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Environmental evaluation of the lighting system at building Z of the ITVH

Mario José Romellón Cerino
Professor at the Tecnológico Nacional de México/Instituto Tecnológico de Villahermosa. Department of Chemistry-Biochemistry-Environmental Chemistry
Email: mario.rc@villahermosa.tecnm.mx

Maria Berzabe Vazquez Gonzalez
Professor at the Tecnológico Nacional de México/Instituto Tecnológico de Villahermosa. Department of Chemistry-Biochemistry-Environmental Chemistry

Maria Antonieta Toro Falcon
Professor at the Tecnológico Nacional de México/Instituto Tecnológico de Villahermosa. Department of Chemistry-Biochemistry-Environmental Chemistry

Julio Cesar Romellón Cerino
Professor at the Tecnológico Nacional de México/Instituto Tecnológico de Villahermosa. Department of Industrial Engineering

Kleber Zacarias Bernal
Professor at the Tecnológico Nacional de México/Instituto Tecnológico de Villahermosa. Department of Chemistry-Biochemistry-Environmental Chemistry

***Abstract*---**The ability of human beings to adapt to the environment is amazing, it is a fact that the comfort, mood and performance of students are affected by light. Insufficient, irregular lighting, excessive contrasts and reflections cause fatigue to appear much earlier in students. This analysis consists of a field visit, a lighting survey in accordance with the methodology indicated in NOM-025-STPS-2008, where the lighting levels are evaluated to establish the optimal requirements in each and every one of the classrooms in building Z, in compliance with current regulations, in order to provide a safe and healthy environment for students to perform their tasks. The risk related to lighting that arises in the student environment due to the amount of luminosity (excess, lack) or its defects (glare, glare, inadequate contrasts) is observed. Results show that inadequate or defective lighting generates fatigue, visual disturbances, increased mental effort, poor performance and even accidents of various kinds.

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Corresponding author: *Cerino, M. J. R.; Email: mario.rc@villahermosa.tecnm.mx*
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The research suggests to have adequate lighting for students of the Instituto Tecnológico De Villahermosa in order to reduce visual fatigue, student absenteeism, increase visual comfort, and stimulate good attitude and overall student satisfaction.

***Keywords*---**environmental, evaluation, lighting system, lighting survey.

Introduction

The proper development of activities requires adequate lighting in places where daily activities are carried out as pleasant environments. Although human beings are able to adapt to any environment quickly and easily, there are certain factors that can affect their mood, well-being and increase their fatigue, such as environmental deficiencies associated with inadequate lighting levels. When evaluating the lighting levels in the work area, it should be understood that both the lack or excess of light, which are the cause of visual disorders, are detrimental to people's health. The lighting in each workplace should be equipped with adequate lighting systems that provide an optimal and comfortable visual environment that allows them to perform all routine and non-routine activities, without demanding an excessive visual effort (Gómez Díaz, & Rivas Laguna, 2021). So, lighting is an aspect that puts at risk the physical integrity of people, since visibility is given thanks to the light projected on the environment and is one of the environmental factors of microclimatic character, to generate the visibility of things allowing the development of daily activities at any time of the day with the same efficiency (García & Rozo, 2010).

Environmental assessment serves to identify ways to environmentally improve projects and minimize, mitigate or compensate for adverse impacts. Alerting about the importance of environmental problems that originate in the workplace allows analyzing the existing opportunities for improvement in the quality and balance of infrastructure, machinery and equipment that positively or negatively affect the economy, health and the environment in general.

Buildings consume 40% of the world's energy, making artificial lighting one of the factors that has the greatest impact on energy consumption in office buildings (Beitia, Gonzalez, Guardia, Guerra, & Peren, 2020). In many buildings, lighting represents a high percentage of electricity consumption. Thus, the percentage of electrical energy devoted to lighting can in some cases reach more than 50%. Worldwide, lighting accounts for approximately 15% of total electrical energy consumption. It is estimated that in Mexico, lighting energy consumption represents approximately 18% of total electrical energy consumption.

The energy consumed by a lighting installation depends on the power of the installed lighting system and the time it is on. Both aspects are important since their variations can affect the energy efficiency of the installation. It is important to know the energy consumption of an installation (existing or future) in order to improve its energy efficiency. Such measures will require an economic investment, but will reduce energy consumption in the future (Montano Arias, 2006).

The lighting conditions in the workplace have the primary objective of establishing the lighting requirements in the areas of the workplace, so that there is the amount of lighting required for each visual activity, in order to provide a safe and healthy environment in the performance of the tasks performed by workers (NOM-025-STPS-2008).

Objectives

General Objective

Evaluate compliance with NOM-025-STPS-2008 of the lighting system in building z of the Villahermosa technological institute

Specific objectives.

- Verify that the building z lighting system complies with NOM-025-STPS-2008.
- A correct distribution of the building's lighting system z
- Identify the environmental and health impacts of the building's current lighting system on the environment z

Methodology

The steps indicated in NOM-025-STPS-2008 were followed. The first step consisted of a reconnaissance of the work areas to identify the conditions in which the activities are carried out (deficient lighting or lighting that could cause glare) in accordance with point 8.2 of the standard. To determine the visual areas and tasks of the workstations, the information from the survey of the lighting conditions of the work areas, as well as the areas where there is poor lighting or glare, and subsequently, as the characteristics of the luminaires or the lighting conditions of the work area change, should be collected and recorded with the following data:

- Distribution of work areas, lighting system (number and distribution of lighting fixtures), machinery and work equipment;
- Lamp wattage;
- Description of the illuminated area: colors and type of surfaces of the premises or building;
- Description of visual tasks and work areas;
- Description of the workstations that require localized lighting, and
- Information on the perception of lighting conditions by the worker to the employer (NOM-0025-STPS-2008).

The walls of the buildings are unfinished concrete, painted white, and the columns are dark green. Subsequently, the light produced by the luminaires in the classrooms of building Z of the ITVH was measured and the values obtained were verified with respect to the Mexican Official Standard NOM-025-STPS-2008. The values obtained from the monitoring of the academic classrooms were recorded in tables, whose illumination values were expressed in lux, obtained with the luxmeter.

The illumination measurement site was carried out at the Instituto Tecnológico de Villahermosa, specifically in building Z, as shown in Figure 1.

Figure 1. Aerial view of ITVH and Building Z

To measure the intensity of the light produced by the luminaires in building Z of the ITVH, the design should take into account the needs of an average classroom, i.e., a classroom of approximately 8.20 m x 7.10 m, whose distribution is uniform to verify if there are dark areas, excess lighting or glare, so the distribution of the luminaires that are currently in the classrooms will be verified.

A representative classroom of the academic building was selected for lighting monitoring, with the firm objective that the results would significantly represent the amount of luxes available in the current lighting design and distribution, taking into account that the classrooms in each building are the same in terms of design and distribution.

The illumination measurement was carried out according to the Westinghouse lighting manual, which indicates that for the calculation of reflectance, the luxmeter should be measured on each wall by placing the light sensor towards the wall at a distance of 15 cm and at chest height; then, the next measurement in the same way, but now placing the sensor with its back to the wall. Figure 2 shows the points where the measurements were taken on each wall, in the center of the classroom and under the luminaire.

Measurement of lighting levels

Measurement of lighting levels in the model classroom in building *z* will use a luxmeter to measure lighting levels and a flexometer to measure classroom area.

1. The representative classroom was identified for the corresponding lux measurement. In this case, the measurements were carried out in classroom No. 83 in building Z.
2. Once the representative classroom was identified, the lux measurement began. According to the Westinghouse Lighting Manual, the amount of illumination emitted to wall 1 was measured with the help of the luxmeter, placing it with the cell facing the wall at 15 cm, at a midpoint of the wall and at chest height, and then in the same way placing the cell facing the opposite side of the wall.
3. The amount of light emitted in luxes, which reaches wall 2, was measured with the help of the luxmeter, placing it with the cell facing the wall at 15 cm, at a midpoint of the wall and at chest height, and then in the same way placing the cell facing the opposite side of the wall.
4. The procedure requires to measure the amount of illumination emitted in luxes, which reaches wall 3, with the help of the luxmeter, placing it with the cell facing the wall at 15 cm, at a midpoint of the wall and at chest height, and then in the same way placing the cell facing away from the wall.
5. In the same way, the amount of illumination emitted in luxes, which reaches wall 4, was measured with the help of the luxmeter, placing it with the cell facing the wall at 15 cm, at a midpoint of the wall and at chest height, and then in the same way placing the cell facing the opposite side of the wall.
6. After measuring the walls of the representative classroom, the emitted amount of lux illumination was measured by placing the luxmeter with the cell towards the ceiling 75 cm from the floor in the center of the classroom.
7. A last measurement was taken by placing the cell 15 cm, at midpoint under one of the luminaires of the representative classroom.

Subsequently, the readings of the measurements recorded in the evidence notebook were entered into a spreadsheet to analyze the data obtained and develop formulas to help interpret the results and check the illumination levels.

Results

Current design and distribution of lighting in the classrooms of Sector "Z" according to the visual tasks performed in each of the classrooms.

Visual task of building z

The rectangles represent the location of the luminaires and the legend on them, the number of lamps in the classroom is shown in Figure 3 (12 luminaires), where each luminaire has a voltage of 36 watts, using 12 LED lamps in each classroom and for the 14 classrooms in the building, resulting in a total of 168 lamps. According to the lighting conditions, the classroom was designated as the representative classroom to carry out the measurements and obtain the required results.

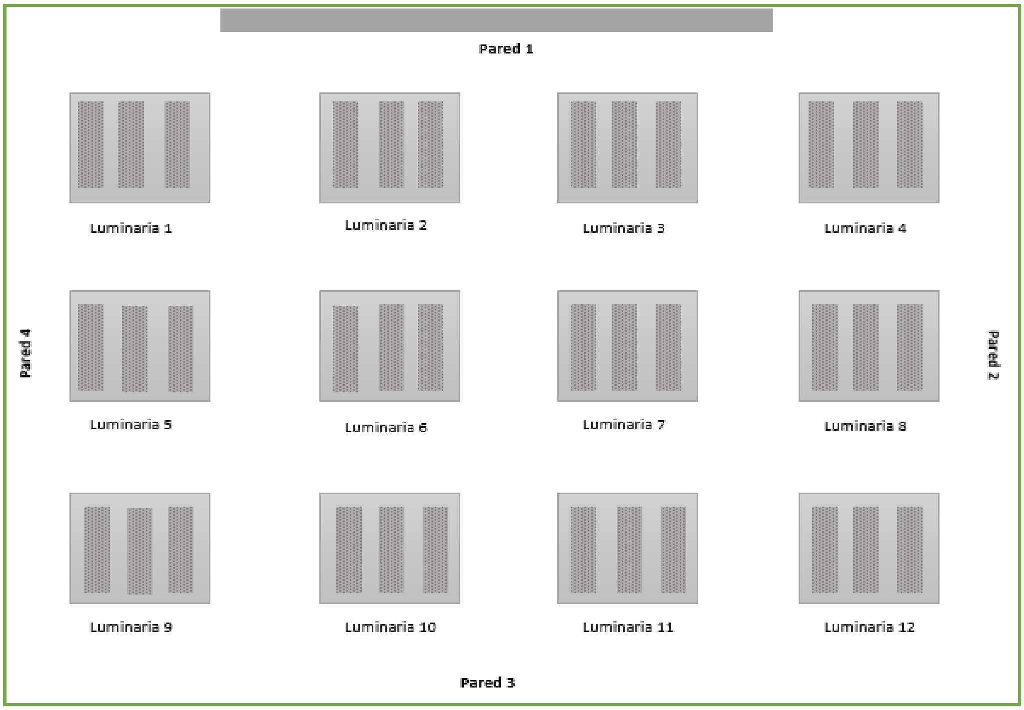

Figure 2. Number of luminaires in classroom No. 83 of the building

Results of the monitoring in Building Z

For data collection at the measurement points, the recommendations were followed as shown in Figure 3, which shows the points where the measurements were taken in the representative classroom No. 83 of building Z. The sensor was placed in the determined areas, in wall 1, wall 2, wall 3 and wall 4, the luxmeter cell was placed facing the wall at 15 cm, in a middle point and at chest height, and then in the same way placing the censor facing the opposite side of the wall. Then it was under the luminaire where the cell was placed at 15 cm. Subsequently, the measurement at 75 cm from the floor indicates the level of illumination that reaches the work plane, i.e., the desks, where the students perform their reading and writing activities.

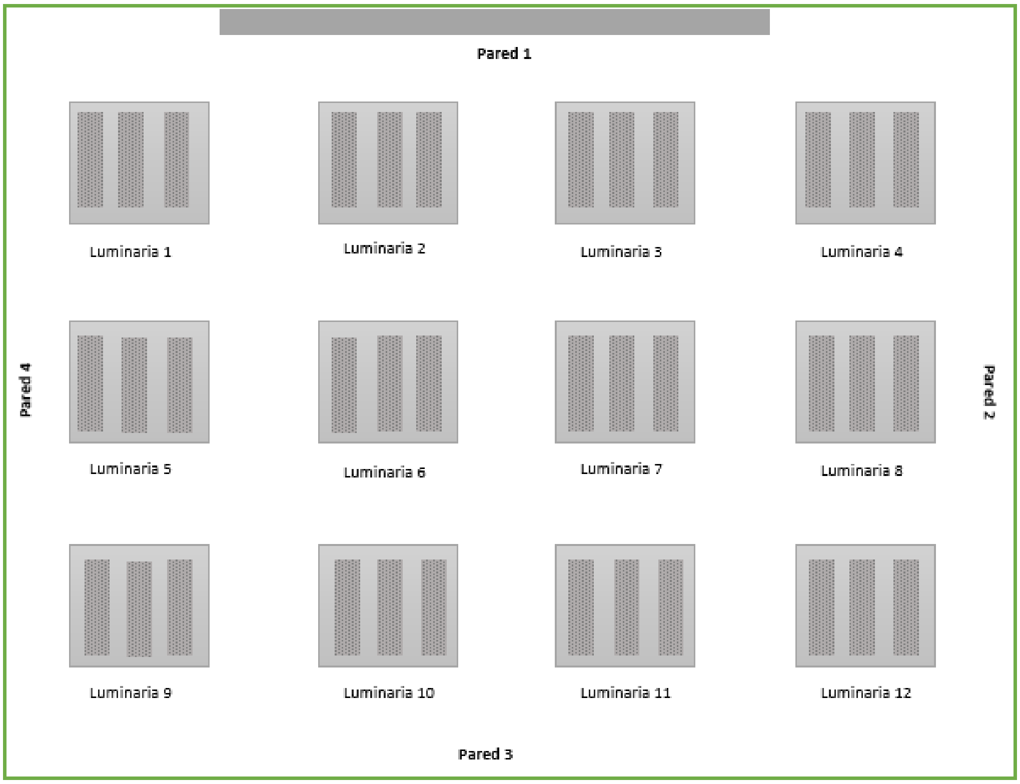

Figure 3: Graphical representation of the measurements in the representative Classroom No. 83 of building Z.

Table 1
Readings obtained in the Model Classroom of the Z building.

Symbol	Point	Measurement	Luxes AB
	Wall 1	15 cm at chest height.	
	Wall 2	15 cm at chest height.	
	Wall 3	15 cm at chest height.	
	Wall 4	15 cm at chest height.	
	Center	75 cm from the ground	212
	Luminaire	15 cm below	2300

With the information obtained from the measurements in the representative classroom No. 83 of building Z, which are expressed in lux, according to Table 1 of lighting levels, It is noted that the classrooms in building Z are below the established value, since the measurement taken with the lux meter in the representative classroom indicates that the level of lighting that reaches the work plane is 212 lux and the value established by NOM-025-STPS-2008 for classrooms is 300 lux, proving that the lighting level is below the established value.

Subsequently, calculations were performed to determine the reflection factor of the sampling points at the illumination levels.

Calculations to determine the reflection factor originated by the walls in each of the buildings.

$$\text{Reflection factor} = \frac{\text{Reading A}}{\text{Reading B}} \quad (1)$$

Calculation of the building refraction factor Z

The recordings in the model classroom were made from 7:00 pm when it was getting dark and the readings remained more constant, the ratio between reading A (lux reflected by the surface) and reading B (lux incident on the surface) was calculated:

Table 2
Values obtained for the calculation of the refraction factor of classroom No. 83 of building Z.

Building Z

Wall	1							
Time Point	A	B	A	B	A	B	A	B
7:00 pm Luxes								

Source: Calculation report.

Table 3
Average lux reading A and B of the refraction factor of classroom No.83 of building Z.

A	**B**
90.75	115.75

Results obtained according to the calculations to determine the reflection factor originated by the walls (values in lux).

- Applying a rule of three we obtain the following relationship:

$$90.75A = 115.75B$$
$$0.7840\ A = 1B$$

It is defined that 1 lux incident on the surface will be equal to 0.7840 lux reflected, and thus it is established that the reflection factor at all times will be the constant 0.7840, since dividing the reading A on reading B, this value will always be obtained.

- **Percentage of the reflection factor. When**

1B= 1A=100% of incident light is reflected.
1B=0.7840A= 78.40 % of the incident light is reflected.

Table 3
Values obtained for the calculation of the refraction factor in the center of classroom No. 83 of the Z building

BUILDING Z		
CENTER	75 cm above the ground	15 cm from the bottom of the luminaire
Time 07:00:00 p. m. / **Luxes**	212	230

Table 4
Average lux reading A and B of the refraction factor in the center of classroom No.83 of building Z

A	**B**
212	230

Results obtained according to the calculations to determine the reflection factor originated by the walls (values in lux).

- Applying a rule of three the following relationship is obtained:

212A = 230B
0.9217 A = 1B

It is defined that 1 lux incident on the surface will be equal to 0.9217 lux reflected, and thus it is established that the reflection factor at all times will be the constant 0.9217, since dividing reading A on reading B will always give this value.

- Percentage of reflection factor.

When:

1B= 1A=100% of incident light is reflected.
1B=0.9217= 90.17 % of the incident light is reflected.

Table 5
Maximum Allowable Levels of Reflection Factor

Concept	Maximum Permissible Reflection Levels, Kf
Walls	
Work plan	50%

Source: Mexican Official Standard NOM-025-STPS-2008.
Note: Glare is considered to exist in the work area and workstation when the reflection value (Kf) exceeds the established values.

This gives us that the incident light on the surface of the walls inside the classroom is reflected by approximately 78.40%, so it is determined that the reflection factor is above the maximum permissible limits established in NOM-025- STPS-2008. The current lighting system in this building exceeds the illumination level, so it does not meet the required amount of light, so the level of light reflected on the walls is high. One of the main factors that help the light to be reflected is the colors of the wall and ceiling. In this case, the classroom has light colors on both the wall and ceiling, so that the excess lighting is reflected and represents high values in the refraction calculation. The excess of lamps in the current design may be one of the factors that prevent the classroom lighting from being optimal.

Environmental health
Occupational lighting

Workplace lighting is an environmental factor that, if adequate, facilitates the visualization of objects in the workspace, allowing activities to be carried out with a higher level of efficiency, comfort and safety. The two main situations that can negatively affect lighting conditions, generating visual fatigue, mental effort, accidents, lack of adaptation and well-being, as well as low performance in the quantity and quality of work, are:

Poor lighting: insufficient lighting increases visual disturbances due to refractive errors and age; however, although it does not cause visual damage by itself, it is a factor that has a direct impact on the occurrence of accidents due to not being able to clearly distinguish elements of the workplace. Symptoms generated by lack of illumination are:

- Accelerated aging of the eyesight.
- Demotivation.
- Headache and eye pain (Armando, 2014).

Excessive illumination: a situation that is better known as glare. Glare is caused by too great differences of illumination in the visual field, its main effects being: A) direct glare (by direct vision of a light source), and B) reflected glare (by reflection on shiny surfaces). In these cases, it is not possible for the eye to adapt quickly to the existing luminance differences, so accidents can occur more easily. The symptoms generated by excessive illumination are:

- Conjunctivitis.
- Headache.
- Fatigue. (Armando, 2014).

Effects of poor lighting on people's health

Inadequate lighting at work can cause eye fatigue, fatigue, headaches, stress and accidents. Working in poor light damages the eyesight. Sudden changes of light can also be dangerous, as it blinds temporarily while the eye adapts to the new illumination. Although lighting tends to create an atmosphere of comfort inside the premises, light as a physical agent can produce the following effects:

- Loss of Visual Acuity: As a consequence of an effort in visual perception required by the task.
- Ocular Fatigue: As an effect of human confinement in enclosures with inadequate lighting.
- Glare: Due to contrasts in the visual field or excessive brightness of light sources.
- Visual Performance: It is affected by lack of uniformity in illumination, generating fatigue of the central nervous system.
- Muscular Fatigue: When maintaining inappropriate postures in order to alter the working distance with respect to the plane in which the work is performed.

Other risks to consider are:

- Radiant Effects
- Calorific Effects.
- When using fluorescent lamps, stroboscopic and flickering effects are produced, generating discomfort to the person and thus creating a potential risk.

Quality is as important as the right amount of light to ensure good illumination and worker performance. The degree of safety with which the work is performed depends on the visual capacity and this, in turn, depends on the quantity and quality of lighting. A well-lit environment is not only one that has sufficient light. Incorrect lighting can also cause inadequate posture, which in the long run can lead to musculoskeletal disorders. Poor lighting can sometimes be the cause of both minor and serious accidents for workers, because they cannot be perceived clearly or react on time to situations that represent a danger and that under normal conditions would not go beyond a simple warning that something is wrong. Constant and successive glare also leads to visual fatigue and eventually to headaches, dissatisfaction and mood disturbances. The distribution of luminances in the visual field can affect task visibility and influence worker fatigue (Armando, 2014).

Psychological effects on the worker

From a psychological point of view, lighting has been shown to cause both positive and negative effects on people.

Natural lighting

From a psychological point of view, natural lighting, and even mere visual contact with the outdoors, have positive effects for most people. These include:

- Facilitate visual accommodation changes (near and far).
- Widens the field of vision and avoids claustrophobic effects.
- Increases sensory stimulation.
- It accompanies the circadian biological rhythms.
- Prevents seasonal depressive syndrome.

Artificial lighting

From a psychological point of view, artificial lighting tends to cause the following effects:

- Sadness
- Anxiety
- Irritability
- Drowsiness
- Withdrawal
- Demotivation

This means that when designing lighting systems, lighting trade-offs should be taken into account with those of comfort and psychological acceptability, among which natural and artificial lighting are important (Armando, 2014).

Harmful biological effects

Radiation associated with lighting can cause harmful biological effects on people and the ecosystem.

On people, the harmful effects of radiation are:

- Photokeratoconjunctivitis
- Cataracts due to U.V. radiation
- I.R. radiation thermal cataract
- Thermal damage of the retina by I.R. radiation
- Blue light photoretinitis
- Thermal damage to the skin
- Erythema and delayed effects on the skin due to U.V. radiation
- Keratitis due to U.V. radiation
- Radiation keratitis I.R. (Thermokeratitis) (Armando, 2014).

Health effects of pollutant emissions from thermoelectric plants.

SOx (Sulfur Oxides) Emissions

During its oxidation process in the atmosphere, this gas forms sulfates, i.e., sulfate salts, which can be transported in respirable particulate matter and which, in the presence of moisture, form acids. These acids are then an important part of the secondary or fine particulate matter. Exposure to both sulfates and SO2-derived acids is extremely hazardous to health because they enter the human circulatory system directly through the respiratory tract.

SO2 is hygroscopic, i.e., when it is in the atmosphere it reacts with humidity and forms sulfuric and sulfurous acid aerosols which then form part of the so-called acid rain. The intensity of aerosol formation and the length of time they remain in the atmosphere depends on the prevailing meteorological conditions and the number of catalytic impurities (substances that accelerate the processes) present in the air. But in general, the average residence time in the atmosphere is about 3 to 5 days, so that it can be transported over long distances. SO2 air pollution causes the following effects:

- Opacification of the cornea (keratitis)
- Difficulty breathing
- Inflammation of the respiratory tract
- Eye irritation due to formation of sulfurous acid on moist mucous membranes
- Psychic alterations
- Pulmonary edema
- Cardiac arrest
- Circulatory collapse

Sulfur dioxide (SO2) has also been associated with asthma and chronic bronchitis, increasing morbidity and mortality in the elderly and children. Sulfur is a highly harmful poison to human health, although one person may be more resistant than other creatures in the region. For example, the level of 0.3 µg per cubic meter of air is a value that implies potential risk to human health, but for trees, a value of 0.2 µg is already very serious. For the same reason, both sulfur oxides (SOx) and sulfuric acid (H2SO4) are related to damage and destruction of vegetation, deterioration of soils, construction materials and water courses (Armando, 2014).

NOx Emissions (Nitrogen Oxides)

Nitrogen oxides, NOx, are pollutants that are equally hazardous to health. Most of the studies on the effects of NOx have dealt mainly with NO_2 as it is the most toxic. The effects of NO_2 on animals and humans almost entirely affect the respiratory tract. It has been observed that an average concentration of 190 micrograms of NO_2 per m3 of air, 40% of the day, increases the frequency of respiratory tract infections in the exposed population. Nitrogen dioxide (NO_2) is the only one that has limit values set for both long- and short-term exposures. However, the close relationship of nitrogen monoxide (NO) with the NO_2formation process means that it is also important in air quality assessment and management.

Brief exposure to NO_2can cause respiratory and eye irritation. In the long term, the main effects may be slower lung development in children and the development of chronic respiratory and cerebrovascular diseases. Although the entire population is exposed to air pollutants, they do not affect everyone equally. Children, the elderly and people with health problems (such as asthma, heart and lung disease) may suffer more effects (Armando, 2014).

CO (Carbon Monoxide) Emissions

The presence of high concentrations of carbon monoxide (CO) in the air poses a health threat. Inhaled CO combines with hemoglobin in the blood, leading to the formation of carboxyhemoglobin, which reduces the blood's ability to transport oxygen from the lungs to the tissues. Carbon monoxide, once in the lungs, reacts with hemoglobin instead of oxygen to form carboxyhemoglobin. It also affects health by interfering with oxygen transport to the heart, other muscles and also to the brain. Therefore, people with coronary heart disease are at increased risk from exposure to this pollutant. Other effects: increased angina, decreased neurobehavioral functions, lower birth weight in newborns and delayed postnatal development.

Carbon monoxide in the air accumulates rapidly in the blood, causing flu-like symptoms such as headache, fatigue, nausea, dizziness, confusion and irritability. As its concentration increases, CO causes vomiting, loss of consciousness, and eventually brain damage and death. People suffering from heart problems are particularly sensitive to CO, experiencing chest pain if inhaled during exercise. Children, the elderly and people with respiratory problems are also particularly sensitive (Armando, 2014).

HC (Hydrocarbon) Emissions

These are substances that can cause cancer, defects, and mutations in the fetus if the person is exposed to high concentrations and for a prolonged period of time. With regard to its impact on the environment, it is a persistent organic substance that is difficult to degrade, so its permanence in the environment can last for years, seriously affecting the aquatic and terrestrial environment. It has been demonstrated that these compounds can cause cancer and functional alterations in animals, generating defects and genetic malformations (Armando, 2014).

Particulates

Suspended particles vary in size, composition and origin. They are relatively easy to perceive, since they reduce visibility, altering the optical properties of the environment. The human respiratory system is responsible for eliminating the largest particles through filters (mucous membranes of the nose); the smallest particles, however, have a much greater capacity for penetration, and their adherence in the bronchi and lungs can cause respiratory problems, such as asthma, bronchitis, and depending on their composition and interaction with other factors, they can cause lung cancer in the medium and long term. The fractions that are studied are called PM10 (diameter less than 10 microns) and PM2, 5 (diameter less than 2.5 microns) (Armando, 2014).

Environmental impact

LED lighting

Technology and the environment are two concepts that are increasingly linked. The fact is that caring for nature has become a fundamental point at any level. Thus, both on a personal and global level, people need to be increasingly sustainable in order to survive, and that means developing new systems that allow them to generate energy without having to reduce non-renewable natural resources. In this sense, luminous energy has been revolutionized to give way to LED ecological lighting to take care of the environment (Carral Ortiz, 2014).

Energy efficiency through LED lighting

One of the biggest problems globally is energy consumption. Currently, there are highly polluting systems that directly affect the reduction of non-renewable natural resources, and they are really expensive. Therefore, it is becoming easier to find LED lights that offer a more sustainable and efficient option, in order to have the necessary lighting on a small scale. Green LED lighting is recommended as it is the best option to contribute to the care of the environment while receiving a greater amount of light at a reduced price.

Traditional lighting is based on incandescent and fluorescent bulbs, which convert only 5% of the energy they emanate into light, while LED lights use 95% of the electricity they receive to generate light. That is why LED lighting is eco-efficient and durable. LEDs allow the light to be focused according to the lighting needs, thus avoiding leakage and waste of luminosity as opposed to traditional lights. These bulbs allow to focus their function always illuminating in the areas and forgetting those where light is not required, making them more effective and efficient. Thanks to its low energy consumption LEDs help to produce less environmental pollution also allow better regulation of lighting power, with a lower impact of light pollution, something that is good for the environment (Moisés Carral Ortiz, 2014).

Materials of a LED

In addition to their long life and eco-efficient function, LEDs have a perfect composition to favor the environment and encourage recycling. Ecological LED lighting does not have toxic elements as do traditional lights containing mercury, therefore LEDs reduce the emission of harmful effects on both health and the environment. They are made from recyclable materials that make this light source an ally for the care of the ecosystem. On the other hand, LED bulbs also offer diverse options in terms of lighting regulation, they can create warmer or cooler environments, adapted spaces with bulbs that give a natural or brighter ai. (Moisés Carral Ortiz, 2014).

Lighting and the environment

Thermal power plants generate pollutants due to two main causes. On the one hand, the burning of fossil fuels such as coal or fuel oil generates ash and fumes, among which are the emissions of CO_2 (carbon dioxide), SOx (sulfur oxides) and NOx (nitrogen oxides). On the other hand, they generate a thermal change in the water used for cooling. CO_2 is one of the greenhouse gases. This effect is responsible for the earth to maintain its temperature, but an excess of CO_2 in the atmosphere can cause an excess of temperature. There are different ways to reduce CO_2 , the most widespread is the use of filters that retain it.

SOx and NOx cause acid rain. The association of oxides with oxygen and water forms nitric acids HNO_3 and sulfuric acids H_2SO_4. These acids change the PH of the rain, which acidifies rivers and waters, killing the living beings in them. Another effect of acid rain is the deposition of H+ protons, which drag certain ions from the soil, impoverishing the nutrients of the ecosystems. To eliminate these pollutants, different treatments are carried out, such as the introduction of catalytic converters in power plants or the addition of alkaline compounds in rivers.

According to the 2010 National Greenhouse Gas Emissions Inventory, the contribution of the energy category represented 67.3%, equivalent to 503,817.6 gigagrams (Gg). The Energy category includes emissions resulting from the exploration, production, transformation, handling and consumption of energy products. The category is subdivided into fossil fuel consumption and fugitive emissions.

In the subcategory of fossil fuel consumption, equivalent to 420,697.9 Gg, emissions of CO_2, CH_4 and N_2O and other gases known as ozone precursors are estimated, which are: carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds other than methane (VOCs other than methane) and sulfur dioxide (SO_2). Emissions of CO_2 and SO_2 depend on the carbon and sulfur content of the fuel. Emissions of the other gases depend on combustion conditions and technology. In the subcategory of fugitive emissions equivalent to 83,119.8 Gg, emissions of CH_4 from coal mining and handling, CH_4 and CO_2 from oil and gas industry activities are estimated; for the latter, emissions of ozone precursor gases are also estimated.

In 2010, the main emission in the Energy category was CO_2, which contributed 80.4% (405,130.2 Gg) of the total, followed by CH4 emissions, 16.9% (84,966.0 Gg of CO_2 eq.), and N_2O, 2.7% (13,721.4 Gg of CO_2 eq.). N_2O emissions are mainly generated by the consumption of fossil fuels in autotransportation. Fugitive emissions from exploration and CO_2 emissions resulting from oil refining have not been considered in the INEGEI due to the lack of activity data. The energy industry subcategory is made up of electricity generation and own consumption, which refers to the primary and secondary energy that the energy sector itself (Pemex and CFE) uses for the operation of its facilities. In this sector, in 2010 the share of emissions generated by the use of fuels was as follows: natural gas, 47.7% (55,140.2 Gg); fuel oil, 25% (28,928.5 Gg); coal, 26.3% (30,386.5 Gg), and diesel, 0.9% (1,082.2 Gg).

Thermoelectric power plants produce electricity using turbines that harness the heat energy of steam produced in boilers. Coal-fired power plants emit pollutants such as SOx, which are basically SO_2 and to a lesser extent SO_3. NOx are mainly NO and NO_2. Particulates are mainly ash and unburned, and sometimes soot is present if combustion is not correct. In Table 28 are the amounts of pollutant emissions expressed in kg per year that are generated in the production of energy from coal, fuel oil and gas fuels (Armando, 2014).

Pollutants (coal, fuel oil and gas) emitted by the production of electricity in thermoelectric power plants.

Table 6 shows the quantities of pollutants in Tm/year that are emitted by the thermoelectric power plants in the production of energy with coal, fuel oil and gas, for the production of a power of 1,000 MW. The data contained in Table 4 are very important because it can estimate the number of pollutant emissions that are released in the production of energy for energy consumption in the classrooms of building Z of the Technological Institute of Villahermosa. Table 6 shows the quantities of SOx, NOx, CO, HC and particles that are emitted when using different energy sources such as coal, fuel oil and gas**.**

Table 6
Emissions in thermoelectric power plants in Tm/Year

Pollutant	**Emission in Tm/year for a power output of of 1,000 MW**	**Emission in Tm/year for a power output of of 1,000 MW**	**Emission in Tm/year for a power output of of 1,000 MW**
	Coal	**Fuel oil**	**Gas**
SOx	150-103	60-103	0.015-103
NOx	23-103	25-103	13-103
CO	0.25-103	0.009-103	Very little
HC	0.5-103	0.7-103	Very little
Particles	5-103	0.8-103	0.5-103

Source: Calvo Mariano (2002). Treatise on atmospheric pollution

In order to begin the calculations and to know the number of pollutants emitted by the energy consumption in the classrooms of building Z of the Technological Institute of Villahermosa, it is necessary to convert the data in Table 6 that are in Tm/Year to Kg/Year for the analysis of the data to be obtained and thus to have a clear dimension of the amounts of pollutants that are generated with the energy consumed by the lamps of building Z of the Technological Institute of Villahermosa.

Table 7
Emissions in thermoelectric power plants in Kg/A

Pollutant	**Emission in Kg/year for a power of 1,000 MW**		
	Coal	**Fuel oil**	**Gas**

SOx	150,000,000	60,000,000	15,000
NOx	23,000,000	25,000,000	13,000,000
CO	250,000	9,000	Very little
HC	500,000	700,000	Very little
Particles	5,000,000	800,000	500,000

Source: Calvo Mariano (2002). Treatise on atmospheric pollution.

Once the quantities are converted into Kg/year, it will start developing rules of 3 to know how many of the different pollutants (SOx, NOx, CO, HC and particles) are emitted by the different energy sources (coal, fuel oil and gas) taking into account the watts of the lamps that building Z has.

Emissions in Kg/year of SOx from coal for the annual use of 1 lamp of 36 watts:
It is then developed by means of rules of 3:

If 1,000 MW = 150,000,000 Kg/year of SOx
1 MW = 150,000 Kg/Year of SOx

Then is:
1MW = 1, 000,000 Watts
0.000001 MW = 1 Watt

So, a 36-watt lamp consumes 48,384 watts annually, now it will convert the watts consumed to MW:

1 Watt = 0.000001 MW
48,384 Watts = 0.048384 MW

So, now that a 36-watt lamp consumes 0.048384 MW, a last rule of 3 is applied to know how many kg/year of SOx are produced annually:

If 1 MW = 150,000 Kg/Year of SOx
0.048384 MW = 7,257.6 Kg/year of SOx from coal

Therefore, the use of a 36-watt lamp annually produces 7,257.6 kg/year of SOx from coal.

Emissions in Kg/year of SOx from fuel oil for the annual use of 1 lamp of 36 watts:

It is then developed by means of rules of 3:
If 1,000 MW = 60,000,000 Kg/year of SOx
1 MW = 60,000 Kg/Year of SOx

Then if:
1MW = 1, 000,000 Watts
0.000001 MW = 1 Watt

So, a 36-watt lamp consumes 48,384 watts annually, the watts consumed to MW will be converted:

1 Watt = 0.000001 MW
48,384 Watts = 0.048384 MW

So, a 36-watt lamp consumes 0.048384 MW, a last rule of 3 is applied to know how many kg/year of SOx are produced annually:

If 1 MW = 60,000 Kg/Year of SOx
0.048384 MW = 2,903.04 Kg/Year of SOx from fuel oil

Therefore, the use of a 36-watt lamp annually produces 2,903.04 kg/year of SOx from fuel oil.

Emissions in Kg/year of SOx from gas for the annual use of 1 lamp of 36 watts:

It is then developed by means of rules of 3:
If 1,000 MW = 15,000 kg/year of SOx
1 MW = 15 Kg/year of SOx

Then if:
1MW = 1, 000,000 Watts
0.000001 MW = 1 Watt
A 36-watt lamp consumes 48,384 watts annually, the watts consumed to MW will now be converted:

1 Watt = 0.000001 MW
48,384 Watts = 0.048384 MW

A 36-watt lamp consumes 0.048384 MW, a last rule of 3 is applied to know how many kg/year of SOx are produced annually:

If 1 MW = 15 Kg/year of SOx
0.048384 MW = 0.72 Kg/Year of SOx from gas

The use of a 36-watt lamp annually produces 0.72 kg/year of SOx from gas.

Emissions in Kg/year of NOx from coal for the annual use of 1 lamp of 36 watts:

It is then developed by means of rules of 3:
If 1,000 MW = 23,000,000 Kg/Year of NOx
1 MW = 23,000 Kg/Year of NOx

Then if:
1MW = 1, 000,000 Watts
0.000001 MW = 1 Watt

A 36-watt lamp consumes 48,384 watts annually, the watts consumed to MW will now be converted:

1 Watt = 0.000001 MW
48,384 Watts = 0.048384 MW

A 36-watt lamp consumes 0.048384 MW, a last rule of 3 is applied to know how many kg/year of NOx is produced annually:

If 1 MW = 23,000 Kg/Year of NOx
0.048384 MW = 1,112.83 Kg/Year of NOx from coal

The use of a 36-watt lamp annually produces 1,112.83 kg/year of NOx from coal.

Emissions in Kg/year of NOx from fuel oil for the annual use of 1 lamp of 36 watts:

The following is developed by means of rules of 3: If 1,000 MW = 25,000,000 Kg/year of NOx
1 MW = 25,000 kg/year of NOx So yes:

1MW = 1, 000,000 Watts
0.000001 MW = 1 Watt

A 36-watt lamp consumes 48,384 watts annually, the watts consumed to MW will now be converted:
1 Watt = 0.000001 MW
48,384 Watts = 0.048384 MW

A 36-watt lamp consumes 0.048384 MW, a last rule of 3 is applied to know how many kg/year of NOx are produced annually:
If 1 MW = 25,000 Kg/Year of NOx
0.048384 MW = 1,209.6 Kg/Year of NOx from fuel oil

Therefore, the use of a 36-watt lamp annually produces 12,096 kg/year of NOx from fuel oil.

Emissions in Kg/year of NOx from gas for the annual use of 1 lamp of 36 watts:

It is then developed by means of rules of 3:
If 1,000 MW = 13,000,000 Kg/Year of NOx
1 MW = 13,000 Kg/year of NOx

Then if:
1MW = 1, 000,000 Watts
0.000001 MW = 1 Watt

A 36-watt lamp consumes 48,384 watts annually, the watts consumed to MW will now be converted:

1 Watt = 0.000001 MW
48,384 Watts = 0.048384 MW
A 36-watt lamp consumes 0.048384 MW, a last rule of 3 is applied to know how many Tm/year of NOx are produced annually:

If 1 MW = 13,000 Kg/Year NOx
0.048384 MW = 628.92 kg of NOx from gas

The use of a 36-watt lamp annually produces 6289.92 kg of NOx from gas.

Emissions in Kg/year of CO from coal for the annual use of 1 lamp of 36 watts:

It is then developed by means of rules of 3:
If 1,000 MW = 250,000 Kg/year of CO
1 MW = 250 Kg/year of CO

Then yes:
1MW = 1, 000,000 Watts
0.000001 MW = 1 Watt

A 36-watt lamp consumes 48,384 watts annually, the watts consumed to MW will now be converted:
1 Watt = 0.000001 MW
48,384 Watts = 0.048384 MW

A 36-watt lamp consumes 0.048384 MW, a last rule of 3 is applied to know how many Kg/year of CO are produced annually:
If 1 MW = 250 Kg/year of CO
0.048384 MW = 12.09 Kg/Year of CO from coal

The use of a 36-watt lamp annually produces 4.7 kg/year of CO from coal.

Emissions in Kg/year of CO from fuel oil for the annual use of 1 lamp of 36 watts:

It is then developed by means of rules of 3: If 1,000 MW = 9,000 kg/year of CO
1 MW = 9 Kg/year of CO

Then if:
1MW = 1, 000,000 Watts
0.000001 MW = 1 Watt

So, a 36-watt lamp consumes 48,384 watts annually, the watts consumed to MW will now be converted:
1 Watt = 0.000001 MW
48,384 Watts = 0.048384 MW

A 36-watt lamp consumes 0.048384 MW, a last rule of 3 is applied to know how many Kg/year of CO are produced annually:

If 1 MW = 9 Kg/year of CO
0.048384 MW = 0.43 Kg/yr of CO from fuel oil

The use of a 36-watt lamp annually produces 0.43 kg/year of CO from fuel oil.

Proposal for good lighting in the classrooms of the "Z" building

To obtain good visual comfort results and ensure high energy efficiency, it is necessary to attribute quality to the design, taking into account all the components involved in obtaining good lighting, such as interior design elements (color and texture of surfaces, furniture, natural and artificial light control elements), together with an appropriate choice of lighting installation components (luminaires, lamps and auxiliary equipment), without forgetting the management, control and maintenance mechanisms.

According to the results obtained in the measurement in the model classroom of building Z, it was observed that it does not have the lighting levels established by NOM-025- STPS-2008 (Lighting conditions in workplaces) for classrooms, so a new design and distribution of the lighting system for the building is proposed, taking into account that each classroom has different characteristics. According to the visual tasks performed in this building, it was observed that the current lighting system could be redesigned with a smaller number of lamps, using the same design and distribution of the luminaires, in order to obtain optimal lighting. Therefore, it is proposed to use only 8 LED luminaires of 36 watts as shown in Figure 4.

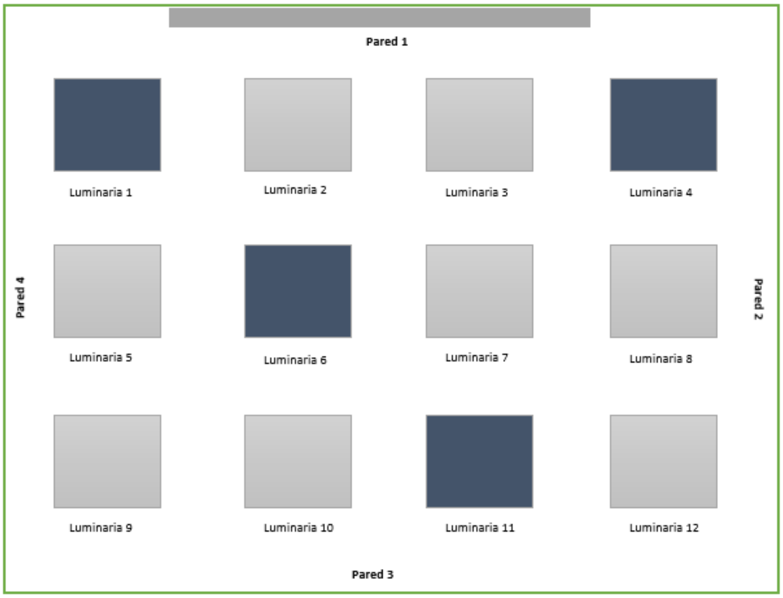

Figure 4. Graphic representation of the proposed lighting design for classroom No. 83 in building Z.

With the proposal of this design, a system that exceeds the lighting level established by NOM-025-STPS-2008 (Lighting conditions in workplaces) would be replaced by a system that provides optimal lighting, with the same quality and technology, providing an area of comfort and convenience for the development of student activities.

In addition to achieving an optimal level of illumination with this design proposal, there would be savings in energy consumption since, compared to the current lighting system, the number of watts used per hour would be reduced and, consequently, there would be economic savings.

To help achieve efficient lighting, the following could be done:

- Make the most of natural light
- Using light colors on the walls will optimize the use of this light
- Keep lamps clean, dirt detracts from brightness
- Turn off the lights when leaving the classroom, even if you are only absent for a few minutes
- Create signs that remind everyone to turn off the light when leaving a location
- Replace LED lamps when they are in poor condition

Conclusions

By monitoring the lighting fixtures in building Z, it was found that the lighting fixtures in this building are in perfect condition, although the lighting in the classroom is not adequate. The lack of lighting standards can cause damage to students' eyesight, ranging from eyestrain to retinal burns. Glare can lead to poor learning outcomes. Taking into account the results of the measurements, it was observed in general terms that the areas under inspection do not comply with the average values established by the standard (NOM-025-STPS-2008), due to the design and reflection of the LED lights, which are above those established in the standard.

From the results obtained, it was identified in the model classroom that the level of illumination is above the range established by the standard; this is generally seen in the afternoon hours. This can lead a student who is doing his activities to suffer from visual fatigue, thus affecting the student's overall health and poor performance. It was also observed that the energy and fuel consumption, which showed that the annual cost in watts for building Z is $6,444.48 and in the case of fuel to generate 1 kW per year was 20.12 m3/kWh of natural gas, 28.68 kg/kWh of carbon and lastly 14.94 kg/Kwh of diesel.

For the above mentioned, a good distribution in the lighting system for the Z building was proposed, using only 8 LED lamps in each classroom to have a better illumination and to make the most of natural light, use light colors on the walls to optimize the use of this light, keep the lamps clean, the dirt detracts brightness, turn off the lights when leaving the classroom, even if they are only going to be absent for a few minutes, replace the incandescent lamps with energy saving lamps such as those installed in this building (LED), even if one is only going to be absent for a few minutes, replace incandescent lamps with low consumption lamps such as those installed in this building (LED), with this, one can offer comfortable facilities for the activities in the work areas, so the institution would improve its levels of competitiveness by offering quality facilities.

Recommendations

- Use natural light (windows) whenever possible.
- Paint the walls of the work centers with light colors such as white to take advantage of natural light and have a good distribution of lighting.
- Clean luminaires regularly.
- Avoid direct eye contact with light sources.
- Keep lamps on only when necessary.
- Raise awareness of the poor use of energy among the students occupying the classrooms.
- Do not damage the luminaire installations.

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