- No

23. Do you think that the hostel corridor lights must be switched to warm tone lights?

    - Yes
    - No, I prefer white lights
    - I don't think there will be a difference

24. Do you think that certain regulations should be put in place to mitigate the effects of light pollution on campus?

    - Yes
    - No

25. Do you think that more education and awareness about light pollution should exist?

    - Yes
    - No
    - Maybe
    - There is no need for any education and/or awareness

Appendix B

Interview Snippets

B.1 Campus Interviews

B.1.1 Synopsis

Ram Sharan, the guard of the sports complex, expressed his concerns about excessive lighting on the campus. He emphasized the need to turn off extra lights in specific areas, such as the village square and the Cnp board, to reduce light pollution and minimize visual discomfort and electricity wastage.

Paras Kanwar from the Drongo Canteen highlighted the responsibility of individuals in preserving the natural beauty of the surroundings. After understanding the concept of light pollution, he suggested practical measures to tackle it, including the use of energy-efficient lighting, turning off unnecessary lights, and directing lights where they are needed.

Both interviews underscored the importance of adopting responsible lighting practices to contribute to a cleaner and healthier environment. By reducing the number of lights and their brightness, IIT Mandi can effectively address light pollution, enhance visual aesthetics, and minimize the ecological impact of excessive artificial lighting.

The interviews reflect the growing awareness and concern within the IIT Mandi community regarding light pollution. They highlight the need for a collective effort to

implement sustainable lighting solutions, promote energy efficiency, and ensure that lighting fixtures are used judiciously to minimize light pollution on the campus.

In conclusion, the interviews with Ram Sharan and Paras Kanwar provide valuable insights into the viewpoints and recommendations of individuals regarding light pollution in IIT Mandi. Their suggestions emphasize the importance of reducing unnecessary lighting, utilizing energy-efficient technologies, and directing lights appropriately to create a more sustainable and environmentally friendly campus.

B.1.2 Interview Snippets

B.1.2.1 On-campus Interviews

"I turn on the lights of the sports campus at 4 PM and turn them off at 9 PM, but if it were up to me, I would turn off most of the lights that remain on during the night. They not only look ugly and cause irritation, but they also lead to wastage of electricity. If I had the authority, I would turn off the extra lights in the village square and the Cnp board, which is directly facing my sitting place. It is essential to reduce the number of lights and their brightness to significantly help in reducing light pollution."

- Ram Sharan (Guard, Sports Complex)

"As responsible citizens, it is our duty to preserve the natural beauty of our surroundings and reduce the impact of our actions on the environment and human health. By adopting responsible lighting practices, we can contribute to a cleaner and healthier environment. We can reduce light pollution by using energy-efficient lighting, turning off unnecessary lights, and ensuring that the lights are directed where they are needed.

-Paras Kanwar (Drongo, Canteen owner)

B.1.2.2 Off-Campus Interviews

Mr.Bashir, Local Doctor and Electrician, Nandli

- Didn't feel there is any adverse effect of light. Light form the campus does not

reach Nandli and Arnehar.

- White lights are clear lights as compared to yellow lights. Nowadays, LEDs are used, and they are better than old bulbs.
- People feel safe from wild animals. Locals counted a total of 6 street lights are enough to light up the complete villages of Nandli and Arnehar combined (One park in IIT Mandi has more than 6 street lights!)

Mr. Jagatram Rao, works in Post office, Kamand

- Light from IIT Mandi Campus (South) is limited, stopped by mountains. Light from petrol pump in Kamand is also limited.
- There used to be a horse farm before IIT Mandi in the same region, which also had lighting at night. No major change in lighting observed in Kamand
- Lack of proper street lights in Kamand. Proper street lighting is needed for safety from wild animals.

Shop Owner in Salgi

- Need streetlights at night for safety. LED lights are much better and help save electricity.
- Observation made that stars are not that visible at night, They have a house in Saalgi, in front of campus.
- They go to bed early, so lights from campus don't affect them that much
- Most light in Salgi at night is due to passing by vehicles. The number of vehicles passing by has increased drastically.

Appendix C

Photo Gallery

C.1 On-Campus Interviews

The recommendations place a strong emphasis on the necessity of minimizing unnecessary lighting, utilizing energy-efficient technologies, and strategically directing lights.

C.2 Buffer Zone Interviews

Interviews were conducted in the neighboring villages of Kamand, Nandli, Arnehar, and Saalgi and also near the Municipal Corporation in Mandi Town. Interviewing candidates in nearby areas of IIT Mandi was a positive experience. The respondents' friendly and enthusiastic attitude makes it easier to acquire insightful information and viewpoints on the issue of light pollution.

C.3 Overly Lit Areas in North Campus

he North campus has areas like the Canteen, Village Square, and Academic area that are overly lit at night with high-intensity lights. However, there is no need for so many bright lights since students cannot be outside their hostels after 2 am. Therefore, it seems unnecessary to maintain such high levels of lighting in those areas.

(a) Drongo Owner, Mr. Paras

(b) Sports Complex Gaurd Interview

Fig. C.1: On-Campus Interviews

Table C.1: Off-Campus Interviews

Table C.2: Off-Campus Interviews

Table C.3: Overly Lit Areas in North Campus

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