MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ECOLOGY

APPROVED TO DEFENCE
Head of the Graduate Department
_____ V.F. Frolov
«_____» _____ 2020

MASTER THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 "ECOLOGY",
TRAINING PROFESSIONAL PROGRAM
"ECOLOGY AND ENVIRONMENTAL PROTECTION"

Theme: «Analysis of the light pollution in the city of Kyiv»

Done by: student of the ЕК-202ма group, Virtoriia V. Kovalska
(student, group, surname, name, patronymic)

Supervisor: PhD in Engineering, Associate Professor Margarita M. Radomska
(academic degree, academic rank, surname, name, patronymic)

Consultant of the chapter "Labor Precaution": _____ Olena V. Konovalova
(signature) (S.N.P.)

Standards Inspector: _____ Andrian A. Iavniuk
(signature) (S.N.P.)

KYIV 2020

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____ В.Ф. Фролов
«_____» _____ 2020 р.

ДИПЛОМНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»,
ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: «Аналіз світлового забруднення у місті Києві»

Виконавець: студентка групи ЕК-202ма Ковальська Вікторія Володимирівна
(студент, група, прізвище, ім'я, по батькові)

Керівник: к.т.н., доцент Радомська Маргарита Мирославівна
(науковий ступінь, вчене звання, прізвище, ім'я, по батькові)

Консультант розділу «Охорона праці»: _____ Коновалова О. В.
(підпис) (П.І.Б.)

Нормоконтролер: _____ Явнюк А.А.
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КИЇВ 2020

NATIONAL AVIATION UNIVERSITY

Faculty of Environmental Safety, Engineering and Technologies

Department of Ecology

Specialty, training professional program: specialty 101 “Ecology”, Training Professional Program “Ecology and Environmental Protection”

(code, name)

APPROVED
Head of the Department
_____ Frolov V.F.
«____» _____ 2020

MASTER THESIS ASSIGNMENT

Viktoriia V. Kovalska

1. Theme: «Analysis of the light pollution in the city of Kyiv» approved by the Rector on October 06, 2020, № 19371/ст

2. Duration of work: from 05.10.2020 to 21.12.2020

3. Output work (project): the research data taken by the measurement of light pollution level in the Kyiv city

4. Content of explanatory note: (list of issues): Analytical review of the literature on the topic of the diploma. Analysis of the level of light pollution in the city of Kyiv. Assessment of hazardous impacts of light pollution on human, flora and fauna. Recommendations for reducing the level of light pollution in Kyiv.

5. The list of mandatory graphic (illustrated materials): tables, figures.

6. Schedule of thesis fulfillment

№	Task	Term	Advisor's signature
1	Receive themes task, search the literature and legislation	05.10.2020	
2	Preparing the main part (Chapter I)	06.10.2020	
3	Preparing the main part (Chapter II)	13.10.2020	
4	Preparing the main part (Chapter III)	22.10.2020	
5	Preparing the main part (Chapter IV)	01.11.2020	
6	Consultation on section V (Occupation safety)	05.11.2020	
7	Preparing the main part (Chapter V)	06.11.2020	
8	Formulating conclusions and recommendations of the thesis	21.11.2020	
9	Making an explanatory note to the previous presentation of the department, consultation with the norms controller	30.11.2020	
10	Presentation of the work at the department	01.12.2020	
11	Taking into account the comments and recommendations and training to protect	06.12.2020	
12	Thesis defense at the department	21.12.2020	

7. Consultant(s) of certain chapter(s):

Chapter	Consultant (academic rank, S.N.P)	Date, signature	
		Given by	Accepted by
Labor Precaution	Olena V. Konovalova Assosiate professor Chair of Civil and Industrial safety		

8. Date of task issue: «5» October 2020

Diploma (project) advisor: _____ Margarita M. Radomska
(advisor's signature) (S.N.P.)

Task is taken to perform: _____ Viktoriia V. Kovalska
(graduate's signature) (S.N.P.)

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
Факультет екологічної безпеки, інженерії та технологій
Кафедра екології
Спеціальність, освітньо-професійна програма: спеціальність 101 «Екологія», ОПП «Екологія та охорона навколишнього середовища»
(шифр, найменування)

ЗАТВЕРДЖУЮ
Завідувач кафедри
_____Фролов В.Ф.
«____» _____ 2020 р.

ЗАВДАННЯ
на виконання дипломної роботи
Ковальської Вікторії Володимирівни

1. Тема роботи «Аналіз світлового забруднення у місті Києві»
затверджена наказом ректора від «6» жовтня 2020 р. №19371/ст

2. Термін виконання роботи: з 05.10.2020 р. по 21.12.2020 р.

3. Вихідні дані роботи: дані дослідження, отримані шляхом вимірювання рівня світлового забруднення в місті Києві.

4. Зміст пояснювальної записки: Аналітичний огляд літератури за темою диплому. Аналіз рівня світлового забруднення у місті Києві. Оцінка небезпечних впливів світлового забруднення на людину, флору та фауну. Рекомендації щодо зниження рівня світлового забруднення в Києві.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Отримання теми завдання, пошук літературних джерел та законодавчої бази	05.10.2020	
2	Підготовка основної частини (Розділ I)	06.10.2020	
3	Підготовка основної частини (Розділ II)	13.10.2020	
4	Підготовка основної частини (Розділ III)	22.10.2020	
5	Підготовка основної частини (Розділ IV)	01.11.2020	
6	Консультація по розділу V (Охорона праці)	05.11.2020	
7	Підготовка основної частини (Розділ V)	06.11.2020	
8	Формулювання висновків та рекомендацій дипломної роботи	21.11.2020	
9	Оформлення пояснювальної записки до попереднього представлення на кафедрі, консультація з нормоконтролером	30.11.2020	
10	Представлення роботи на кафедрі	01.12.2020	
11	Урахування зауважень, рекомендацій та підготовка до захисту	06.12.2020	
12	Захист дипломної роботи на кафедрі	21.12.2020	

7. Консультація з окремого(мих) розділу(ів):

Розділ	Консультант (посада, П.І.Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	Коновалова Олена Вікторівна, доцент Кафедра цивільної та промислової безпеки		

8. Дата видачі завдання: «5» жовтня 2020 р.

Керівник дипломної роботи (проекту): _____ Радомська М.М.
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: _____ Ковальська В.В.
(підпис випускника) (П.І.Б.)

ABSTRACT

Explanatory note to thesis «Analysis of the light pollution in the city of Kyiv»: 79 pages, 13 figures, 13 tables, 35 references.

Object of research – processes of pollution formation under the influence of artificial light sources.

Aim of work – assessment of the light pollution level and its impact on environment.

Mehods of research: methods of analysis of sky by Bortle scale; comparative analysis of the obtained values of light level in the Kyiv city.

LIGHT POLLUTION, LIGHT, BORTLE SCALE, SKY, ILLUMINATION, GLARE, BRIGHTNES, SKY GLOW, LEVEL OF LIGHT.

CONTENT

INTRODUCTION

Relevance of the work. Nowadays, artificial light sources are an integral part of modern cities. However, the problem is that their number far exceeds that needed to provide a sufficient level of lighting on the city streets. Nowadays, the problem of light pollution in cities is becoming increasingly important, as this issue is poorly regulated at the pre-trial level. And the impact of light pollution is felt by both the city population and the biota on the whole.

Aim of the work – assessment of the light pollution level and its impact on environment

Tasks of the work:

1. To analyze the problem of light pollution in the world and Ukraine;
2. To evaluate the level of light in Kyiv during a year;
3. To study the the condition of sky in terms of light pollution ffects in Kyiv;
4. To analyze impact of light pollution on humans, flora and fauna;
5. To make conclusions and recommendations to reduce level of light pollution in Kyiv.

Object of research is the process of pollution formation by artificial light sources.

Subject of research is level of light pollution on the streets of Kyiv.

Methods of research – photometric measurements; visual observation; methods of analysis of sky by Bortle scale; comparative analysis; human health risks assessment.

Scientific novelty of the obtained results. For the first time the analysis of the level of light pollution in the city of Kyiv was conducted and the related human health risk for the population in the study area were assessed, as well as implications for biotic components.

Practical importance of the obtained results. Improvement of the light level at the studied areas through the recommendations for administration of these areas on methods of regulation of light level; reduction of health risks for population and biota.

Personal contribution of the graduate: measuring the level of lighting in the city of Kyiv in the period from December 2019 to September 2020, analysis of the results, comparison of the results with the background values, development of recommendations for reducing the level of light pollution in the city of Kiev.

Approbation of results:

1. Radomska M.M., Kovalska V.V. Regulation of light pollution: тези доп. XI Міжнародної науково-практичної конференції «Архітектура та екологія», Київ, 10-12 листопада 2020 р. – С. 152.

2. V.V Kovalska, M. M. Radomska, Light pollution as an environmental issue: тези доп. Всеукр. наук.-прак. конф. „Екологічна безпека держави", Київ, 23 квітня 2020 р. – С.48-49.

3. Ковальська В. В., Радомська М. М. Світлове забруднення у місті Києві: VIII Міжнародної наукової конференції молодих вчених «Екологія, неоекологія, охорона навколишнього середовища та збалансоване природокористування», Харків, 26 – 27 листопада 2020 р.

Publications*:*

1. M. Radomska, I. Horobtsov, L. Cherniak, O. Tykhenko and V. Kovalska. The analysis of airports physical factors effects on wildlife. IOP Conference Series: Materials Science and Engineering, September 2020.

CHAPTER 1
LIGHT POLLUTION AS A PROBLEM OF MODERN CIVILIZATION

1.1. Natural lighting and its properties

The development of mankind as a species largely depends on the state of its environment. The attention of ecologists has traditionally been drawn to the global issues of the state of the atmosphere, hydrosphere and vegetation of our planet, i.e. to the macroenvironment. However, human health is primarily affected by the microenvironment. It is here that various fields play a significant role, the mechanism of action of which, as a rule, is insufficiently studied. Such fields include electromagnetic, radiation, gravitational and light. The results of the first three can be judged from experimental data, which indicate that any deviations from the natural background value have a detrimental effect on living organisms. The impacts of light, however, are not studied well.

Light or visible light is electromagnetic radiation within the portion of the electromagnetic spectrum that can be perceived by the human eye. Visible light is usually defined as having wavelengths in the range of 400–700 nanometers (nm), or 4.00×10^{-7} to 7.00×10^{-7} m, between the infrared (with longer wavelengths) and the ultraviolet (with shorter wavelengths). This wavelength means a frequency range of roughly 430–750 terahertz (THz).

From a physical point of view, the concept of "light field" does not exist. Light is an electromagnetic wave in the wavelength range of 0.4 to 0.8 μm, i.e. is one of the manifestations of the electromagnetic field. However, unlike other electromagnetic waves, light has a fundamentally different way of affecting the human body. It is known that more than 90% of information a person receives through its vision and it is, in turn, provided by the impact of optical radiation on the eye. This may be perceived as the concept of "light field", which involves the entire human world in terms of light waves received by the eye. In addition to its informational significance, this field has a powerful impact on the general condition of man, which allows us to consider it as an independent component of the

environment. Despite this, its influence was clearly underestimated, and sometimes even ignored.

When man emerged as a species, the only source of light on the Earth was the Sun. The sun's rays either reach the earth's surface directly or are previously scattered in the atmosphere. This determines two characteristic spectra of natural radiation: warm "solar" and cool "day". This is the natural light climate of our planet to which the biorhythms of human body are adapted. Optical radiation is characterized by the total intensity, as well as distribution along the spectrum, time and space. Natural radiation is relatively evenly distributed in space, and its intensity changes smoothly from sunrise to sunset.

Sunlight provides the energy that green plants use to create sugars mostly in the form of starches, which release energy into the living things that digest them. This process of photosynthesis provides virtually all the energy used by living things. Some species of animals generate their own light, a process called bioluminescence. For example, fireflies use light to locate mates, and vampire squids use it to hide themselves from prey.

Light is an important environmental factor that determines the biological rhythms (daily, lunar, annual) in the life of most animals and their ability to orient in space. The sources of light on the Earth are the Sun, stars and bioluminescence. An important aspect of light as an environmental factor is its intensity and spectrum in both the visible and ultraviolet and infrared wavelength ranges.

Light is the main source of energy that is absorbed by plants in the form of chemical bonds in sugars, and those with plant biomass are food for animals. Solar energy, which green plants absorb and use in the process of photosynthesis, is called physiologically active radiation. These are rays with a wavelength of 0.4… 0.71 μm, but the plant absorbs energy within these limits differently. In addition, in the life of plants the amount of light is of great importance, i.e. the intensity of light, which is different in different months of the growing season and also depends on the latitude. Plants on our planet grow in different light conditions: from excessively illuminated mountains, deserts, steppes to semi-dark caves and sea depths. Therefore, plants in the process of natural selection have made numerous adaptations to life in accordance with a particular light regime. In relation to

light, plants are divided into three main groups: light-loving, or heliophytes, shade-loving, or sciophytes, and shade-tolerant.

Light affects the biological rhythms of animals, due to the adaptation of animals to natural light sources on the planet's surface. Daily changes in illumination are highly regular, as they occur due to astronomical processes - the rotation of the Earth around its axis, and cause daily changes in the activity of animal behavior. Similarly, the annual changes in illuminance are due to the angle of inclination of the planet to its axis, and cause the emergence of annual biorhythms in animals. Lunar biorhythms of animals are due to the cyclical change of phases of the Moon, and, accordingly, the increase or decrease in the level of night light. Animal perception of spectral differences in light is called vision, which can be monochrome or black and white (for example, some worms, bivalves and gastropods), dichromic or bicolor - perceived colors are blue and red (for example, most mammals), trichrome or tricolor - perceived colors are blue, yellow and red (for example, primates and humans) and tetrachrome or four-color – perceived colors are ultraviolet, blue, yellow and red (for example, most insects, birds, reptiles, fish, cephalopods, etc.). Some animals (for example, rattlesnakes, mosquitoes) also perceive infrared radiation, which is heat, or thermal radiation [20].

The primary properties of visible light are intensity, propagation direction, frequency or wavelength spectrum, and polarization, while its speed in a vacuum, 299,792,458 meters per second, is one of the fundamental constants of nature. Visible light, as with all types of electromagnetic radiation (EMR), is experimentally found to always move at this speed in a vacuum [1].

Lighting is differentiated into natural, artificial and combined. Sources of natural light are the sun and direct light from the sky. The sources of artificial light today are lamps of various types. With combined lighting, the room is illuminated with both natural and artificial light in certain proportions.

The main requirement for natural light in residential, public and industrial buildings is to provide the best lighting for the workplace or object that is perceived by a person under observation. Not only the conditions of visibility of the object are important, but also the "field of adaptation" - the surrounding light environment, which is very important,

especially in residential, school buildings, as well as in kindergartens and nurseries. Natural lighting has a very large impact on human well-being, his psychophysical condition and productivity. But technically speaking, humans now live more under daylight, than under natural light. Day lighting is a technique that efficiently brings natural light into your home using exterior glazing (windows, skylights, etc.), thereby reducing artificial lighting requirements and saving energy. Natural lighting has been proven to increase health and comfort levels for building occupants.

Effective natural lighting will admit natural light, but will avoid admittance of direct sun on task surfaces or into occupants' eyes. Daylight inside a home can come from three sources:

- Direct sunlight - direct light from the Sun.
- External reflection - light reflecting off of ground surfaces, adjacent buildings, light shelves, and wide window sills. Excessive reflectance is undesirable as it causes glare.
- Internal reflection - light reflecting off of internal walls, ceiling, and the floor of your home. This also includes high reflective surfaces such as smooth or glossy surfaces, light colored finishes, and mirrors around a room.[2]

1.2. The concept of light pollution

The first artificial light source was an open flame, which was used to produce fires, later - candles and oil lamps. The transition to better burner designs provided a high flame brightness, which reached its maximum in gas lamps with the so-called Luscher cap - a piece of fire-resistant fabric that glowed in the flame and gave a bright white light.

From the point of view of ergonomics of light, the intensity of radiation of the source is, although important, but not the only criterion for assessing its quality. The recognition of this fact did not come simultaneously with the beginning of the widespread use of artificial lighting. Electric lamps first appeared in the second half of the XIX century. They improved only in the direction of increasing their light output, i.e. the amount of light produced per 1 watt of electric power. It is interesting to note that initially electric light was considered ineffective, because the first samples of incandescent lamps were significantly inferior in brightness to the then common gas and kerosene lanterns.

The first source of light used by people in their work was the flame of the fire. Over time and with the growth of experience, people have found that more light can be obtained by burning any resinous species of wood, natural resins, oils and waxes. In terms of chemical properties, such materials contain higher percentage of carbon by weight and during combustion, sooty carbon particles are heated in the flame and emit light.

Further, with the development of metalworking technologies, the development of methods of rapid ignition and, to a large extent, with the improvement of the first independent light sources that could be installed in any spatial position, transferred and recharged with fuel were invented and are widely applied since then. Similarly, the progress in the processing of oil, waxes, fats, oils and some natural resins allowed to allocate the necessary fuel fractions: refined wax, paraffin, stearin, palmitin, kerosene and more. Such sources were, first of all, candles, torches and later oil lamps and lanterns. Light sources that use the energy of fuel combustion are very convenient, but from the point of fire safety (open flame), emissions of incomplete combustion products (soot, fuel vapor, carbon monoxide) pose danger as a source ignition. History knows many examples of large fires, caused by oil lamps and lanterns, candles and more.

Further progress and development of knowledge in the field of chemistry, physics and materials science, allowed people to use various combustible gases, producing more light during combustion. A special convenience of gas lighting was that it was possible to illuminate large areas in cities, buildings, etc., due to the fact that gases could be very conveniently and quickly delivered from the central storage (cylinders) using rubberized hoses (hoses), or steel or copper piping, and, it is easy to cut off the gas flow from the burner by simply turning the shut-off valve. The most important gas for the organization of urban gas lighting was the so-called "light gas", produced by pyrolysis of marine animal fat (whales, dolphins, seals, etc.), and later produced in large quantities from coal during coking on gas lighting factories.

One of the most important components of light gas, which gave the greatest amount of light, was benzene, discovered in light gas by M. Faraday. Another gas that was widely used in the gas lighting industry was acetylene, but due to its ignitability at relatively low temperatures and large concentration limits, it was not widely used in street lighting and

was used in mining and bicycle "carbide" lanterns. Another reason for this was its high cost compared to light gas.

In parallel with the development of a variety of fuels in chemical light sources, improved their structure and the most cost-effective method of combustion (regulation of air flow), as well as design and materials to enhance light and power (wicks, gas incandescent caps, etc.) to replace short-lived wicks of plant materials yarn), began to use impregnation of plant wicks with boric acid and asbestos fibers, and with the discovery of the mineral monazite found its excellent property for calcination, very bright and contribute to the complete combustion of light gas. To increase the safety of use, the working flame began to be enclosed with metal nets and glass caps of various shapes.

The scientific progress of the XX century brought new era of lighting technologies due to the discovery of electricity and the invention of current sources. At this stage of scientific and technological progress, it has become clear that to rise the brightness of light sources, it is necessary to increase the temperature of the area emitting light. If combustion reactions of various fuels in air are applied, the temperature of the combustion products reaches 1500-2300°C, but with application of electricity, the temperature can be significantly increased. When heated by electric current, various conductive materials with the high melting point emit visible light and can serve as light sources of varying intensity. The following materials were proposed: graphite (carbon fiber), platinum, osmium, tungsten, molybdenum, rhenium and their alloys. To increase the durability of electric light sources, their working bodies (spirals and filaments) were placed in special glass cylinders (lamps), vacuumed or filled with noble or inactive gases (hydrogen, nitrogen, argon, etc.).

When choosing the working material, the lamp designers were guided by the highest operating temperature of the spiral heating, and the main preference was given to carbon and, further, tungsten. Tungsten and its alloys with rhenium are still the most common materials for manufacturing electric incandescent lamps, because under the best conditions, they are able to heat up to temperatures of 2800-3200°C.

In parallel, the work on electric arc light source and light sources based on the glow discharge (Yablochkov's candle) was also started and significantly developed with an. Arc light sources made it possible to obtain light fluxes of huge power (with the light intensity

of hundreds of thousands and millions of Candelas), and light sources based on a glow discharge demonstrate extremely high efficiency. At the beginning of the XXI century, the most advanced light sources are those based on electric arc sodium, krypton, xenon, mercury discharge and metal halide lamps; based on incandescent discharge in inert gases (helium, neon, argon, krypton and xenon) with mercury vapor; based on the effect of electroluminescence, and LED lamps and matrices. The most powerful and bright artificial light sources, as of 2017, were lasers. Very powerful light sources are also a variety of pyrotechnic lighting compounds used for photography, lighting of large areas in the military field (photo bombs, flares and lighting bombs).

The artificial illumination has turned to be the sign of civilization; as a result it was considered a must for infrastructure development and marketing purposes. This has led to the situation, when the cities are now the islands of light – glowing through the whole night. This has not only changed the visual environment we live in, but distorted the natural view and hid the view of natural surroundings. Thus, a study conducted using satellite ground-based surveillance systems shows that the next generation of Earthlings will not be able to observe the Milky Way without special devices. According to the data, even now for two-thirds of the world's population, the sky will never be just black and strewn with stars. Artificial light is probably the most reliable sign of human dominance on the planet.

According to some studies, the night sky over the European Union is 85% brighter than its natural state. In the US, this figure is 62%, in Japan – 98.5. In countries such as Germany, Austria, Belgium and the Netherlands, the night sky no longer exists as such: it is constantly illuminated by the reflected light of cities. Today, the inhabitants of megacities, instead of 2,500 stars, really visible in the night sky with the naked eye, can see only a few dozen of the brightest of them. Everything else is drowning in the city light. And what's worse, this trend is growing steadily these days.

The reason for this phenomenon is the light "pollution" of the atmosphere. That is, the presence of anthropogenic and artificial light in the night environment. It is formed by excessive, misdirected or obtrusive use of light, but even carefully used light fundamentally alters natural conditions. As a major side-effect of urbanization, it raises

concerns due to human health effects, ecosystems disruption and spoiling aesthetic environments. This "extra light" is mainly due to the poor design of lanterns that scatter rays horizontally and into the sky. This light blinds drivers and pedestrians, putting their lives at risk. At the same time, the senseless consumption of electricity is billions of dollars a year around the world.

Astronomy is also very sensitive to artificial sky lighting. Most observations, especially in the field of extragalactic research and cosmology, can now be made only in places hundreds of kilometers away from large cities. Some old observatories suffer greatly from urban skylight. The new observatories are located in remote locations, and astronomy enthusiasts have to travel far beyond the city to conduct their observations.

The thing is that artificial light interrupt starlight, which is even more scattered and the result of light pollution is the phenomenon of "glow" of the sky: artificial light directed upward is scattered by atmospheric particles (molecules and aerosols) and produces glow. The glow of the sky, which is present during observations from astronomical observatories, plays the role of a light veil, which reduces the visibility of the sky and creates difficulties in observing the stars.

Italian astronomers Fabio Falchi et al. have recently compiled the first atlas of night sky illumination [DOI: 10.1126/sciadv.1600377]. The first images of terrestrial lights were taken from satellites in the late 80's, they can see not only large cities, but also oil fields, which burn fugitive gas, large forest fires and even clusters of fishing vessels in the ocean. But for the first time, the Italians were able to take into account the effects of light scattering from terrestrial sources on clouds and atmospheric dust. It turned out that the light of a single street lamp can interfere with the observer, who is at a distance of 200 kilometers. The light of large cities is already damaging even telescopes installed in the Canary Islands, the mountains of Chile and Hawaii.

The advent of electric lamps has created another significant problem. When the lamp is supplied with alternating current, the light emitted by it pulsates with the frequency of this current. There is a significant difference from natural radiation. Excess night lighting not only causes an increase in the brightness of the sky, but also adversely affects the environment, interfering with the natural rhythms of the biosphere.

1.3. The main sources of light pollution

The main cause of light pollution is outdoor luminaires that emit light upwards or sideways. Any light that bursts upward, except when a tree or building can block it, will scatter throughout the atmosphere and brighter the night sky, thereby reducing the view of it. Particulate air pollution will also increase light scattering at night, as will visibility during the day. Some light is reflected from the earth and scattered across the sky, but this has less effect than light that shines straight up. Recent studies show that light emitted slightly above the horizontal (slightly upwards) is the most likely cause of light pollution (Luginbuhl, Walker & Wainscoat, 2009). Such light, which grazes on the entire surface of the Earth, is several times more harmful than light that is emitted directly upwards. This emphasizes the importance of using well-designed luminaires with a full design.

Outdoor lighting consumes about three to five percent of electricity demand in developed countries. Depending on how light is identified and local lighting practices, the proportion of outdoor lighting that contributes to light pollution can range from 20 to more than 50 percent. Thus, minimizing light pollution also provides significant energy savings nationwide and provides an economic incentive to upgrade or replace outdoor lighting with more sustainable solutions.

In some cases, even a single light can be destructive to the natural landscape. Although one light may not affect the entire night sky, a bright spot light source can irritate neighbors (a problem called light breakthrough), reduce notions of loneliness and naturalness, confuse nocturnal animals, migratory birds, insects, and spoil cultural landscapes. Even a candle that can be seen from a mile is brighter than every star in the Big Dipper, so very small amounts of stray light can affect natural lights.[4]

Here are the main sources that contribute to light pollution.

1. Electronic bulletin boards and commercial centers. Many large electronic signs in cities and on the highway are illuminated by powerful lights that focus on the boards below. The lights eventually bounce off the boards. Restaurants, discos, pubs, games and shops in the cities also use a lot of light to attract customers. Many of the ones they use are not targeted to any particular location, making its scattering greater than expected.

2. *Playgrounds for night sports.* Spotlights, light stadiums and other sports venues often contribute to light pollution as powerful lights end up. These include large light ports in parking lots.

3. *Street lights and car lights.* In some cities, hundreds of miles of powerful streetlights remain overnight. This, together with vehicles that use roads, all contributes a lot to the light being directed higher and to other unintentional places. It is estimated that 35 to 50% of all light pollution is produced by road lighting.

4. *City parks, airports, public places.* Many of these areas use a lot of old-fashioned lamps that are not protected by a screen and emit a lot of light upwards.

5. *Residential areas.* Light pollution in these areas tends to glare and overflow. Garden and landscape lights designed to add to the aesthetics of the landscape and architecture often end up as a nuisance at night, as they tend to irritate people when they walk or drive in these areas.[5]

1.4. Types of light pollution

There are many different types and sources of light pollution. Light pollution can mean a violation of visible light from the flooding of too much man-made light (as in the example of city lights); it can also mean a lack of light - again, city lights take the form of natural light and replace it with artificial means; and it can also mean changes in light that are not visible.

Light pollution is caused by inefficient or unnecessary use of artificial light. Specific categories of light pollution include light outgrowth, overexposure, glare, light accumulation, and lightning. One offensive light source often falls into more than one of these categories.

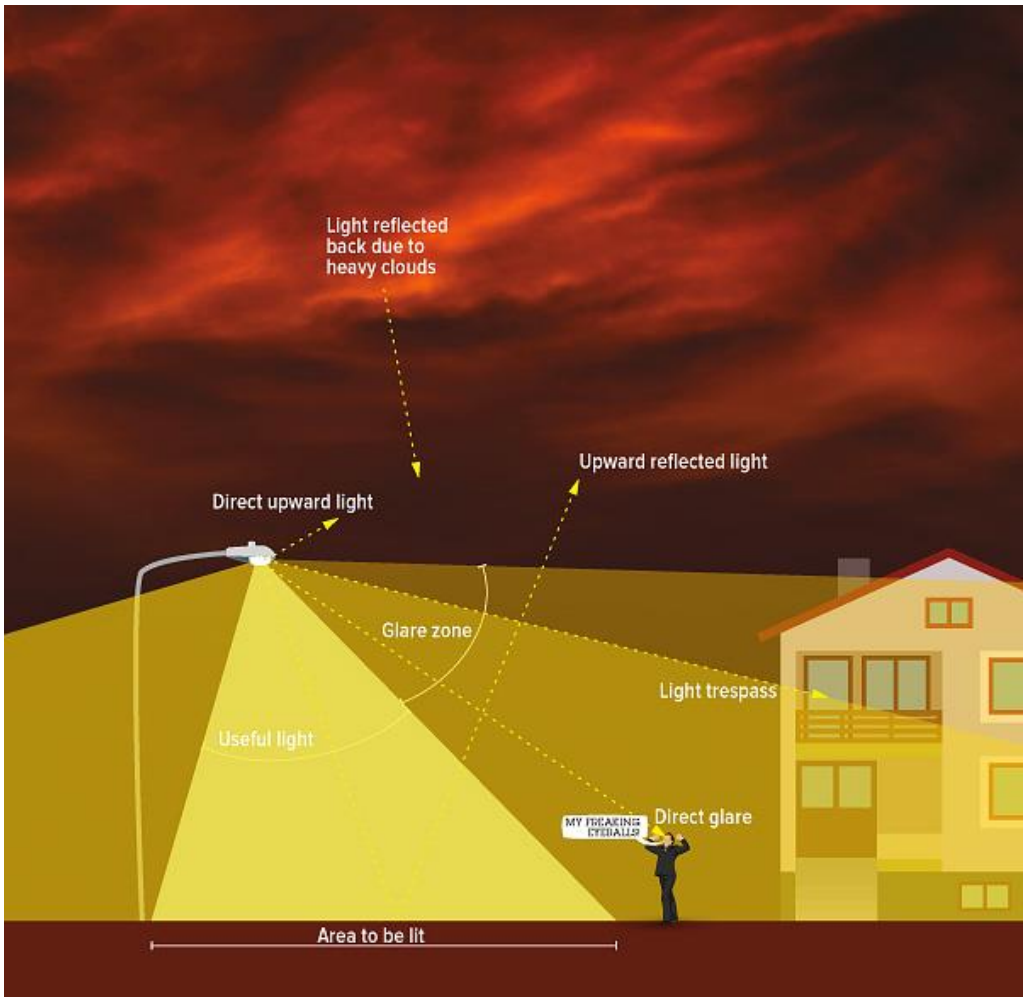

Fig.1. “The infographic above illustrates the different components of light pollution and what “good” lighting looks like. (Image by Anezka Gocova, in “The Night Issue”, Alternatives Journal 39:5 (2013)”

1.4.1. Light trespass

Light disturbance occurs when unwanted light enters the property, for example, through glare through a fence. A common problem of light penetration occurs when strong light enters the window of your home from the outside, causing problems such as lack of sleep. A number of cities in the United States have developed standards for outdoor lighting to protect the rights of their citizens from light encroachment. To help them, the International Dark Sky Association has developed a set of model lighting regulations [6].

1.4.2. Over-illumination

Over-illumination is the excessive use of light. Specifically within the United States, over-illumination is responsible for approximately two million barrels of oil per day in

energy wasted.

Over-illumination stems from several factors:

- Consensus-based standards or norms that are not based on vision science;[10]
- Not using timers, occupancy sensors or other controls to extinguish lighting when not needed;
- Improper design, by specifying higher levels of light than needed for a given visual task;[11]
- Incorrect choice of fixtures or light bulbs, which do not direct light into areas as needed;[11]
- Improper selection of hardware to utilize more energy than needed to accomplish the lighting task;
- Incomplete training of building managers and occupants to use lighting systems efficiently;
- Inadequate lighting maintenance resulting in increased stray light and energy costs;
- "Daylight lighting" demanded by citizens to reduce crime or by shop owners to attract customers;[12]
- Substitution of old lamps with more efficient LEDs using the same electrical power;
- Indirect lighting techniques, such as illuminating a vertical wall to bounce light onto the ground.

1.4.3. Glare

Glare can be categorized into different types. One such classification is described in a book by Bob Mizon, coordinator for the British Astronomical Association's Campaign for Dark Skies [13], as follows:

- Blinding glare describes effects such as that caused by staring into the Sun. It is completely blinding and leaves temporary or permanent vision deficiencies.
- Disability glare describes effects such as being blinded by oncoming car lights, or light scattering in fog or in the eye, reducing contrast, as well as reflections

from print and other dark areas that render them bright, with significant reduction in sight capabilities.

- Discomfort glare does not typically cause a dangerous situation in itself, though it is annoying and irritating at best. It can potentially cause fatigue if experienced over extended periods.

According to Mario Motta, president of the Massachusetts Medical Society, "... glare from bad lighting is a public-health hazard—especially the older you become. Glare light scattering in the eye causes loss of contrast and leads to unsafe driving conditions, much like the glare on a dirty windshield from low-angle sunlight or the high beams from an oncoming car."[14] In essence bright and/or badly shielded lights around roads can partially blind drivers or pedestrians and contribute to accidents.

The blinding effect is caused in large part by reduced contrast due to light scattering in the eye by excessive brightness, or to reflection of light from dark areas in the field of vision, with luminance similar to the background luminance. This kind of glare is a particular instance of disability glare, called veiling glare. (This is not the same as loss of accommodation of night vision which is caused by the direct effect of the light itself on the eye.)

1.4.4. Light clutter

Light clutter refers to excessive groupings of lights. Groupings of lights may generate confusion, distract from obstacles (including those that they may be intended to illuminate), and potentially cause accidents. Clutter is particularly noticeable on roads where the street lights are badly designed, or where brightly lit advertisements surround the roadways. Depending on the motives of the person or organization that installed the lights, their placement and design can even be intended to distract drivers, and can contribute to accidents.

1.4.5. Satellites

Another source of light pollution is artificial satellites. With future increase in numbers of satellite constellations, like OneWeb and Starlink, it is feared especially by the astronomical community, such as the IAU that light pollution will increase significantly, beside other problems of satellite overcrowding[15][16].

1.4.6. Industrial facilities

Separate issues are raised by illumination from industrial facilities, as they use considerable level of illumination for safety reasons it is obviously non-solvable problem as it is impossible to limit such practice. The typical exclusions for any form of light pollution restrictions are:

- Airports
- Bus stations and associated facilities
- Logistics centers
- Harbours
- Lighthouses
- Railway premises
- Tramway premises
- Prisons
- Public service operating centers (emergency, fire stations and police etc.)
- Defense premises

The levels of light pollution at these objects are typically very high and constant, creating nuisance for neighboring residential areas and other facilities operation.

1.5. Light pollution in the cities of the planet

Scientists explain that in Europe, light pollution prevents 60% of the population from admiring the stars, in North America - 80%. Among the countries where the colors of the night sky are most distorted by city lights - Kuwait (98%), Qatar (97%), United Arab Emirates (93%), Saudi Arabia (83%), South Korea (66%), Israel (61%), Argentina (58%), Libya (53%), and Trinidad and Tobago (50%). Among developed countries, the best conditions for observing stars are in Australia. Light pollution in Hong Kong and Singapore was declared the 'worst on the planet' in March 2013.

Examining the map of the world on light pollution (fig.2), we can observe that the main centers of light are located in large, developed and densely populated cities around the world. If we take into account the most polluted areas, we can distinguish the following: the southern coast of North America, Europe, central Russia, the United Arab Emirates, India, the east coast of China and Japan. The most light-polluted cities include the following: New York, Chicago, Atlanta, Toronto, Cairo, Madrid, Lisbon, Barcelona, Milan, Paris, London, Rome, Wroclaw, Moscow, St. Petersburg, Kiev.

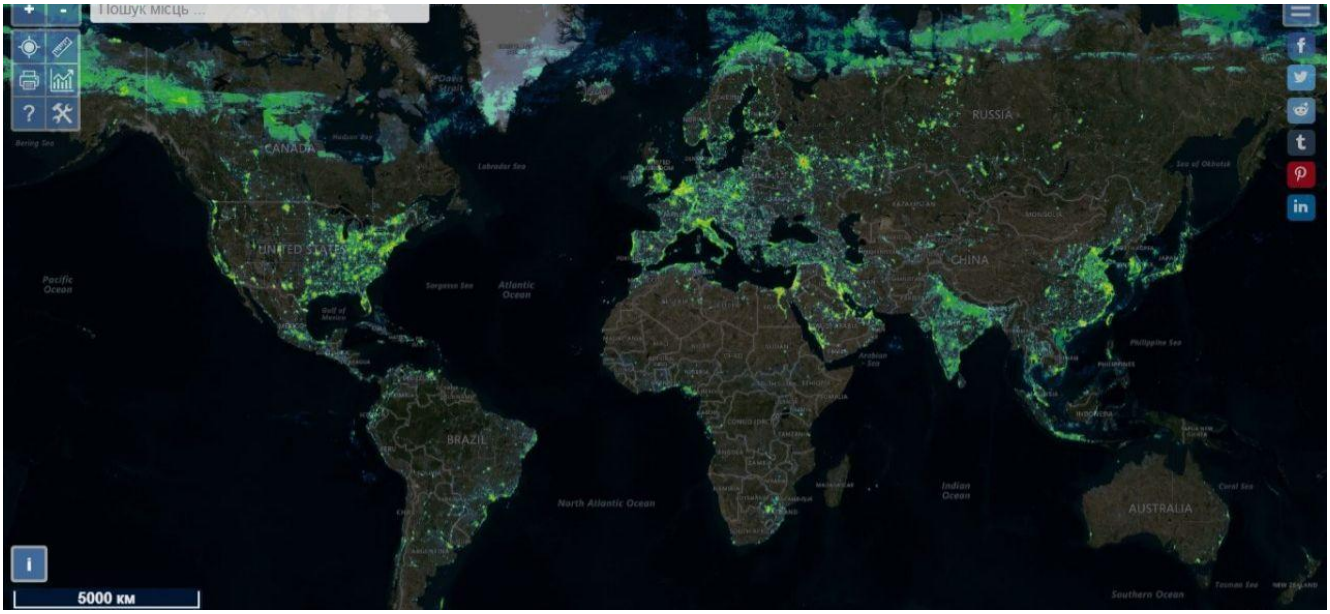

Fig.2. Map of light pollution in the world

The map of light pollution in Europe (fig.3) clearly shows that this problem is very relevant for Europe as a whole, because the light level in this area is much higher than normal. This situation can be caused by densely populated cities and location of cities is generally dense as well. Similarly, infrastructure connecting European cities is very well developed and illuminated at night by artificial light sources for safety reasons. Europe is special because it has a large number of cultural and historical centers, which makes it necessary to illuminate all parts of the city for tourists.

Fig.3. Map of light pollution in the Europe

An inspection of the area surrounding Madrid found that the effects of light pollution caused by a single large conglomeration could be felt 100 km from the center. The global effects of light pollution are also becoming apparent. The whole area, which consists of southern England, the Netherlands, Belgium, western Germany and northern France, has the sky brightness at least two to four times the background value (see above right). The only places in continental Europe where the sky can reach its natural darkness are in northern Scandinavia and on islands far from the mainland.

In North America, the situation is comparable. There is a significant problem with light pollution, ranging from the maritime provinces of Canada to the American Southwest. The International Dark Sky Association is working to identify areas that have quality night skies. These areas are supported by communities and organizations involved in reducing light pollution (such as the Dark Sky Reserve). The Department of Natural Sounds and Night Sky in the National Park measured the quality of the night sky in national park units in the United States. The quality of the sky in the United States varies from pristine (Capitol Reef National Park and Big Band National Park) to severely degraded (Santa Monica Mountain National Vacation) Square and Biscayne National Park. [18] The National Sky Service National Park Monitoring Database is available online (2015).

Comparing the map of light pollution in Ukraine (fig.4) and Europe, it is seen that Ukraine is less polluted. This is due to the fact that Ukraine is not as densely populated as Europe, has smaller number of large cities and the problem of light pollution is directly related to cities. The most polluted cities are Kyiv, Dnipro and Lviv and Odessa. These cities are the largest in Ukraine and are the cause of light pollution.

Fig.4. Map of light pollution in the Ukraine

The results of the assessment of the level of light pollution in the protected areas in the Steppe zone and the Crimean mountains show that even some of the most protected areas in the Steppe zone and the Crimean mountains have certain level of artificial night lighting. The minimum level of artificial brightness that has a significant effect on biodiversity is unknown. However, the sky with the light pollution from 8 to 16% (from 6.96 to 55.7 μcd/m^2) can be considered polluted from the astronomical point of view. Of the studied protected areas, 44.2% have naturally dark night sky, 40.1% have artificial brightness from 8 to 16%, and the rest (15.7%) are polluted with artificial brightness over 16%. Areas with more than 16% light pollution are often located near large cities or industrial centers [own analysis is based on the studied literature].

In Ukraine, there are examples of protected areas with very low level of artificial brightness, which is less than 1% (Azov-Siva NPP and the Danube Biosphere Reserve). Such low levels of pollution are unique to Europe. In general, the level of light pollution within protected areas in other European countries is higher, as is the growth rate of light pollution. The low level of light pollution in our country is most likely due to the

economic and industrial decline of the last 5-6 years.

Although the effects of night lighting on biodiversity are not taken into account by scientists or the authorities in the country, light pollution of the night sky has serious consequences for reproduction, navigation, feeding, habitat selection, communication, trophic and social interactions of all biota, including man. It is documented that this is one of the main reasons for the global decline in insect populations, which provokes cascading effects in ecosystems, rebuilding ecological communities, modifying the interaction between species and affecting pollination and seed productivity of plants. The struggle to reduce the level of night lighting must already begin and the first efforts should be invested in stabilization of the situation in protected areas.

Despite the fact that in the past light pollution has received relatively little attention from environmentalists, it is considered one of the most common forms of environmental change. It is also striking that it can be seen hundreds of miles from its source (for example, the bright domes of Las Vegas and Los Angeles can be seen from Death Valley National Park). However, in addition to the global environmental consequences, light pollution poses health problems, can even affect human culture and, of course, consumes energy and money.

The diagrams below show 40 countries whose populations have suffered the most and least from artificial sky brightness. The most polluted country is Singapore, where the entire population lives under such a bright sky that the eye cannot fully adapt to dark vision. Other groups affected by this level of light pollution are Kuwait (98%), Qatar (97%), the United Arab Emirates (93%), Saudi Arabia (83%), South Korea (66%), and Israel. 61%), Argentina (58%), Libya (53%), Trinidad and Tobago (50%); in all these countries, more than half of their inhabitants live under extremely bright skies[24].

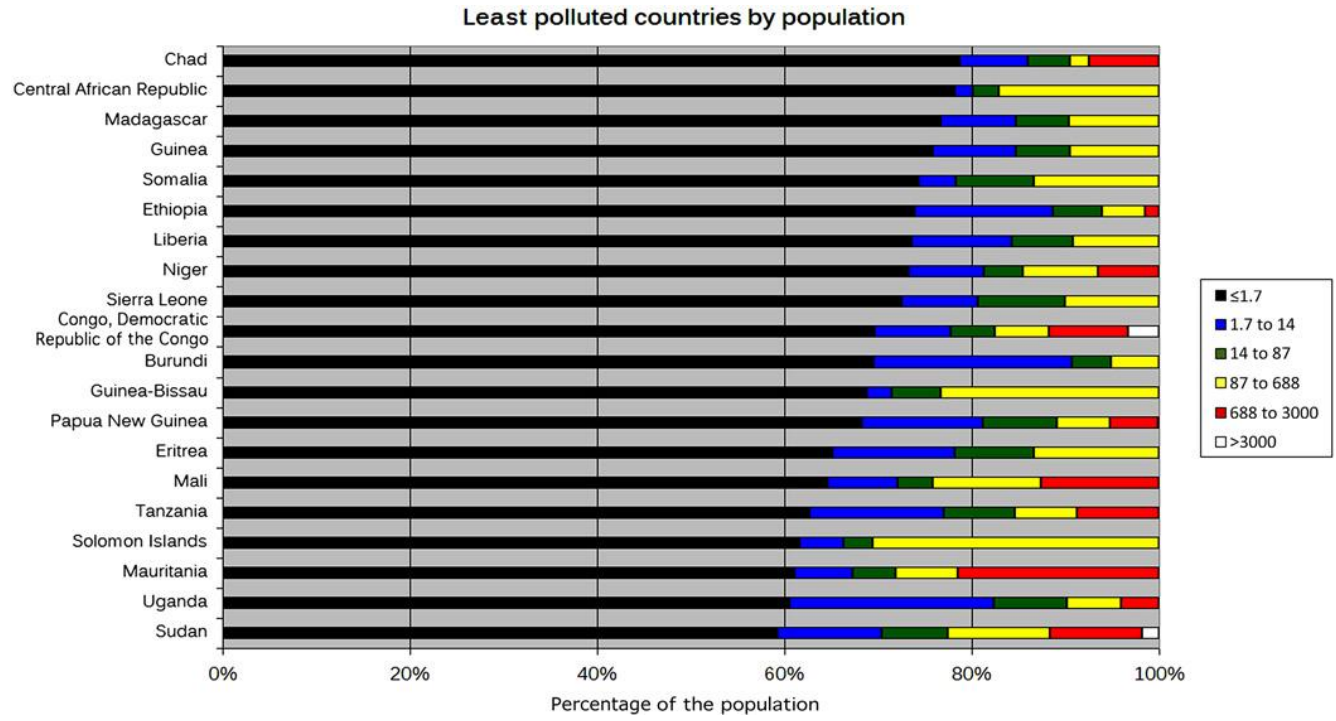

Fig.5. "Countries whose populations are exposed to the least light pollution. Color ranges are shown on the right and indicate the pollution level (μcd/m^2)"[24]

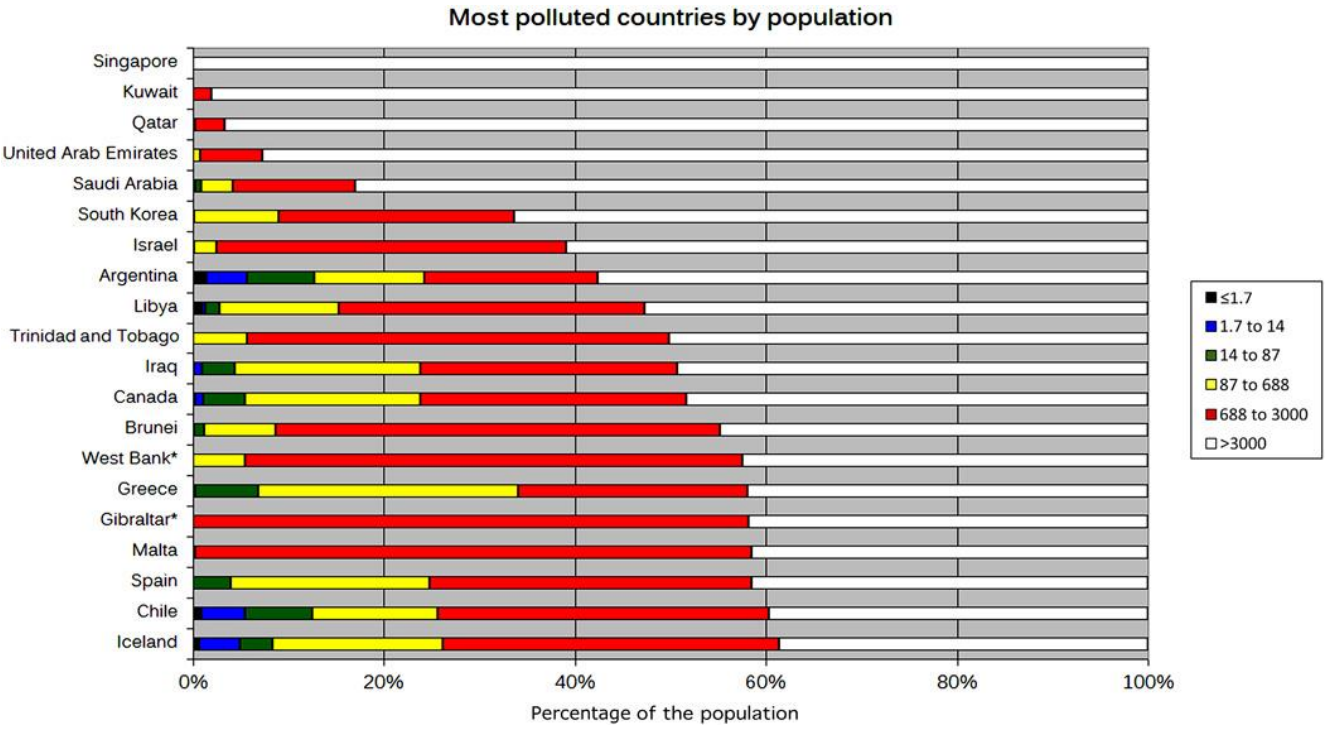

Fig.6. "Countries whose populations are most exposed to light pollution. Color ranges are shown on the right and indicate the pollution level (μcd/m^2)"[24]

1.6. Conclusions to chapter 1

Light pollution is a new type of environment quality degradation. It is formed by the active use of artificial illumination at streets and service facilities of urban territories. The images of the night Earth, taken in the period from 2012 to 2016 by the NASA satellite equipped with radiometer, showed that the artificially illuminated area of the planet increased by 2% annually. At the moment the residents of megacities are not able to see the real night sky.

The problems raised by light pollution are very diverse and yet are not well studied. However, the range of possible effects include violation of living activity for wild nature, urban flora and fauna, disruption of human biorhythms and increased accidents probability. The other side of the problem is complication of astronomic observations and waste of energy due to excessive illumination.

The drivers of the problem are both structural (inefficient illumination equipment) and organizational (incorrect planning of illumination devices location). The advertizing activity and marketing trends also contribute to the deepening of the problem. Thus there is a need to study the level of this type of pollution at the territory of Kyiv city, being the biggest urban area of our country.

CHAPTER 2
METHODS FOR ASSESSING THE LEVEL OF LIGHT

2.1. Methods of measuring the level of illumination

Light is electromagnetic waves of the visible spectrum. The visible range includes electromagnetic waves within the frequencies perceived by the human eye (7.5 × 1014 - 4 × 1014 Hz), i.e. with a wavelength of 390 to 750 nanometers.

In physics, the term "light" has a slightly broader meaning and is synonymous to optical radiation, i.e. covers the infrared and ultraviolet regions of the spectrum.

The properties of light are studied in physics by optics and spectroscopy. Measurement of light intensity is the realm of photometry.

Physical bodies whose atoms and molecules emit light are called light sources. Light sources are artificial and natural, thermal and fluorescent, point and long. Light sources are the sun, lightning, incandescent, TV screen, monitors and more. Light can also be emitted by organisms (some marine animals, fireflies, etc.).

Devices that can be used to detect light radiation are called light receivers. The natural receivers of light are the organs of living beings. Of the human senses, the most information about the environment gives us sight. Man sees electromagnetic waves in the visible range because he has the appropriate receptors (rods and cones of the retina) that absorb light of such frequencies, causing the corresponding impulses in the nervous system. The retina of the human eye has two types of light-sensitive cells.

Optics is one of the oldest sciences. The doctrine of light phenomena arose several centuries BC as a result of numerous attempts to understand the nature of vision. Still the nature of light is not completely clear. Nevertheless, humans learnt to create artificial light sources and their wide use and extreme importance made it necessary to measure parameters of light. In terms of light pollution discussion, it is also important to measure light intensity and define whether it is a problem or not.

The main quantitative indicators of light are light intensity, luminous flux, illuminance, brightness.

Several measures of light are commonly known as intensity:

- Radiant intensity, a radiometric quantity measured in watts per steradian (W/sr)
- Luminous intensity, a photometric quantity measured in lumens per steradian (lm/sr), or candela (cd)
- Irradiance, a radiometric quantity, measured in watts per meter squared (W/m2) or
- Intensity – the name for irradiance used in other branches of physics
- Radiance, commonly called "intensity" in astrophysics ($W \cdot sr^{-1} \cdot m^{-2}$)

Luminous flux or luminous power is a quantitative value of "light" power in the entire radiation flux, measured in lumen. In other words it is the measure of the perceived power of light. It differs from radiant flux, the measure of the total power of electromagnetic radiation (including infrared, ultraviolet, and visible light), in that luminous flux is adjusted to reflect the varying sensitivity of the human eye to different wavelengths of light. It depends on the spectral sensitivity of the average person's eye. Artificial light sources used today have different luminous flux:

- traditional incandescent lamp with a power of 100 W - 1350 lm;
- LED lamp - 860 lm;
- gas-filled fluorescent lamp - 2000 lm.

Brightness is defined as the ratio of the intensity of light emitted by a surface element in this direction to the area of the glowing surface.

As a result, most people use the terms illuminance and brightness interchangeably which leads to confusion, as brightness can also be used to describe luminance. To clarify the difference, illuminance refers to intensity of light falling onto a surface, while brightness refers to the visual perceptions and physiological sensations of light. Brightness is not a term used for quantitative purposes at all.

Illuminance is measured in suites (lux). The surface has an illuminance of one lux if the surface luminous flux density is equal to one lumen per square meter. Brightness is measured in candelas per square meter (sq/m2).

The main task of lighting calculations is:

- Under natural light - determining the required area of light slots;

- At artificial - necessary quantity of fixtures of electric lighting installation.

Luxmeters, photometers, visibility meters, etc. are used to measure lighting values.

In production conditions, luxmeters and photometers are used to control the illumination of workplaces and the general illumination of premises, the operation of which is based on the phenomenon of the photoelectric effect – the conversion of light energy into electricity.

Measurements of illuminance at working surfaces are carried out using special devices – luxmeters of a range of modifications (Yu-16, Yu-17, Yu-116). The Yu-116 light meter (Fig. 4) includes a measuring device, a selenium photocell type F 55C and nozzles K, M, P, T, which are used to expand the range of the device when measuring illuminance.

At natural lateral lighting the necessary area of light apertures, m2 is calculated; with overhead lighting - area of light lanterns, m2.

The calculation of artificial lighting in the premises can be carried out by the following four methods: point method, the method of specific power (based on the tables of specific power), graphical method and the method of light flux. Graphic method by prof. A.A. Trukhanov gives the greatest accuracy in the calculation of lighting fixtures with directional light. The calculation is based on nomograms. The method of light flux utilization is designed to calculate the total uniform illumination of horizontal surfaces.

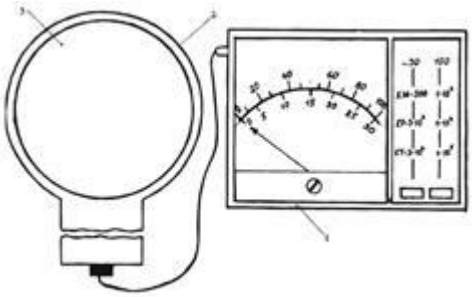

Fig. 7. - Yu-116 Luxmeter, 1- meter; 2 - photocell; 3 - nozzle

2.2. Assessment of the level of light pollution by qualitative indicators

For the assessment of light pollution in cities specific parameters are necessary, as they must characterize the intensity of excessive light and overall effect of pollution phenomenon, but not the light itself. One of the important parameters of such kind is sky luminance and sky glow.

Sky glow- is light that is scattered and reflected by air molecules and atmospheric aerosols. The observer sees in the sky anthropogenic light coming from the earth. The sky looks radiant. This type of light pollution damages the aesthetics of the night sky and unnaturally illuminates the observer and the landscape.

Measuring the effect of sky glow on a global scale is a complex procedure. The natural atmosphere is not completely dark, even in the absence of terrestrial light sources and light from the moon. This is caused by two main sources: air glow and diffused light.

At high altitudes, especially above the mesosphere, enough short-wavelength UV radiation from the sun is enough to cause ionization. When ions come into contact with electrically neutral particles, they recombine and emit photons in the process, causing an air beam. The degree of ionization is large enough to allow constant radiation, even at night, when the upper atmosphere is in the shadow of the Earth. Below in the atmosphere, all solar photons with energies exceeding the ionization potential of N2 and O2 have already been absorbed by the higher layers, and therefore no appreciable ionization occurs.

Fig.8. “Example of sky glow”

Illuminance is a measure of the luminous flux on the surface of a given area or the luminous flux density. This is most important when the human eye tries to examine objects

with reflected light. Illumination is a very useful indicator for the quantification of anthropogenic light in the natural environment.

Illumination is divided into three types by it`s characteristics:

1) Horizontal illuminance is the illuminance from a light source measured on the surface of a horizontal plane. A good indicator of the zenith brightness of the sky or measuring illumination from a lamp mounted on a pole.

2) Vertical illumination - Illumination from a light source at a distance to the horizon (or from the sky facing a certain direction) can be measured by a detector in a vertical plane, usually normal to the direction of the light source.

3) Hemisphere illumination - illumination from all over the sky that strikes an imaginary hemispherical surface (like the top of a golf ball on the ground) is an unbiased measure of light reaching an observer from all over the sky.

4) The light from the source is reflected on the object, then on the object, which is observed at some distance and at an angle. The brightness of an object's surface is its brightness. Or an extended (non-point) source can produce its own light, like a computer monitor screen or the surface of the sun. Each part (angle of view from the point of view of the observer) of these objects has a measure of illumination, and also the combined light (illumination) of all or part of object can be measured.

Indicator	Observed		Estimated Artificial		Light Pollution Ratio (Artificial/Natural)
Sky Luminance Measures					
	mag/ arscec²	µcd/ m²	mag/ arscec²	µcd/ m²	
Zenith	21.77	212	> 24.5	< 17	< 0.10
Mean all-sky	21.11	391	22.27	132	0.53
Brightest	17.76	8,407	17.79	8,210	48.01
Darkest	21.97	175	> 24.5	< 17	< 0.10
Median	21.49	272	25.01	11	0.04
Illuminance Measures					
	mags	milli-lux	mags	milli-lux	
Horizontal	-6.33	0.86	-4.09	0.11	0.14
Max Vertical	-6.69	1.20	-5.96	0.62	1.54

Fig.9. “Light pollution ratio”

In addition to the emission of light, the sky also scatters incoming light, primarily

from distant stars and the Milky Way, but also zodiacal light, sunlight that is reflected and scattered by interplanetary dust particles.

The amount of radiance and zodiacal light is quite variable (depending, among other things, on the activity of sunspots and the solar cycle), but under optimal conditions, the darkest possible sky has a brightness of about 22 magnitudes / square arc per second. If there is a full moon, the brightness of the sky increases to about 18 magnitude/sq. arc second, depending on local atmospheric transparency, 40 times brighter than a dark sky. In densely populated areas, the brightness of the sky is 17 magnitudes/sq. the second arc is not uncommon or 100 times brighter than natural.

To accurately measure how bright the sky is, satellite images of the earth at night are used as input for the number and intensity of light sources. They are embedded in a physical model of scattering by air molecules and aerosols to calculate the total brightness of the sky. Maps showing the increased brightness of the sky have been prepared for the whole world [17].

The Bortle scale is a nine-level measurement system used to track the amount of light pollution in the sky. Five or less is the amount needed to view the Milky Way, while one is the "primitive", the darkest possible [19].

The Bortlet scale for assessing the degree of darkness in the sky was created in 2001, and measures the darkness of the sky in the range from 1 to 9. The levels of this scale differ in the following way (fig. 10):

- Marking 1 on the scale is a really dark sky. Then there are a lot of technical details (such as stars and constellations that can be seen with the naked eye), but 1 is when you cannot see your car in the parking lot, even if it is right in front of you.
- Marking 2 is when you start to see a faint light on the horizon, and even though the Milky Way is visible, it's not easy to see it.
- Marking 3 is the sky that can be seen in any village.
- Marking 4 is the sky that can be observed at the border of the countryside and the suburbs.
- Marking 5 is the sky in the suburbs.

- Marking 6 is also a "suburban sky", but brighter.
- Marking 7 - such a sky can be observed on the border of the city and suburban areas.
- Marking 8 is the night city sky. Marking 9 - the sky in a brightly lit city. When you get to 9, you can hardly see any stars or constellations at night, even with a telescope. You can only make out large celestial bodies, such as the Moon.

The International Dark Sky Association is trying to preserve the first type of darkness today by promoting luminaires that emit diffused light and minimize light pollution. They also map places where everyone, including astronomers, can see a truly dark sky [25].

Fig.10. “The Bortle scale”

2.3. Regulation of light pollution in the world

The map of the world clearly shows that Europe stands out significantly in terms of light pollution among other parts of the world. In the legal framework of countries such as the United States, Britain, Italy, France, Slovenia and Australia, pacts and bills have appeared that reflect the first steps in addressing the efficient use of light energy and reducing global noise in cities.

The European Union has Standard EN 12464 (-2) [21] with guidelines for the control and reduction of global pollution. This document contains lighting requirements for various outdoor workplaces, from power plants to railway areas. The chapter on "intrusive lighting" discloses the CIE / Ile [22] guidelines for reducing light pollution in accordance with the zoning of outdoor lighting facilities at 4 levels, described in detail in this document.

Regional laws on light pollution have already been implemented in 13 Italian regions (Lombardy 17/00, Emilia Romagna 113/03, Marche 10/02, Lazio 23/00, Campania 13/02, Veneto 22/97, Tuscany 37/00, P ' Emont 31/00, Valle d'Aosta 17/98, Basilicata 41/00, Abruzzo 12/05, Umbria 20/05, Puglia 15/05), which cover more than two thirds of the settlements of Italy and major cities (Milan, Rome , Venice, Florence, Bologna, Naples). In addition, three Italian Technical Standards work directly or indirectly to address light pollution (UNI10819, UNI10439, UNI9316) [23]. The initial technical measures to reduce light pollution in accordance with these laws are as follows [23]:

1) the provisions of the law must be observed throughout the territory, because light pollution spreads over long distances from light sources;

2) the provisions of the law must be applied to all newly designed lighting installations, both public and private facilities;

3) in the conditions of necessity of observance of requirements to safety of movement at night the average brightness or illumination should not exceed the minimum value necessary for safety (roads, pedestrian zones, workplaces). For other types of lighting, the maximum brightness of objects is allowed in 1 Cd / m 2 (for example, architectural lighting);

4) the restriction of the direct components of the radiation rays from the JV in any

direction above the horizontal level, should be regulated by the parameter depending on the direction of light, and not on the luminous flux. As an example, the parameter is the intensity of radiation in units of flux emitted by the lighting installation (Kd / km). The light flux propagated in small angles from the horizontal level (the first 45^0) should be limited with special care, because it is in these areas that the most negative and inefficient illumination is formed;

5) the direct component of the radiation from the lamps, which enters the upper hemisphere, should be limited as 0 Kd per 1000 lm of luminous flux of the JV in any direction above the horizon (gamma angle $\geq 90^0$) for almost all types of LIGHTING 2'2014 LIGHT installations. However, in practice, a value of 0.49 Cd / km is allowed. the limit is set as an integer, and then the measurements can be rounded to the nearest integer;

6) buildings and monuments should be illuminated in such a way that the light flux from the JV is directed from top to bottom, except where the impossibility of such an arrangement of equipment is proved (in this case it is allowed to direct the light flux from bottom to top, but the radiation should not object);

7) lighting installations for large areas also meet the requirements of p. № 5;

8) only light sources with high efficiency should be used, because it saves electricity and reduces light pollution outside the photo oven group and inside the scotopic group;

9) upward tracking of searchlights and similar lighting systems is prohibited, because they are sources that distract drivers during traffic, which reduces traffic safety;

10) penalties for non-compliance are set in proportion to the number of lights;

11) existing lighting installations that create significant light pollution or belong to the most polluting category must be adapted;

12) the lighting project of any lighting installation is developed only by a professional certified lighting engineer, except for small lighting objects (indoor interior design with the number of light points 5 pcs.). The following rules can also be observed, the positive results of which have already been noted:

1) the annual growth rate of the installed luminous flux for night outdoor lighting, public and private facilities, in any municipal district may not exceed 2%;

2) the annual growth rate of electricity consumption for night outdoor lighting,

public and private facilities, in any municipal district may not exceed 1.5%;

3) the luminous flux emitted by the lighting installation, to minimize as much as possible. Restrictions on the annual growth rate of electricity consumption for night outdoor lighting are already in place in some regions of Italy.

Outdoor lighting regulations or codes are an excellent tool to ensure that municipalities use quality, safe outdoor lighting. A well-written ordinance with proper lighting will save public money and will increase security. Thousands of cities in the United States have adopted such codes, and they can be a great tool for the community to control light pollution, including glare, light failure, and luminaire. In 2011, IDA and the North American Lighting Society approved the Model Lighting Ordinance, an outdoor lighting template designed to help municipalities develop outdoor lighting standards that reduce glare, light transmission, and light beam.

Many American cities and US lawyers believe that the adoption of the code is the end of their efforts. Instead, it is often just the beginning. Continuing education is a key factor. Otherwise, the community may forget why it even adopted the original code and how it helps its citizens. If this happens, it may be necessary to redefine local leaders and city workers to ensure that the code is followed [26]. This approach is quite effective, because it is based on human consciousness and public position, as well as at the legislative level.

The London authorities have also developed a system of light pollution regulation. The Department for Environment, Food & Rural Affairs and Environment Agency have created special group of specialists - the Enforcement Response Team, who investigate complaints about light pollution and first try to resolve the matter informally. If it is decided that a statutory nuisance does exist, the Enforcement Response Team and the person affected are able to take legal action. Of course, there are exemptions from the rules. In particular, some types of premises require high levels of light for safety and/or security reasons. Consequently, the regulatory legislation is not applied to artificial light from the transport facilities, like airports, public transport premises, emergency services facilities and navigation facilities. The street lighting is not exempted, but in most cases it is hard to manage the problem if it originates from street illumination, as it is also

considered a safety issue.

In most cases the regulations of light pollution contain no numerical values, but rather describe the "best practicable means" for industrial, trade or business premises, as well as sports facilities or other public objects like trade malls etc. in case of any assize, the business, being the source light pollution must satisfy a court that they did their best to mitigate the effects of the light nuisance. An important issue is to prove, that the light, which is disturbing or annoying, is a statutory nuisance as defined in the legislation. Thus, it must do one of the following: unreasonably and substantially interfere with the use or enjoyment of a home or other premises; injure health or be likely to injure health. As under current level of knowledge and insufficient medical statistics on the given situation, it is very hard to provide such substantiation.

2.4 Conclusions to chapter 2

The analysis showed that the methodology for studying the levels of light pollution is provided with a variety of tools and techniques, despite the fact that its development began not so long ago. After all, the problem of global light pollution has been actively discussed by scientists only during the last 30 years. To choose the correct method it is necessary to define the type of light pollution under investigation. It is also important that at the legislative level the issue of light pollution is resolved only in relation to some factors and not in all countries of the world.

Thus, the main conclusion of this analytical study is the belief there is the need to develop a systemic regulatory document to set the standard of measuring light pollution and differentiation of sources, as well as define permissible levels of such physical factor. It is also clear, that the level of light pollution in our country is not well studied and needs thorough research.

CHAPTER 3
ASSESSMENT OF THE LEVEL OF LIGHT POLLUTION IN KYIV

The improvement of the modern business district at night is largely determined by the work of outdoor lighting installations of various functional purposes (utilitarian, architectural decoration, advertising, demonstration, lighting, etc.). Currently, all these settings are developed separately, without taking into account their relationship and interaction, which does not ensure the coordination of parameters and, consequently, does not provide possible efficiency and cost-effectiveness.

The main purpose of outdoor artificial lighting of the city is the safety of traffic and pedestrians, as well as creating the appearance of the city at night. Numerous studies conducted in our country and abroad show that the quality of utilitarian lighting significantly reduces the number of traffic accidents and the number of offenses in the dark. At the same time, the appearance of the city is determined not only by the utilitarian lighting of streets and squares, but also by architectural and decorative lighting and illuminated advertising. Despite the great importance of utilitarian and architectural-decorative lighting of city streets, the status of these types of lighting cannot be considered satisfactory in Kyiv.

The main reasons for the poor condition of outdoor artificial lighting of streets and squares of the city and the irrational use of power allocated to outdoor artificial lighting are;

- inconsistency of parameters of parameters of external lighting of different function;
- insufficient use of modern lighting equipment;
- lack of consistency of outdoor lighting fixtures with quantitative and qualitative parameters (indicators) of lighting systems;
- lack of requirements and methods of complex calculation and design parameters of outdoor lighting installations for various purposes.

One of the main problems faced by scientists, engineers and architects is the

creation of optimal conditions for humans, in particular, the optimal parameters of the lighting environment of the night city. Proper and complete consideration of the relationship and interaction of different parameters of the target parameters creates the necessary conditions for solving this problem.

3.1. Measurement scheme

In the framework of this scientific work, an analysis of the level of light pollution in the city of Kyiv was conducted. For the analysis, light levels were measured at fifteen points in the city each season during the year. Measurements were performed in the central part of the city (Pechersk district) in order to demonstrate a sufficient contrast between the permissible values of the light level and those obtained as a result of measurements. The points at which the measurements were made belong to 3 categories:

- Business area
- Natural area
- Residential area.

Business areas are points near the outlets, which are typically the brightest places in this area of the city. This category includes 5 points:

1. IQ business center - a business center located at 15 Bolsunovska Street, next to the building is a highway and residential buildings, across the road park area.

2. Gulliver Mall - a multi-storey shopping center located at 1A Sportivna Street, near the highway with heavy traffic and the concert hall "Palace of Sports".

3. Khreshchatyk Street - the central street of Kyiv, along the street there are shopping centers, catering establishments and highway.

4. Embankment (Dnipro station) - the embankment of the Dnieper River, near the road with high traffic and the bridge for subway trains.

5. NSC Olympic - stadium, near the square and the road, as well as residential buildings and catering establishments (table 3.1).

The level of illumination near the points of this category was measured three times. The first measurement was taken at a distance of 25 meters from the building, the second – at the distance of 50 meters from the building and the third – at the distance of 100 meters from the building. Measurements were performed at different distances to track changes in

the level of illumination of the territory depending on the distance to the point of interest.

Table 3.1.

Characteristics of business areas

Business areas				
№	Name of point	Adress of point	Characteristics of the light environment	The presence of greenery
1	IQ business center	street Bolsunovskaya 15	Street light	shrubs and single trees
2	Gulliver Mall	street Sports 1A	Street light	no
3	Khreshchatyk Street	Khreshchatyk Street	Street light	single trees
4	Embankment (Dnipro station)	Quay	Street light	no
5	NSC Olympic	street Vasylkivska 55	Street light	no

The next category is natural areas; this category includes points of natural origin, parks. Lighting levels were measured in 5 parks:

1. Navodnytsky Park is near the Dnieper River and a road with high traffic. The measurements to the founders of Kiev were taken near the monument.

2. Mariinsky Park is in the city center, near Independence Square, the waterfront and the central city of Kiev. The measurements were taken near the Arch of Friendship of Peoples.

3. Park of Eternal Glory - a park located near the metro Arsenalna, the Eternal Flame and the Monument to the World War II victims are located there. The road with high traffic and residential buildings are located nearby, measurements were taken near the monument.

4. Park of Fame - the park in which the monument the Motherland is located, measurements were made right next to the monument.

5. Taras Shevchenko Park is located near the central building of the Taras Shevchenko National University. High-traffic roads and residential and public buildings are near the park.

The level of illumination at the points of this category was checked twice. The first measurement was taken directly under the trees, and the second measurement was taken on the path (table 3.2).

Table 3.2.

Characteristics of natural areas

Natural areas				
№	Name of point	Adress of point	Characteristics of the light environment	The presence of greenery
6	Navodnytsky Park (monument to the founders)	-	Street lights	trees of different sizes, bushes
7	Mariinsky Park (Arch of Friendship of Peoples)	-	Street lights	trees of different sizes, bushes
8	Park of Eternal Glory	-	Street lights	trees of different sizes, bushes
9	Park of Fame	-	Street lights	trees of different sizes, bushes
10	Taras Shevchenko Park	-	Street lights	trees of different sizes, bushes

The third category of points cover residential areas – these are measuring points near residential buildings. The following 5 points belong to this category:

1. John Paul II Street, 5 - the area near the grocery store, next to the road.

2. Boulevard of Friendship of Peoples 16 a - residential, next to the road with heavy traffic.

3. Residential areas near Khreshchatyk Street - residential buildings located at Shota Rustaveli 3, near the road with heavy traffic and catering establishments.

4. Residential areas near University metro station - the area near residential buildings at 35 Pirogov Street, near the road.

5. Residential areas near Arsenalna metro station - residential buildings at Ivana Mazepa Street 4 (table 3.3)

Measurements of light levels at these points were made three times. The first measurement was taken in the yard, the second - directly near the house, the third - near the road passing ин the house (if any).

Table 3.3.

Characteristics of residential areas

Residential areas				
№	Name of point	Adress of point	Characteristics of the light environment	The presence of greenery
11	John Paul II Street, 5	Street John Paul II, 5	Street lights	single trees and bushes

table 3.3

12	Boulevard of Friendship of Peoples 16 a	bul. Friendship of Peoples 16 a	Street lights	single trees and bushes
13	Residential areas near Khreshchatyk Street	street Shota Rustaveli 3	Street lights	single trees and bushes
14	Residential areas near stm. University	street Perogova 35	Street lights	single trees and bushes
15	Residential areas near the Arsenalna metro station	street Ivan Mazepa 4	Street lights	single trees and bushes

The measurement points were selected from the above categories in order to monitor how the level of light pollution changes depending on the point. After all, near shopping malls, in the central parts of the city and in public places of the city, in addition to Street lights, there is a large number of advertising banners and architectural lights, which causes high levels of physical pollution and impact on people and the environment. Measurement of the level of lighting in the parks was carried out to analyze the possible effects of light pollution on flora and fauna.

3.2. Measurement results

To analyze the level of light pollution in the city of Kiev, measurements were taken at the onset of complete darkness. The time of measurement, the nature of the underlying surface (dry, wet), the nature of the light environment (the presence of lanterns), and the presence of greenery were taken into account.

The nature of the underlying surface is an important indicator, because it affects the level of illumination. According to the results of measurements on a wet surface, light is absorbed, and the light level is lower if the underlying surface is dry - on the contrary, the light is reflected and the light level is higher.

Also, for the analysis of the obtained results, the phase of the moon and the time of the moonrise were taken into account. These indicators are necessary to compare the received results of measurements with normal level of illumination as the moon also illuminates. Thus, at nights with the full moon, the background value of the light level is 0.2, on a moonless night the light background value is in the range of 0.001-0.002, if the night is moonless and the sky is covered with clouds, the background value of the light level is 0.0002.

Table 3.4.

Results of measurement in winter

Winter						
Points	Date	Time	The nature of the underlying surface	Lighting level		
Business area						
IQ business center	11.02.2020	20:16	wet	3±0,3	1,5±0,15	1,5±0,15
Gulliver Mall	11.02.2020	18:05	wet	4±0,4	1±0,1	1,5±0,15
Khreshchatyk Street	10.02.2020	19:05	dry	3±0,3	3±0,3	3±0,3
Embankment (Dnipro station)	09.02.2020	19:35	dry	2±0,2	1,5±0,15	1,5±0,15
NSC Olympic	11.02.2020	18:19	wet	0,5±0,05	0,5±0,05	0,25±0,025
Natural areas						
Navodnytsky Park (monument to the founders)	15.02.2020	19:20	dry	2±0,2	0,5±0,05	
Mariinsky Park (Arch of Friendship of Peoples)	12.02.2020	19:10	wet	0,5±0,05	0,1±0,01	
Park of Eternal Glory	08.02.2020	20:37	dry	1,25±0,125	0,2±0,02	
Park of Fame	07.02.2020	18:46	dry	0,75±0,075	0,2±0,02	
Taras Shevchenko Park	09.02.2020	21:12	dry	1,5±0,15	0,75±0,075	
Residential areas						
John Paul II Street, 5	03.02.2020	18:25	dry	0,5±0,05	1±0,1	0,3±0,03
Boulevard of Friendship of Peoples 16 a	03.02.2020	19:49	dry	0,5±0,05	0,5±0,05	1,5±0,15
Residential areas near Khreshchatyk Street	06.02.2020	19:15	wet	0,25±0,025	1±0,1	1,25±0,125
Residential areas near stm. University	06.02.2020	20:55	wet	1±0,1	0,5±0,05	0,5±0,05
Residential areas near the Arsenalna metro station	08.02.2020	18:30	dry	0,5±0,05	1±0,1	0,1±0,01

Table 3.5.

Results of measurement in spring

Spring				
Points	Date	Time	The nature of the underlying surface	Lighting level
Business area				

table 3.5.

IQ business center	18.04.2020	22:15	dry	5,5±0,55	1,5±0,15	1,5±0,15
Gulliver Mall	18.04.2020	21:41	dry	8,5±0,85	1±0,1	1,5±0,15
Khreshchatyk Street	18.04.2020	22:30	dry	6±0,6	4±0,4	1,5±0,15
Embankment (Dnipro station)	18.04.2020	22:58	dry	3±0,3	2±0,2	1,5±0,15
NSC Olympic	18.04.2020	21:59	dry	2,5±0,25	1±0,1	0,5±0,05
Natural areas						
Navodnytsky Park (monument to the founders)	24.04.2020	21:32	dry	2,5±0,25	0,5±0,05	
Mariinsky Park (Arch of Friendship of Peoples)	24.04.2020	21:46	dry	3,5±0,35	0,5±0,05	
Park of Eternal Glory	24.04.2020	22:09	dry	2,5±0,25	0,5±0,05	
Park of Fame	24.04.2020	22:39	dry	1,5±0,15	0,5±0,05	
Taras Shevchenko Park	24.04.2020	23:06	dry	2±0,2	1±0,1	
Residential areas						
John Paul II Street, 5	30.04.2020	21:50	dry	1±0,1	1,5±0,15	0,5±0,05
Boulevard of Friendship of Peoples 16 a	30.04.2020	22:17	dry	1±0,1	0,75±0,075	2,5±0,25
Residential areas near Khreshchatyk Street	30.04.2020	22:44	dry	1,25±0,125	1,5±0,15	1,25±0,125
Residential areas near stm. University	30.04.2020	23:08	dry	1±0,1	0,5±0,05	0,5±0,05
Residential areas near the Arsenalna metro station	30.04.2020	23:26	dry	0,75±0,075	0,5±0,05	0,1±0,01

Table 3.6.

Results of measurement in summer

Summer						
Points	Date	Time	The nature of the underlying surface	Lighting level		
Business area						
IQ business center	20.08.2020	21:16	dry	2±0,2	1±0,1	0,5±0,05
Gulliver Mall	18.08.2020	20:59	dry	2,5±0,25	1±0,1	0,5±0,05
Khreshchatyk Street	18.08.2020	21:31	dry	2,5±0,25	2,5±0,25	2,5±0,25
Embankment (Dnipro station)	20.08.2020	20:39	dry	1±0,1	0,5±0,05	0,5±0,05
NSC Olympic	18.08.2020	20:45	dry	0,5±0,05	0,25±0,025	0
Natural areas						

table 3.6

Navodnytsky Park (monument to the founders)	15.08.2020	20:49	dry	2±0,2	0,5±0,05
Mariinsky Park (Arch of Friendship of Peoples)	15.08.2020	22:25	dry	0,5±0,05	0,1±0,01
Park of Eternal Glory	16.08.2020	20:33	dry	1±0,1	0,2±0,02
Park of Fame	20.08.2020	22:10	dry	0,05±0,005	0,2±0,02
Taras Shevchenko Park	19.08.2020	20:42	dry	1±0,1	0,5±0,05
Residential areas					
John Paul II Street, 5	17.08.2020	21:48	dry	0,5±0,05	1±0,1	0,5±0,05
Boulevard of Friendship of Peoples 16 a	16.08.2020	21:25	dry	0,25±0,025	0,5±0,05	1±0,1
Residential areas near Khreshchatyk Street	19.08.2020	21:15	dry	1±0,1	0,5±0,05	1,25±0,125
Residential areas near stm. University	19.08.2020	22:23	dry	1±0,1	0,5±0,05	0,3±0,03
Residential areas near the Arsenalna metro station	17.08.2020	20:39	dry	0,5±0,05	1,25±0,125	0,2±0,02

Table 3.7.

Results of measurement in autumn

Autumn						
Points	Date	Time	The nature of the underlying surface	Lighting level		
Business areas						
IQ business center	12.10.2020	19:48	dry	3,5±0,35	1,5±0,15	1,5±0,15
Gulliver Mall	12.10.2020	20:58	dry	4,5±0,45	1±0,1	1,5±0,15
Khreshchatyk Street	12.10.2020	21:37	dry	3±0,3	3±0,3	2±0,2
Embankment (Dnipro station)	12.10.2020	22:10	dry	2±0,2	2±0,2	1,5±0,15
NSC Olympic	12.10.2020	20:27	dry	1,5±0,15	1,5±0,15	0,25±0,025
Natural areas						
Navodnytsky Park (monument to the founders)	13.10.2020	19:55	dry	2±0,2	0,5±0,05	
Mariinsky Park (Arch of Friendship of Peoples)	13.10.2020	22:57	dry	1±0,1	0,2±0,02	
Park of Eternal Glory	13.10.2020	22:26	dry	1,5±0,15	0,2±0,02	
Park of Fame	13.10.2020	20:27	dry	1±0,1	0,5±0,05	
Taras Shevchenko Park	13.10.2020	21:42	dry	2±0,2	1±0,1	

table 3.7.

Residential areas						
John Paul II Street, 5	14.10.2020	20:05	dry	1±0,1	1±0,1	0,3±0,03
Boulevard of Friendship of Peoples 16 a	14.10.2020	20:47	dry	0,5±0,05	0,3±0,03	1±0,1
Residential areas near Khreshchatyk Street	14.10.2020	21:25	dry	1±0,1	0,5±0,05	1±0,1
Residential areas near stm. University	14.10.2020	22:20	dry	1±0,1	0,7±0,07	0,3±0,03
Residential areas near the Arsenalna metro station	14.10.2020	22:55	dry	0,5±0,05	1,2±0,12	0,2±0,02

3.3. Analysis of results

Analyzing the results of measurements traced a certain pattern of change. The first thing to note is that the level of light pollution in business areas is much higher than in other categories. Taking into account the nature of the underlying surface, the dependence of the light level on it can be traced, so with a dry surface the indicators are higher than with a wet surface. It should also be noted that the level of illumination largely depends on the season.

Thus, from tables 3.4 and 3.5, we see a significant contrast of indicators, in the winter the level of illumination is much lower compared to the indicators obtained in spring.

Comparing the obtained results taking into account the error, there is a significant excess of indicators with the allowable level of illumination.

Analyzing each group of points separately, we can trace a certain dependence of changes in lighting levels on the season.

If we consider business areas, we can see from tables 4-6 that the level of lighting in spring compared to winter is much higher. This can be attributed to the increase in daylight and the higher angle of incidence of the sun's rays.

Point №1 in winter has the light levelof 3 ± 0.3 in the spring 5.5 ± 0.55, the light level is higher by 2.5 points in the spring. Point №2 in winter has the light levelof 4 ± 0.4 in spring 8.5 ± 0.85 light level is 4.5 points higher than in winter. Point №3 in winter has the light levelof 3 ± 0.3 in the spring 6 ± 0.6 difference of 3 points at the peak of the spring season. Point №4 in winter has the light levelof 2 ± 0.2 in spring 3 ± 0.3, 1 point in spring

at this point higher light level. Point №5 in winter has the light levelof 0.5 ± 0.05 in spring 2.5 ± 0.25, 2 points higher level of light compared to the winter season. Considering each point of this category separately, it is possible to observe contrast in results of measurements on the average on 3 points (table 4.4).

In general, the results of autumn and winter measurements are similar, no sharp contrasts are observed.

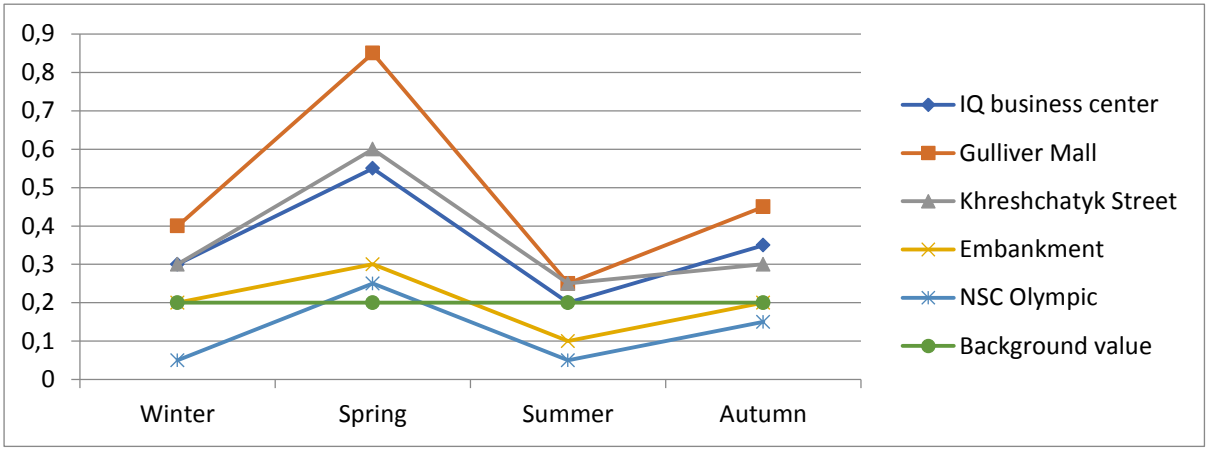

Fig. 11. The level of light pollution at the Business areas

In the Business areas, the main source of light pollution is the excessive number of lights installed along the roads, as well as a large number of illuminated advertising banners, architectural lighting and light from car headlights, because car traffic in these places is quite high.

After analyzing the results of measurements at Natural areas (fig. 12), we have defined, that the level of illumination in spring in comparison with a winter season is higher by 2 points on average.

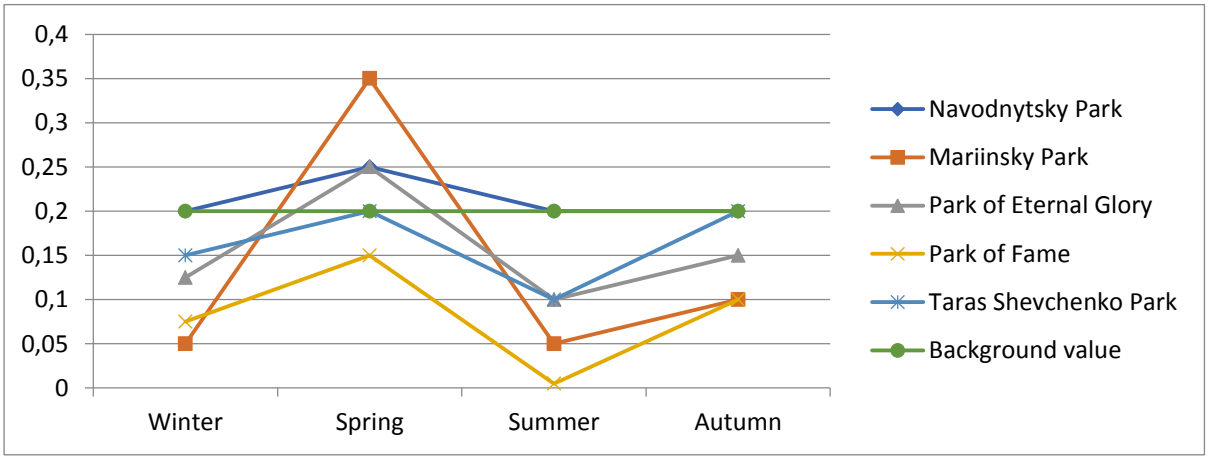

Fig. 12. The level of light pollution at the Natural areas

Sources of light pollution at these points are spotlights located along the alleys and architectural lighting of monuments. Due to the excessive brightness of these light sources, light is emitted in excess.

The results of Residential areas measurements during the year have no dynamics of change. In general, the level of illumination at these points varies between 1 ± 0.1 - 1.25 ±0.125 during the year (fig 13).

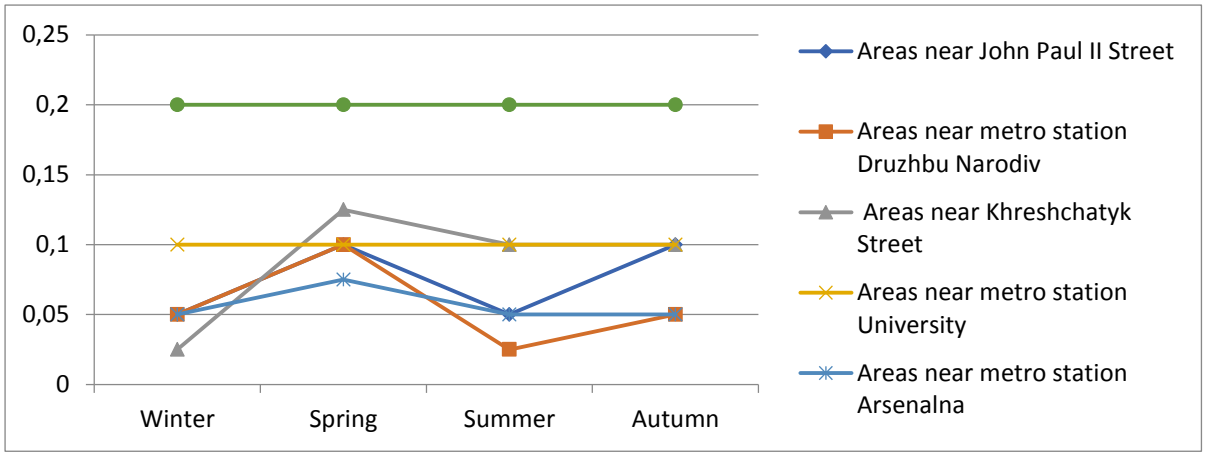

Fig. 13 The level of light pollution at the Residential areas

As can be seen from the graph, the light level in these areas is normal. The sources of stray lighting in these areas are mainly light from the windows of residential buildings and street lights located in the neighborhood.

The comparison of the results for all categories of areas, the highest level of light pollution is observed in business areas. These are the points with the highest density of artificial light sources compared to other categories. Business areas are characterized by combined illumination from street lights with architectural lighting, illuminated advertising banners and heavy car traffic.

In addition to measurements of the level of illumination of the territory during the year, observations were made to assess the state of the sky on the Bortle scale. Table 8 presents the average values by months of the sunset time and state of the sky in the city of Kiev. On average, the state of the sky has epy score of 5-7 on the Bortle scale, so the average for the month we have a score of 6.

Table 3.8.

Assessment of the sky condition

Bortle scale												
	October	November	December	January	February	March	April	May	June	July	August	September
Average	6,21	6,86	6,22	6,81	6,61	5,55	6,00	6,11	6,23	6,13	6,15	6,16
Sunset time delay												
Average	0:07:00	0:07:53	0:06:07	0:14:10	0:07:00	0:08:04	0:08:06	0:06:00	0:09:08	0:06:34	0:07:53	0:06:36

The worst state of the sky by the Bortle scale is observed in cold months of the year, such as November, December, January, and February. The possible reasin is that the humidity at this time of year is quite high, which contributes to the scattering of light, especially that from artificial sources.

Under the influence of light pollution in the city, the subjective perception of the sunset by population has changed. This is the time during which a person thinks that the sun has already set, this concept does not coincide with the astronomical time of sunset by 7-14 minutes on average. This difference is formed by the fact that people catch artificial lighting as natural, so it seems that the sun sets later than it really is (table 3.8).

3.4 Conclusions to chapter 3

To analyze the level of light pollution in the city of Kyiv, measurements of the level of illumination were carried out at fifteen different points in each season during a year. The state of the sky was evaluated by the Bortle scale during the year, and the subjective perception of the sunset was observed during the year.

Summing up the results of the analysis of the level of light pollution in the city of Kyiv, it was found that the level of lighting in the city exceeds the background value 10-100-fold. By the Bortl scale, the state of the sky in the city has the average rating of 7, which is typical for the city sky and the sky in the suburban area. Under the influence of high levels of illumination, the subjective perception of the sunset is different from the astronomical by 8 minutes on average. This deviations from the natural way of things might condition human health disorders and affect other living organisms negatively.

CHAPTER 4
ANALYSIS OF THE CONSEQUENNCES OF LIGHT POLLUTION

4.1. Implications for the phytosphere

In green plants, light is absorbed for photosynthesis by chlorophylls and carotenoids at wavelengths from 400 to 700 nm. Although this range covers a significant proportion of visible artificial light radiation, in most cases the levels of photosynthetically active radiation (surfactant) associated with night light pollution are extremely low relative to sunlit conditions (usually less than 0.5 μmol/(m^2·sec) compared to between 100 and 2000 μmol /(m^2·sec) for sunlit conditions), and the effect of light pollution on carbon fixation is likely to be negligible in most cases, although Raven & Cockell (2006) estimate that the combined PAR flux from the glow of the sky in urban areas and the moonlight from the full moon could theoretically exceed the lower limit for photosynthesis, in most cases only direct lighting in close proximity to light sources.

For example, tree leaves a few inches from street lighting are likely to be able to maintain a clean carbon fixation at night and at lower light levels to compensate for nocturnal respiratory loss. The effects of this highly localized effect on individual plants and ecosystems have not been largely studied yet.

One of the environments in which light pollution has a significant impact on ecosystems through photosynthesis is in artificially lit cave systems. The introduction of lighting into caves used as attractions for visitors contributes to the highly localized growth of Lampenflora communities, which are completely dependent on artificial light as a source of energy. These communities may include autotrophs such as photosynthetic algae, mosses and ferns growing near lamps, as well as fungi and other heterotrophs that use organic matter (Johnson, 1979). These communities can displace or disrupt the trophic ecology of energy-limited cave ecosystems. The growth of algae on the walls can also seriously damage and dampen geological and archaeological interest in caves (Lefebvre, 1974), and this is a cause for concern.

4.2. Risks to human health

The effect of "light blindness". Bright streams of light coming from poorly designed road lighting create the effect of "light blindness". This effect has the least intense effect, causing the eyes to be diverted from the light veil that covers the retina. This light veil reduces the property of contrast of vision, color perception, the ability to focus failure. With age, the adaptive functions of the visual analyzer decrease, so older drivers are particularly prone to light blindness.

Circadian rhythms. The 24-hour cycle of days and nights affects the order of brain waves, changes in the hormone melatonin, regulation and activity of living cells. Violation of these data lead to fatigue [30], depression [31], cancer [32] and cardiovascular disease [33].

The evidence that artificial lighting in the room at night affects human health is strong enough. Work in this research field has just begun, but two studies in Israel have yielded some intriguing conclusions. One research team used satellite imagery to measure nighttime artificial lighting in 147 Israeli communities and then attached a photograph detailing the incidence of breast cancer. The results showed a statistically significant correlation between artificial street lighting at night and breast cancer, even with population density control. Women living in areas where it was quite bright to read a book on the street at midnight had a 73% higher risk of developing breast cancer than those living in areas with the least outdoor artificial lighting. However, the risk of lung cancer has not been identified. The findings appeared in the January 2008 issue of Chronobiology International.

Insomnia. The tendency of an unnaturally long day in a modern city can lead to a disynchronization of our biological clocks. According to the World Health Organization (WHO), the change in the daily cycle indicates our ability to fall asleep and wake up at the right time, namely to reduce the level of intelligent and automatic functions, which increases the ability to recover, stress, depression, diabetes. When persuading the WHO, if outdoor lighting disturbs sleep, it is recommended to block the light or limit the lighting for the common good.

To assess the health risk of people living in the area affected by light pollution, we

take into account the points near which there are houses. Namely, all urban points except point №4 (this embankment is not a residential building). Next, calculate the total number of potentially affected population and have the following data.

Table 4.1.

Total number of potentially affected population at the research area

Points	Total number of potentially affected population
IQ business center	20
Gulliver Mall	864
Khreshchatyk Street	1872
NSC Olympic	2970

To determine the level of health risk, we determine the excess of the level of light in the points (table 4.2).

Table 4.2.

Excess of the level of light in the points

Season	Winter		Spring		Summer		Autumn		Background value
Points	The obtained values	Ratio to the background value	The obtained values	Ratio to the background value	The obtained values	Ratio to the background value	The obtained values	Ratio to the background value	
№1	0,3	1,5	0,55	2,75	0,2	1	0,35	1,75	0,2
№2	0,4	2	0,85	4,25	0,25	1,25	0,45	2,25	0,2
№3	0,3	1,5	0,6	3	0,25	1,25	0,3	1,5	0,2
№4	0,2	1	0,3	1,5	0,1	0,5	0,2	1	0,2
№5	0,05	0,25	0,25	1,25	0,05	0,25	0,15	0,75	0,2
№6	0,2	1	0,25	1,25	0,2	1	0,2	1	0,2
№7	0,05	0,25	0,35	1,75	0,05	0,25	0,1	0,5	0,2
№8	0,125	0,625	0,25	1,25	0,1	0,5	0,15	0,75	0,2
№9	0,075	0,375	0,15	0,75	0,005	0,025	0,10	0,5	0,2
№10	0,15	0,75	0,2	1	0,1	0,5	0,2	1	0,2
№11	0,05	0,25	0,1	0,5	0,05	0,25	0,1	0,5	0,2
№12	0,05	0,25	0,1	0,5	0,025	0,125	0,05	0,25	0,2
№13	0,025	0,125	0,125	0,625	0,1	0,5	0,1	0,5	0,2
№14	0,1	0,5	0,1	0,5	0,1	0,5	0,1	0,5	0,2
№15	0,05	0,25	0,075	0,375	0,05	0,25	0,05	0,25	0,2

To calculate the risk assessment for public health based on the level of excess lighting at the points, we rely on the data in table 4.3.

Table 4.3.

Percent of exposed individuals to have the symptom displayed

Symptom	Intensity of light pollution influence			
	50% over the natural in summer and spring	50% over the standard in winter and autumn	50% minutes during the whole year	Night illumination exposure
	Repeatability of influence			
	2-3 times a week	Every day for 1 hour and less	Every day for 2-5 hours	Every day for more than 5 hours
Headache and eyes pain	2%	11%	29%	46%
Fatigue, vertigo	-	8%	18%	39%
Sleeping disorder	-	7%	15%	50%
Drowsiness during the day	4%	14%	28%	48%
Mood instability	6%	10%	17%	30%
Increased irritability	3%	9%	12%	41%
Depression	3%	7%	12%	50%
Pain in the heart area, misbalance in heart rate, short breath	-	3%	5%	22%
Reduction of sexual activity	-	8%	11%	24%
Memory deterioration	-	3%	9%	33%
Breast cancer probability	3%	5%	13%	19%

Table 4.4.

Health risk

Symptom	Points			
	№1	№2	№3	№5
	Number of people with symptoms			
Headache and eyes pain	6	251	543	861
Fatigue, vertigo	4	156	337	535
Sleeping disorder	3	130	281	446
Drowsiness during the day	6	242	524	832
Mood instability	3	147	318	505
Increased irritability	2	104	225	356
Depression	2	104	225	356
Pain in the heart area, misbalance in heart rate, short breath	1	43	94	149
Reduction of sexual activity	2	95	206	327
Memory deterioration	2	78	168	267
Breast cancer probability	3	112	243	386

When calculating the risk to human health, the number of people who will have certain symptoms from the total number of people living in the area affected by light

pollution was calculated.

According to the obtained results, the largest number of affected population is in the area of point №5, due to the fact that there is generally larger population.

In general, it should be noted that light pollution, although considered a minor problem, has a very negative impact on human health.

After analyzing the results of the calculation of the risk to human health on the example of point №1, we observe the following indicators. If 20 people get the systemic effects of excessive artificial lighting, then 6 of them will have headache and eye pain, 4 of them - fatigue, vertigo, 3 - sleeping disorder, 6 - drowsiness during the day, 3 - mood instability, 2 of 20 people will have increased irritability, 2 people will have depression, 1 of them will have pain in the heart area, misbalance in heart rate, shortness of breath, 2 of them will have problems with reduction of sexual activity, 2 of them will have memory deterioration and 3 – increased breast cancer probability.

The residential areas are less affected by health risks, as generally residentical building facing the inside areas of residential complexes demonstrate lower exceedance of the standards. This raises the possible risks to only the first level of risks, to which only the most sensitive categories of population might be sensitive.

4.3. Impact on economic and other human activities

Although the impact of light pollution on the environment is extremely large-scale and difficult to quantify, it is possible to get an idea of what it is doing to the world economy. The light that is abused at night must come from somewhere, and the energy that feeds it is worth the money.

According to James Madison University, the amount of electricity lost at night is a third of all lighting use. In financial terms, this is about $ 2.2 billion in annual losses [35]. To create the electricity that keeps these lights on, coal plants around the world emit about 15 million tons of air pollution, exceeding the emissions produced by 9 million cars each year.

Human resources are no less important for the economy, but under the influence of light pollution, the efficiency of staff decreases. People systematically exposed to excessive illumination have health problems. Disorders caused by light pollution, like

chronic fatigue due to insomnia, result in reduced concentration and efficiency of labor resources, increased accidents at work, as well as the systematic payment of sick leave by the employer. In general, all these problems lead to financial costs of individual industries and economic instability in general.

4.4. Impact on animals

Light pollution can affect areas around cities for tens or even hundreds of miles, reaching no living thing that never remains untouched.

After all, light creates problems for the environment, as plants and animals live in a 24-hour cycle dictated by the sun. As life on the Earth evolved, creatures became accustomed to the day and night cycles and passed this acquaintance on to their genes. This rhythm is known as "circadian rhythm".

When traveling between time zones, a person usually experiences a "change" in their own circadian rhythm. If a person goes to bed at 23:00 and wakes up at 7 am every day and then travels to the time zone 3 hours behind, the circadian rhythm will take a few days to adjust - this is traditionally called "jet lag". This is a sleepy, lethargic feeling that a person gets when traveling. Wildlife is no different. The very recent advent of powerful artificial light has dramatically (and negatively) affected the behavior of animals during mating, migration, sleep and hunting.

Nocturnal animals evolved to function at night. Night, in a very real sense, is a very important part of their environment - no different from trees and food. Their eyes are very sensitive to light, similar to human eyes when a person first wakes up or leaves a dimly lit room in the sun. Animals such as bats, raccoons, coyotes, deer and elk use various natural functions in the dark.

Among these species, there exists the possibility of decline in reproduction and difficulty in finding food. In addition, predators who are not normally able to see these nocturnal creatures can do so more easily, resulting in increased mortality as a result of both the predator's ability to see its prey more easily and the prey's inability to recover properly.

Many species of birds migrate and / or hunt at night. They depend on darkness and the stars to find their way.Their sensitivity to dim starlight makes them extremely

vulnerable to bright city lights. As a result, 100 million birds die every year in the world due to collisions with lighted buildings and towers.

It is known that migratory birds are taken far away due to light pollution, which prevents them from reaching their natural destination. Birds are also known to fly to lighthouses, wind turbines and offshore drilling rigs, as well as many other illuminated obstacles.

Another prominent example of drastic negative impact of light pollution is turtles. Female sea turtles like to nest on remote and dark beaches. Naturally, coastal cities and haze of light pollution make beaches brighter and inhibit nesting. In addition, sea turtle broods are often disturbed by city lights and instinctively crawl into the city instead of the ocean, resulting in millions of deaths a year. Naturally, almost all species of nocturnal reptiles undergo considerable reduction of population.

A recent study, "Light Pollution Drives Insect Reduction," states that artificial lighting at night is one important but often overlooked cause that has played a role in reducing insects worldwide.

Light affects insect movement, food production, reproduction and predation, according to research, which, however, suggests that insect biodiversity loss can be mitigated through more knowledgeable lighting practices.

“Artificial light at night is unique among anthropogenic habitat disturbances in that it is quite easy to improve and leaves no residual effects. Greater recognition of the ways in which artificial light at night affects insects can help conservationists reduce or eliminate one of the main factors in reducing insects” [34].

Of course, the list goes on, but these are some of the highlights of the detrimental effects of artificial lighting on the environment. By lighting responsibly, people can restore the night ecosystem just as they plant trees or create national parks to help protect and restore that environment.

4.5. Recommendations for reducing the level of light pollution in Kyiv

To reduce the level of light pollution it is necessary to change the culture of using artificial light sources by an average person and the assessment of proper lighting. Of course, this process is time consuming and will affect various aspects of our lives, from

home life or work to leisure and social activities.

In order to change the situation of light pollution, which has developed in Ukraine on the example of the city of Kyiv, the main efforts should be directed to the key source of pollution - the glow, which is sent directly to the lower atmosphere. By eliminating the root cause, we will simultaneously reduce both the amount of annoying light and the radiance of the sky. Regardless of whether the pollution is local or global, it can still be reduced.

Scientists have developed the zoning system that introduces a kind of quotas, quantitative restrictions on the illumination of large regions. In my opinion, it would be rational to apply this system in Ukraine. Control and regulation of this issue should be entrusted to local authorities and professionals to fully manage the situation.

Intrusive lighting should also be actively studied by Ukrainian experts to form its own precedent base. Within this scheme, citizens could complain to local authorities about too bright lighting from retail outlets, etc.

Officials are obliged to consider such cases seriously, and demand adjustments when experts confirm the real background of the claims, as well as to issue orders to the owners of problematic light sources. Depending on the severity of the offense, it may be referred to a court or other authority. That is, this issue must be under the control of local executive bodies.

As for signs and city lights, it is necessary to adjust the lighting, but the laws passed more than ten years ago have simply lost their relevance in terms of the modern level of electronics. With the development of technology, the streets were filled with LCD screens and LED signs with much greater progressive brightness. In fact, they need to be tackled by revising previously adopted standards in the light of technical advances - and then at least in this area of responsibility the problem will be solved.

On the example of European countries, in particular Slovenia, the Czech Republic and some provinces of Italy, where there are quite strict laws, they can be implemented in Ukraine. It is possible to introduce a direct ban on the use of architectural floodlights, powerful street lighting on the facades of buildings and in general any light, part of which falls on anything above the building that needs lighting. Public use of lamps should be

regulated by the principle of permissible kilowatt-hours per person per year, and instructions to use light sources directed exclusively from top to bottom. In addition, the billboards themselves should be turned off at night - at 23:00 or 00:00 to reduce the overall light pollution.

It would be expedient for local authorities to implement regulations on the example of Asian countryside, which contributed to the development of citizens' awareness of the rational use of light. As an example, such laws may include the following rules: dim the light or turn it off according to a set schedule (recommended after 22:00), minimally use secondary lighting at home.

4.6 Conclusions to chapter 4

Light pollution is a very serious problem that affects various components of the environment. The effect of light pollution on plants causes changes in plant biorhythms and the process of photosynthesis.

One of the consequences of light pollution is the decrease in the populations number of nocturnal of animals, violation of birds and reptiles migration, a decrease in the number of mammals due to greater activity of predators due to artificial light sources.

Excessive light reduces the contrast property of vision, color perception, the ability to focus. For humans, this is especially important because the adaptive functions of the visual analyzer are reduced. Light pollution is also a cause of insomnia and chronic fatigue in people, which is interrelated with the economics of production.

Also one of the consequences is a significant economic cost of energy for the production of light energy.

In order to improve the situation, a number of legislative acts should be introduced to regulate this issue in the cities of Ukraine on the example of the experience of developed countries in Europe and Asia.

CHAPTER 5
LABOUR PREAUTION

5.1. Analysis of harmful and dangerous production factors

According to the theme of my diploma project “ Light pollution of the city of Kiev”, to determine the level of light pollution in the city of Kyiv.

To conduct a qualitative analysis, the first stage was to measure the level of illumination of the territory directly in the city of Kiev at different points. The next stage was the analysis of the obtained data, which was carried out using computer and electronic resources. The main amount of work of the analysis was carried out by working with a computer , the assistant may be affected by such dangerous and harmful production factors in accordance with the standard ГОСТ 12.0.003-74 "Occupational safety standards system. Dangerous and harmful production factors. Classification":

1. Factors which belong to physical harmful factor

- increased level of ultraviolet radiation;
- increased level of static electricity;
- increased level of dust in the air of the working area;
- reduced or increased humidity of the working area;
- reduced or increased air mobility of the working area;
- increased noise level in the workplace (from fans, processors, audio boards, printers);
- increased or decreased light level;
- increased level of direct and reflected brightness;
- increased level of blindness;
- uneven distribution of brightness in the field of view;
- increased brightness of the light image;
- increased level of pulsation of light flux;
- electric shock;

2. Factors which belong to psychophysiological harmful factor

- visual stress;
- tension of attention;
- intellectual loads;
- emotional loads;
- prolonged static loads;
- monotony of work;
- a large amount of information processed per unit time;
- irrational organization of the workplace [27].

5.1.1. Requirements for the workplace

When choosing a room for workplaces, keep in mind that the windows can shine on the display screens and cause significant glare in those sitting in front of them, especially in summer and on sunny days. Premises with a PC (personal computer) and VDT (video display terminal) must have natural and artificial lighting. Unsatisfactory lighting reduces the productivity of the PC operator (VDT), possible myopia, fatigue.

The organization of the workplace of the user of the PC and VDT has to provide conformity of all elements of a workplace and their arrangement to ergonomic requirements of ГОСТ 12.2.032 “ССВТ. Workplace when performing work sitting. General ergonomic requirements ”; nature and features of labor activity. It is not allowed to place PC workstations in basements and basements.[28]

Workplaces with VDT and PC during creative work, which requires significant mental effort or high concentration, should be isolated from each other by a partition height of 1.5 m. It is recommended to place workplaces with VDT in separate rooms. In the case of VDT workplaces in halls or rooms with sources of hazardous and harmful factors, they should be located in completely isolated rooms with natural light and organized air exchange.

The floor surface should be smooth, without potholes, non-slip, easy to clean and wet clean, have antistatic properties. When placing workplaces, it is necessary to exclude the possibility of direct illumination of the screen by a source of natural light.

The design of the desktop should provide the possibility of optimal placement on the work surface of the equipment used, taking into account its number, size, design features

(size of VDT, keyboard, printer, PC, etc.) and the nature of its work. The width and depth of the working surface must provide the ability to perform labor operations within the motor field, the limit of which is determined by the area within the visibility of the devices and the reach of the controls.

Preference should be given to the modular dimensions of the table, on the basis of which the design dimensions are calculated; width should be considered: 600, 800, 1000, 1200, 1400; depth - 800 cm, with unregulated height. The surface of the table should be matte with low reflection and heat insulating.

The chair should provide maintenance of a rational working pose during performance of the basic production operations, to create conditions for change of a pose. In order to prevent fatigue, the chair should reduce the static tension of the muscles of the neck and shoulders and back. The type of work chair should be chosen depending on the nature and duration of work. It must be swivel and adjustable in height and angles of the seat and back, as well as the distance of the back from the front edge of the seat. The adjustment of each parameter must be independent and have a secure fixation. All levers and handles of the device (for adjustment) must be easy to operate.

5.1.2. Workplace illumination requirements

Lighting requirements for the visual perception by operators of information from two different media (from the VDT screen and paper media) are different. Too low brightness impairs the perception of information when reading documents, and too high reduces the contrast of the characters on the screen. Therefore, the ratio of the brightness of the VDT screen to the brightness of the surrounding work surfaces should not exceed 3: 1 in the work area, and work surfaces and surrounding objects (walls, equipment) - 5: 1.

Artificial lighting in rooms with VDT should be carried out in the form of a combined lighting system using fluorescent light sources in general lighting fixtures, which should be placed above the work surfaces in a uniform and rectangular order. To prevent the illumination of VDT screens by direct light fluxes, the lines of the lamps must be located with sufficient lateral offset relative to the rows of workplaces or zones, as well as parallel to the light openings. It is desirable to place windows on one side of the work area. In this case, each window should have light curtains with a reflection coefficient of

0.5-0.7.

Artificial lighting should provide 300-500 lux illumination at PC workplaces. If it is impossible to provide this level of illumination, the general lighting system allows the use of local lighting fixtures, but there should be no glare on the screen surface and increase the brightness of the screen more than 300 lux.

In the case of natural light, the presence of sunscreen should be provided, for this purpose, you can use films with a metallic coating or blinds with adjustable vertical slats. The workplace equipped with VDT must be located in such a way that windows or lighting fixtures do not fall into the operator's field of vision; they should not be directly behind him.

The workplace should be provided with uniform illumination by means of mainly reflected or diffused light distribution. There should be no glare from the keyboard, screen or other parts of the VDT in the direction of the operator's eyes.

To exclude them, it is necessary to use special screen filters, protective visors or place light sources parallel to the direction of view of the VDT screen on both sides. To prevent glare, local lighting fixtures should have reflectors made of opaque material or milk-colored glass. The protective angle of the reflector must be at least 40 °.

It is not desirable for the operator's clothing to be light and particularly shiny. Diffuse-reflecting materials with reflection coefficients should be used for finishing of premises with VDT: ceilings - 0,7-0,8; walls - 0.4-0.5; floors - 0.2-0.3.

5.2. Measures to reduce the impact of harmful and dangerous production factors

One of the main requirements for the workplace is the noise level contained. High noise levels interfere with concentration on the workflow, resulting in reduced work efficiency. Workplaces in VDT premises are characterized by the presence of mechanical noise (caused by oscillations of machine parts and their mutual movement), aerodynamic noise (occurring in elastic structures in gas or liquid) and noise of electric machines.

Some VDTs are potential sources of a number of sound vibrations, both audible and ultrasonic. Most often, the levels of acoustic radiation emanating from the VDT cover the frequency range from 6.3 to 40 kHz. Frequencies from 16 to 40 kHz associated with the

horizontal deployment frequency (occurring in the core of the horizontal deployment converter) are dominant.

In rooms with computers, sound pressure levels, sound levels and equivalent sound levels in the workplace must meet the requirements of ГОСТ 12.1.003 ССВТ "Noise. General safety requirements", ДСН 3.3.6.037-99, ГР № 2411-81 "Hygienic recommendations for installation noise levels in the workplace, taking into account the intensity and severity of work ", approved by the Ministry of Health of Ukraine. Noise levels at the workplaces of persons working with video terminals and computers are determined by ДСанПіН 3.3.2-007-98 (table 5.1).

Table 5.1.

Noise levels in workplaces with VDT

Type of work	**Sound pressure levels in dB**									
	in octave bands with geometric mean frequencies, Hz									
	31,5	63	125	250	500	1000	2000	4000	8000	Sound levels, eq. levels of so-called, dBA / dBAeq.
Programmers	86	71	61	54	49	45	42	40	38	50
Operators in information processing halls, computer set operators	96	83	74	68	63	60	57	55	54	65

The main means of noise control are the elimination or attenuation of the causes of noise at its source in the design process, the use of sound absorption, rational planning and acoustic treatment of industrial premises. The most rational way is to reduce the noise at the source (creation of low-noise equipment), change the direction of radiation, the introduction of technical standardization of machine noise.

In accordance with the standard or technical conditions in the passport of the machine indicates its noise characteristic - a set of sound power levels of the machine in standard octave bands.

Noise from aerodynamic noise sources can be reduced by using vibration-insulating gaskets, which are installed between the stand of the machine, the device and the support surface. Rubber, felt, cork, shock-absorbers of various designs are used as linings. Noisy desktop devices, computers, perforating machines can be installed on soft mats made of synthetic materials, and under the legs of the tables on which they are installed - pads made of soft rubber, felt 6… 8 mm thick. Fastening of linings is possible by gluing them to basic parts. Replacement of rubber gaskets is carried out in 4… 5 years, and from felt - 2… 2,5 years.

One of the main ways to reduce the overall sound pressure level in VDT rooms is to reduce aerodynamic noise on the ways of its distribution, which is achieved by equipping ventilation systems with sound absorbers and sound insulation of air ducts, timely prevention and repair of process equipment and ventilation systems. To ensure normalized noise levels in industrial premises and workplaces, noise-absorbing means are used, the choice of which is justified by special engineering and acoustic calculations.

Non-combustible or non-combustible special perforated plates, panels, mineral wool with a maximum sound absorption coefficient within the frequencies of 31.5… 8000 Hz, or other materials of similar purpose approved for decoration of premises by the state sanitary and epidemiological surveillance shall be used as noise absorption means. In addition, it is necessary to use suspended ceilings with similar properties[29].

5.3. Occupational Safety Instruction

5.3.1. General safety requirements

1. Persons who have reached the age of 18, have passed a medical examination, are acquainted with the instructions on labor protection when working with office equipment are not allowed to work independently with a computer, laptop, printer, copier, scanner, plasma panel, LCD display and other office equipment. have contraindications for health reasons.

2. The following dangerous and harmful factors can affect a teacher when working on a computer and other office equipment:

electric current and radiation;

overexertion of vision when working with electronic devices, the monitor, especially at an

irrational arrangement of the screen in relation to eyes.

3. Lighting installations must provide uniform illumination and must not create blinding glare on the keyboard as well as on the monitor screen in the direction of the eyes.

4. When working with a computer, printer, copier and other peripherals, it is not allowed to place the workplace in rooms without natural light, without the presence of natural or artificial ventilation.

5. The workplace with a computer and office equipment should be located at a distance of at least 1 m from the wall, from the wall with window openings - at a distance of at least 1.5 m.

6. The angle of the screen of the monitor or laptop in relation to the vertical should be 10-15 degrees, and the distance to the screen - 500-600 mm.

7. The angle of view of the screen should be straight and 90 degrees.

8. To protect from direct sunlight should provide sun protection devices (film with a metallic coating, adjustable blinds with vertical panels, etc.).

9. Lighting should be mixed (natural and artificial).

10. In the office and in the workplace it is necessary to maintain cleanliness and order, to conduct systematic ventilation.

11. All equipment malfunctions detected during operation must be reported to the manager, in case of breakdown it is necessary to stop work until the emergency situation is eliminated. In case of possible danger, warn others and immediately inform the manager; keep the workplace clean, do not clutter it with foreign objects.

12. The eyewitness, the worker who found the accident, or the victim himself must report the accident directly to the head of the institution and take measures to provide medical care.

13. Persons guilty of violating the requirements required by this instruction on labor protection when working with a computer, printer, copier and other office equipment, are subject to disciplinary action in accordance with applicable law.

5.3.2. Safety Requirements before starting work

1. Inspect and make sure the equipment and wiring are in good condition. In case of

malfunctions, do not start work. Notify the supervisor and, only after troubleshooting and permission, get to work.

2. Check the lighting of the workplace, if necessary, take measures to normalize it.

3. Check the presence and reliability of protective earthing of the equipment.

4. Check the condition of the power cord and plug.

5. Check the serviceability of switches and other controls of personal computers and office equipment.

6. If any faults are detected, do not turn on the computer and office equipment and immediately notify the head of the preschool.

7. Thoroughly ventilate the room with a personal computer and office equipment, make sure that the microclimate in the room is within acceptable limits: air temperature in the cold season 22-24 ° C, in the warm season - 23-25 ° C, relative humidity - 40 -60%.

8. Turn on the monitor and check the stability and clarity

5.3.3. Safety Requirements during operation

1. Switch on the computer, laptop and other office equipment only with switches, it is forbidden to switch off by pulling the plug out of the socket.

2. It is forbidden to remove protective devices from the equipment and work without them.

3. Do not allow outsiders who do not participate in the work to the computer and office equipment.

4. Do not move or relocate the system unit, monitor, printer, or any live equipment.

5. It is forbidden to drink any drinks or eat during work.

6. Any physical interference with the device of the computer, the printer, the scanner, the photocopier during their work is forbidden.

7. Do not leave the included equipment unattended.

8. It is forbidden to place objects on computer equipment, monitors, screens and office equipment.

9. Strictly comply with the general requirements for electrical safety and fire safety.

10. When removing paper jams from a photocopier or printer, disconnect the equipment from the electrical outlet to avoid electric shock. It is also necessary to

disconnect the equipment from the network during prolonged downtime.

11. It is strictly forbidden to disassemble and repair electronic and electronic-mechanical parts of computers, peripherals, and office equipment on your own. These works can be performed only by a specialist or computer engineer.

12. The total time of direct work with a personal computer and other office equipment during the working day should not exceed 6 hours, for teachers - no more than 4 hours a day.

13. The duration of continuous work with a personal computer and other office equipment without a regulated break should not exceed 2 hours. Every hour of work should take a break lasting 15 minutes.

14. During regulated breaks, in order to reduce nervous and emotional stress, fatigue of the visual analyzer, eliminate the effects of hypodynamics and hypokinesia, prevent the development of posttonic fatigue, you should perform sets of exercises for the eyes or organize exercise breaks.

15. The computer, any of its peripherals, office equipment must be used in strict accordance with the operating documentation for them.

16. During work it is necessary to be attentive, not to pay attention to extraneous things.

5.3.4. Safety Requirements after work

1. Unplug the computer, laptop, TV, plasma panel, LCD screen, printer, copier, scanner, speakers, and other office equipment by unplugging the switches and then gently unplugging them.

2. Wipe the outside of the computer with a clean damp cloth. At the same time do not allow the use of solvents, cologne, drugs in aerosol packaging.

3. Clean the workplace. Fold the discs into the appropriate storage location.

4. Thoroughly ventilate the room with a personal computer and other office equipment.

5.3.5. Safety Requirements at emergency situations

1. If voltage (current sensation) is detected on the metal parts of the equipment, the ground wire is broken, the equipment must be switched off, immediately report the fault to

the electrical equipment to the manager and do not start work without his instructions.

2. When the power supply is cut off, turn off the equipment.

3. If there is an unusual sound, the smell of burns, involuntary shutdown of the computer and office equipment, stop work immediately and notify the manager.

4. In the event of a fire, immediately turn off the equipment, de-energize the electrical network except for the lighting network, report the fire to all employees and start extinguishing the fire with available fire extinguishing means.

5. In the event of an accident, it is necessary, first of all, to release the victim from the traumatic factor, to go to the emergency room, to keep, if possible, the place of injury in the condition in which it was at the time of injury. When releasing the victim from electric shock, make sure that you do not come into contact with the live part and under voltage.

CONCLUSIONS

1. The city of Kyiv, like most modern cities, has significant problems with excessive lighting. An integrated approach is needed to solve the problems of light pollution in the city. The main problem is that the issue of light pollution in Ukraine is currently only being studied. Compared to the United States and developed countries in Europe and Asia, which have already started to implement measures to address the problem of light pollution.

2. The main drivers of this problem are inefficient lighting equipment, improper planning of lighting fixtures. Advertising and marketing trends also exacerbate the problem. Thus, there is a need to study the level of this type of pollution in the city of Kyiv, which is the largest urban area of our country.

3. Analysis of methodology for studying light pollution showed that it is equipped with a variety of tools and techniques, despite the fact that its development began not so long ago. The level of light pollution in our country is insufficiently studied and requires careful study. Thus, there is a need to develop a systemic normative document to establish a standard for measuring light pollution and differentiation of sources, as well as to determine the permissible levels of impacts from this physical factor.

4. In the course of our research, lighting levels were measured at 15 points in Kyiv. Measurements were performed during the year in each season. The study also assessed the state of the sky by the Bortl scale during the year and subjective perception of the sunset was observed during the year. The obtained results were compared to background levels.

5. Comparative analysis has showed that in general the level of lighting at all points is similar to the background levels except for the category of Business areas. The level of light pollution in Business areas significantly exceeds the background levels 10-100-fold.

6. According to the Bortl scale, the state of the sky in the city has an average rating of 7, which is typical for the city sky and the sky in the suburban area. Under the influence of high levels of light, the subjective perception of the sunset differs from the astronomical

one by an average of 8 minutes. These deviations from natural phenomena can cause damage to human health and adversely affect other living organisms.

7. Having studied in detail the problem of light pollution, we summarize that this physical factor has a very negative impact on flora, fauna and humans. Light pollution is the cause of the extinction of nocturnal species of animals and plants, causing human health risk from insomnia to cancer.

At the end of all this work it can be determined that the problem of light pollution in Ukraine at the present stage requires solution and maximum attention of scientists and local governments. It is possible to reduce the level of light pollution by introducing fairly simple legislation and restrictions. The thesis provides information on approaches and specific recommendations for reducing the level of lighting in the study area**.**

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