

Microbiological and total particles suspended indoor air quality at the Universidad Iberoamericana Torreón

Calidad microbiológica y de partículas suspendidas totales en el aire interior de la Universidad Iberoamericana Torreón

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DOI: 10.35429/JESN.2020.18.6.20.34Received July 20, 2020; Accepted December 30, 2020

Abstract

Indoor air quality was analyzed in the period from 2016 to 2019, in the Universidad Iberoamericana Torreón, with the objective of determining if it complied with the reference norms: ISO 14644-1-2015 and UNE 100012:2005; due to in Mexico there are no applicable norms for the monitoring or indication of the Maximum Permissible Limits to determine indoor air quality. Methodology applied was focused on: 1) Determining the PSTs (from 0.3 to 10 µm) using a FLUKE particle counter; 2) Microbiological analysis; 3) Identifying isolated strains and 4) Calculating origin and wind intensity using a METPAK II climatological data and a WRPLOT software. PST and microbiological concentrations were found to be above the standards used. PS<sub>0.3</sub> showed a significant difference (p<0.05) in the Auditorium, which had the highest concentrations in 2019 of evening schedule. Some of the biological material were identified as: 1) pathogenic bacteria of the genera *Salmonella*, *Klebisella* and *Escherichia*, and 2) fungi of the genera *Aspergillus*, *Trichophyton* and *Candida*; whose exposure could produce different allergies, asthma, develop respiratory symptoms, chronic cough, laryngitis, sinusitis and urticaria.

Indoor air, TSP, Biological particles

Resumen

Se valoró la calidad del aire interior en el período de 2016 a 2019, en la Universidad Iberoamericana Torreón, con el objetivo de determinar si cumplía con las normatividades de referencia: ISO 14644-1-2015 y UNE 100012:2005; debido a que en México no se cuenta con normatividad aplicable para el monitoreo o señalamiento de los Límites Máximos Permisibles para determinar la calidad del aire interior. La metodología aplicada se centró en: 1) Determinar los PST (de 0.3 a 10 µm) empleando el contador de partículas FLUKE; 2) Análisis microbiológicos; 3) Identificar las cepas aisladas y 4) Calcular la procedencia e intensidad del viento utilizando los datos climatológicos del METPAK II y el software WRPLOT. Las concentraciones de PST y microbiológicas se encontraron arriba de las normatividades empleadas. Las PS<sub>0.3</sub> mostraron una diferencia significativa (p<0.05) en el Auditorio; el cual, tuvo las mayores concentraciones en 2019 del horario vespertino. Parte del material biológico fue identificado como: 1) bacterias patógenas de los géneros *Salmonella*, *Klebisella* y *Escherichia*, y 2) hongos de los géneros *Aspergillus*, *Trichophyton* y *Cándida*; cuya exposición podría producir diferentes alergias, asma, desarrollar síntomas respiratorios, tos crónica, laringitis, sinusitis y urticaria.

Aire-interior, PST, Partículas biológicas

Citation: MARTÍNEZ-VILLALBA, José Antonio, LUNA-PORRES, Mayra Yudirian, GILIO-VILLA, Alejandra Mayela and ARREDONDO-GUERRERO, Sebastián Jafet. Microbiological and total particles suspended indoor air quality at the Universidad Iberoamericana Torreón. Journal of Environmental Sciences and Natural Resources. 2020. 6-18:20-34.

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## Introduction

In recent years, indoor air quality has taken on increased interest. In indoor environments, the air can contain total suspended particles (TSP) of dust, biological and non-pathogenic microorganisms, to which users have developed some tolerance. For this reason, these interior spaces become important when people begin to develop very diverse symptoms that put their health at risk.

Approximately, people spend 90% of their time in indoor environments, whether public or private, such as: homes, schools, workplaces, transport vehicles, etc. (Cincinelli and Martellini, 2017) so indoor air becomes a very important factor in assessing health and quality of life. Because there are few works focused on determining indoor air quality and the absence of applicable regulations in the country, this work is pertinent to establish solutions that protect the health of the public who use the facilities.

At the Universidad Iberoamericana Torreón (UIA), students can spend between 6 and 8 hours a day indoors and perform various actions in each of the spaces, altering the atmosphere of the place. These environments can also be easily modified due to the location of the university, which is in the fastest growing area of the city; In them, housing complexes, hotels, hospitals, shopping centers and industries have been built in recent years. In addition, the UIA is located in front of a busy avenue of vehicles.

Exterior particles generated by all these activities, endemic weather phenomena and wind direction, can influence the increase in concentrations of PST and biological particles within the facilities.

Previous studies have shown that mainly ventilation, temperature and humidity favor the increase and re-suspension of particles. Which, when found in high concentrations, can cause serious respiratory problems, and even internalize in the lungs of users (Kermani et al., 2016). In the same way, they affect the comfort or convenience of students, generating fatigue, difficulty concentrating, headaches and eye irritations (Vilcekova *et al.*, 2017).

It is important to note that indoor air quality has become a critical environmental health problem with little emphasis on the Comarca Lagunera. The region has several industrial complexes, uncontrolled urban development has been generated in recent years, vehicle use is excessive, sustainable projects are scarce, there are few well-defined routes for the use of bicycles, public transport is in poor condition and it is an area with a very large livestock sector. These activities are the consequence of a significant growth of PST and microorganisms that generate poor outdoor air quality and that is reflected inside buildings, homes and schools. Having mentioned this, an increase in external agents in the university facilities is expected in recent periods as a result of the increase in some activities around the university. Therefore, it is pertinent to find new alternatives that improve the air breathed indoors, as well as the quality of life of users.

Based on this context, the objective of this research work is to assess the indoor air quality (PST and microbiological) of the UIA, and its possible relationship with some health effects that users may have in the most frequented places. In the same way, the hypothesis was raised that if the increase in activities inside and outside the university increases the concentration of PST in indoor environments. In turn, this research contributes mainly to knowing the causes of the accumulation of PST and microorganisms in the last 4 years in the university, as well as, to propose the pertinent solutions for their reduction of said pollutants.

First, a brief context of indoor air quality and pollution is described. Secondly, the methodology of analysis and measurement of: 1) particulate matter, 2) microbiological and 3) climatological parameters, which were implemented in the conduct of the research, is mentioned; defining in turn, the selection of study sites and describing in detail the statistical analysis performed. Subsequently, the results obtained are presented and discussed, detailing those that had statistical significance. Finally, we thank the students of the degree in Environmental Engineering of the Universidad Iberoamericana Torreón who supported this project, and the conclusions of the work are detailed.

## Study Background

### Air pollution

Air pollution is the concentration of various pollutants in the air. This phenomenon is caused by physical situations, substances or elements in the three states, causing adverse effects on the environment. This pollution decreases the quality of life of people, which is reflected in an increase in respiratory diseases. Likewise, it is not only found in the outdoor environment, but also occurs in the so-called “indoor” or intramural environment, so that it includes homes, workplaces, educational centers, means of transport and other spaces. closed (Wolkoff, 2018).

In recent years, air pollution has increased in industrialized countries due to the economic boom they have had. The most harmful atmospheric pollutant to health is particulate matter (PM), with a diameter equal to or less than 10  $\mu\text{m}$  (microns) (Singleto, *et al.*, 2018). In general, these particles are emitted from the burning of fossil fuels.

Elevated levels in airborne concentrations of particles less than 10 microns may be associated with pulmonary and cardiovascular disease. They can cause asthma attacks, chronic bronchitis, reduce lung function and increase susceptibility to respiratory infections, they can even cause heart attacks, arrhythmias, damage the reproductive system and the central nervous system. In more severe cases, they can cause cancer and lead to death (Watson et al., 2015; Yang et al., 2020).

The Comarca Lagunera is a region with high levels of air pollution. It has metallurgical, cement and marble industries, electricity generation plants, quarries and brickyards. The economy of the area is based on industrial activities, which generate large emissions of suspended particles and sulfur oxides. An example is the data produced by the Program to Improve Air Quality in the Comarca Lagunera Region. The report shows that PM10 levels exceed the limits up to three or four times what is set by NOM-025-SSA1-1993 (SEMARNAT, 2012).

### Indoor air quality

One of the less visible consequences of poor air quality is a concept called: The sick building syndrome. This phenomenon was named by the World Health Organization (WHO). This organization defines it as the set of symptoms that the individual occupants present in a structure or building and that disappear or improve when they leave it (National Institute of Safety and Hygiene at Work, 2019).

The WHO shows two types of sick buildings, such as temporary buildings, which include new buildings or recent renovations, causing a decrease in symptoms causing them to disappear in half a year. The next type is the permanent building, it is when the symptoms are persistent and often lasting for years (Reaad, 2009).

Likewise, this organism describes some basic characteristics of the sick building. He mentions that almost always this type of construction has a forced ventilation system or there is partial recirculation of air. Most of them are lightweight and inexpensive in construction. The interiors are generally covered with textile material on the walls and floors, which favors a high ratio between interior surface and volume. They stay relatively warm with a homogeneous and thermal environment. Finally, they are characterized by being hermetic (National Institute of Safety and Hygiene at Work, 2019).

The sick building can be found in the presence of biological agents in the indoor air such as: bacteria, fungi, and even Total Suspended Particles (TSP), causing diseases in the respiratory tract, eyes and the skin of the occupants (Hayleeyesus and Manaye, 2014).

Some of the concentrations of air pollutants outdoors may be similar indoors. The high temperatures of the Lagunera region, the bad ventilation systems in the buildings, the surroundings of the constructions, as well as the bad conditioning of the cooling systems, are some of the causes that deteriorate the quality of the indoor air in the area. of work. According to ISO 14644-1 (ISO, International Organization for Standardization, for its acronym in English), interior spaces are classified as clean rooms based on their air cleanliness or concentration of particulate matter (ISO, 2015).

Limited studies have been conducted in developing regions regarding indoor air and your health. Studies have mainly shown the unventilated burning of biomass, and health effects such as acute respiratory infections, chronic obstructive pulmonary disease, and lung cancer. The WHO has shown that the burning of solid fuels for cooking and heating could be responsible for almost 4% of the global burden of disease (Sundell, 2004).

In a study by Crook and Burton (2010) it was concluded that microbiological agents are very common in indoor air. Fungi and bacteria are among the most abundant in work environments. In Mexico, researchers isolated pathogenic microorganisms such as *Escherichia*, *Protesus* and *Entereoccus* indoors with good aeration conditions. This indicates that it is very difficult to rule out the presence of infectious etiological agents (Rivera-Tapia et al., 2009).

## Methodology to be developed

### Study area

The UIA is located north of the city of Torreón, Coahuila, Mexico, at the following coordinates: 25 ° 36 '36.051''N and 103 ° 24' 5,881''W and an altitude of 1125 m above sea level.

### Selection of study sites within the facilities

A survey was used as an evaluation instrument to select the places most frequented by students, where the assessment of indoor air quality would be carried out in the UIA, and through which, possible health conditions could be identified. presented by the students. For the purposes of this research, the instrument contained 10 reagents on a nominal scale. The surveys were applied to a representative sample of the student population in a deterministic way (Hernández et al., 2014), in order to choose students from the different degrees offered at the university.

### Analysis carried out at the UIA

Obtaining air samples, for the analysis of particulate and microbiological material, were carried out inside the seven buildings most frequented in the UIA by students, according to the results of the applied survey.

In addition, for the analysis of microbiological samples, samples were also collected in 4 places taken outdoors (Fig. 1), in order to corroborate if the microbiological strains are similar to those found in indoor environments. The monitoring was only carried out in the spring semesters (January-May), during the years from 2016 to 2019; during this period is when the greatest amount of winds or dust whirls occur in the region. The samples were collected during the week, in the Morning (M) and Evening (V) hours.

### Analysis of particulate matter

The Fluke 985 particle counter was used, with which the PST concentrations were obtained, in a range from 0.3 to 10 µm, the measurement time was 5 min and with a volume of 2.83 L. The monitoring equipment was placed at a distance of 30 cm from the wall and between 1.5-2.0 m in height (Argunhan and Avci, 2018). A weekly sampling frequency was established for each of the selected sites. It is important to mention that at the end of the COVID19 pandemic, monitoring will begin in the autumn period (August-December), where the endemic meteorological phenomena of the region greatly decrease.

### Microbiological analysis

10 Petri dishes were placed open for 60 min and distributed uniformly at a standard height of 1.20 m from the floor. Nutrient agar (AN) was used for the isolation of bacteria, Sabouraud agar (AS) and potato dextrose agar (PDA) were used to obtain fungi. Bacterial colonies were re-seeded in selective media: Mac Conkey (MC), Methylene blue eosin (EMB) and Salmonella Shigella (SS), in order to be able to associate them with health problems. The bacteria were incubated for 24 h at 37 ° C and the fungi at 25 ° C for 72 h (Leiva et al., 2017). Finally, the colony forming units (CFU) per m3 of air were determined according to the equation described by Bogomolova and Kirtsideli (2009):

$$N = 5a \cdot 10^4 (bt)^{-1} \quad (1)$$

Where: N is the microbial concentration in CFU / m3, a is the number of colonies per plate. Petri, b is the surface of the plate (cm2), and t is the exposure time in min.

### Identification of the isolates

The isolated strains were identified physically, morphologically and biochemically, according to Bergey's manual of bacteriology (Holt et al., 1994).

### Measurement of climatological parameters

The climate measurements were taken from the meteorological station that the UIA has; using the "METPAK II" climatological equipment; which performs an automatic daily record of temperature, humidity and air pressure. In addition, the station is equipped with an integrated acoustic anemometer that allows the horizontal speed and direction of the wind to be measured (Gill Instruments, 2015). The WRPLOT View Freeware 8.0.2 software was used to graphically represent the data obtained from the UIA Solar Tower weather station (Fig. 2).

### Statistical analysis

Statistical analyzes were performed using the MINITAB version 19 statistical software to determine if there was any significant statistical difference ( $p < .05$ ) in PST concentrations with respect to the specific diameter of the particulate material. A "oneway" ANOVA was carried out considering as factors: the year of sampling, place of sampling and the registered concentration of the TSP whose diameters vary from 0.3 to 10  $\mu\text{m}$ . In addition, a post-hoc Tukey test was performed on the significant differences found.

## Results

### Selection of sampling sites

The results of the student assessment instrument, applied to the 16 UIA degrees, indicated that the places most frequented by students during their activities are: 1) Auditorium (A); 2) Library (B); 3) Cafeteria (Ca); 4) Computer Laboratory (Co); 5) Gym (G); 6) health science laboratory (L); and 7) The study rooms (S). In Figure 1, the sites where the indoor air was analyzed are detailed.

About 20% of the students interviewed spent more time in open spaces than inside the facilities, during their stay at Ibero Torreón. Of the surveyed population, 46% considered that indoor air quality was good. However, 78% of those surveyed had some symptoms of allergies, cough, fatigue, asthma and irritation in the eyes and throat, without knowing the exact cause of their problem. Some of these symptoms have been reported in previous studies in educational facilities (classrooms) and have been related to high concentrations of particulate matter less than 10  $\mu\text{m}$  (Choo et al., 2015), and in turn, it has been shown that the Environmental quality of the indoor air is proportional to the symptoms developed by the occupants, and they have even been associated with skin problems, but not with eye symptoms (Savelieva et al., 2019).



**Figure 1** Satellite map of the Universidad Iberoamericana Torreón. The seven sampled locations are observed. Red pointers indicate: (A) Computer lab, (B) Health science lab, (C) Classrooms, (D) Library, (E) Cafeteria, (F) Auditorium, and (G) Gymnasium. In addition, the four outdoor air sampling locations are observed, represented with the yellow belts

Source: Google earth

The high percentage of people who develop some type of health problem at the university may be due to the poor air quality present in the different spaces they usually visit. It has been identified that total suspended particles, especially ultrafine ones, originating from the combustion of fossil compounds, can cause considerable health problems. These can be acute or chronic; Among the main affectations, respiratory infections, bronchitis, asthma, irritation and damage to the mucosa stand out. Cardiovascular problems and lung cancer have even been detected. All these problems are due to the fact that PSTs smaller than 2.5  $\mu\text{m}$  can be deposited in the most distal areas of the lungs (Kermani et al., 2016; Bonyadi et al., 2016).

Similarly, these can be very easily internalized in buildings or classrooms and reach a higher concentration than in outdoor environments (Jovanović et al., 2014).

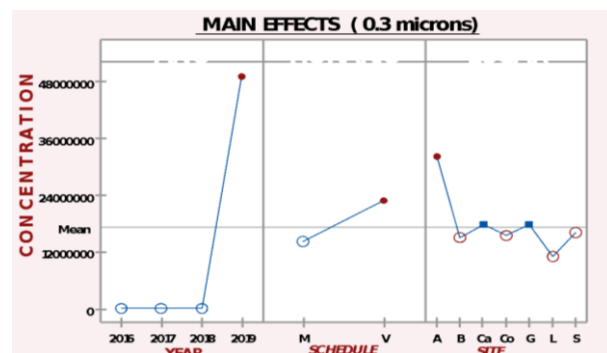
### Particulate matter

The results of the evaluation of PST concentrations are presented in Annex 1. The statistical analyzes determined that there was only a significant statistical difference in the year 2019 (Fig. 2). This may be related to the large number of construction sites in the vicinity of the university.

Although the Ibero Torreón is close to an urban area, there are many constructions that began in late 2018 and early 2019 in a range less than 500 m, causing a greater suspension of dust, microorganisms and PST in the environment. For this reason, starting in 2019, particle concentrations began to be analyzed in both shifts (morning and evening), which increased considerably in that period.

After conducting a global analysis of the results presented in Annex 1, it is observed that the 0.3  $\mu\text{m}$  fine particles were those that presented a statistically significant difference (Fig. 2) with respect to the year 2019 and the evening shift. In the four years sampled, most of the interior spaces remained close to the value of the geometric mean. The site that showed the highest concentration of fine particles (0.3  $\mu\text{m}$ ) throughout the years analyzed was the auditorium and the least variation was presented by the health sciences laboratory.

The intense activity in the auditorium, due to its multiple uses in the afternoon and the little or no air ventilation, are considered important factors due to which this significant difference is attributed with respect to the other sampled sites and the other concentrations reported. in graphic 1.



**Graphic 1** Average particle concentration of 0.3  $\mu\text{m}$ . This graph presents the results of the statistical analysis of main effects for the: 1) Years evaluated (2016, 2017, 2018 and 2019); 2) Sampled schedules (M and V); and 3) Sampling sites [A (auditorium), B (library), Ca (cafeteria), Co (Computation), G (Gymnasium), L (Health sciences laboratory) and S (study classroom)]

According to Kim *et al.* (2015), ventilation is an important factor that is related to indoor air quality. Poor ventilation influences the concentration of the different PSTs and increases the health risk of users. Likewise, in work or study places there is no constant aeration rate and the windows are manually operated to regulate the temperature of the area. Therefore, adequate ventilation is necessary to reduce the concentration of PST in the air (Dutton and Fisk, 2014; Jin *et al.*, 2015). It is important to consider the removal of the hydraulic hinges that are in some spaces in the UIA to promote ventilation.

In the same year 2019, the places where the greatest amount of PST was concentrated were the library and cafeteria in the morning hours (Annex 1). In the morning construction work intensifies in the area and this causes an increase in dust and particulate matter in the early hours of the day. In the afternoon, the gymnasium and auditorium showed a considerable increase in PST. It is inferred that it is due to the great demand in both spaces by the students. In both places it can be attributed to the influence of the wind, which comes directly from the west side with greater intensity towards the buildings (Fig. 2). In the particular case of the auditorium, the null ventilation, the air ducts, the entrance and exit of the students, and the absence of extractors, are factors that helped to potentiate this increase or resuspension of the PST. It is important to mention that indoor air quality is also related to temperature. PST<sub>2.5</sub> and other pollutants can increase or remain constant with this variable (Lin *et al.*, 2017). Physical activities, maintenance work, or multiple tasks performed in such spaces can maintain or increase temperature.



In general, in the four years that the measurements were made, the afternoon shift showed a higher concentration of particles than the morning shift. Although the occupation of spaces decreases with the passage of time in the university, with the exception of the auditorium, the increase in particles was constant in the microenvironments analyzed. That is, the concentration that is generated in the morning is accumulated with that generated in the evening.

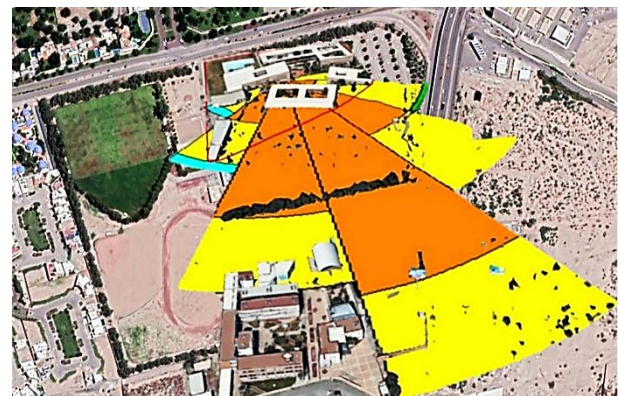
The wind is an important factor in the dispersion of PST in the interior spaces of the University and was considered key for the increase of fine particles. The frame of the windows, the warm air that is internalized and the isolation of the site are important parameters that potentiate this problem (Mendes *et al.*, 2015).

The data obtained by the climatological station of the University indicated that the drafts come from the South. This direction brings with it concentrations of PST produced by constructions made around the UIA such as hotels, offices, shopping centers, hospitals and residential areas. In addition to the passage of dust collectors or whirlwinds, and the combustion caused by different types of transport (cars, buses, cargo trucks, motorcycles, etc.) that travel less than 50 m from the main entrance of the Ibero Torreón. All these factors exacerbate the situation.

The constant traffic circulating close to the UIA is the main factor in the resuspension of dust and increase of particulate matter. According to studies carried out by Goyal and Khare (2011), they demonstrated through a mathematical model that PM10 and PM2.5 from vehicular escape from roads near the building can favor the increase of said particles in indoor environments. Tree planting around university buildings is a suggestion from the authors to decrease the increase in PST. The use of filters in living rooms and offices can favor the reduction of up to 30% of ultrafine TSP from busy roads, likewise, reduce the health problems of the occupants (Van der Zee *et al.*, 2017).

Rojano *et al.* (2013) verified that mobile sources are the main ones in the emissions of polluting gases and PST. The poor road conditions and the constant passing of vehicles potentiate this problem.

For this reason, buildings near roads without good paving, plus the weather conditions of the wind and a constant traffic flow, manage to achieve an increase in particles in the air, at the same time that they transport bacteria and fungi, among other microorganisms.



**Figure 2** Wind rose at the Universidad Iberoamericana Torreón. Wind direction and speed in 500 m radius. Nomenclature of colors related to wind speed (m / s): orange 0.5-2.1, yellow 2.1-3.6, turquoise 3.6-5.7, purple 5.7-8.8, blue 8.8-11.1 and green  $\geq 11.1$

Source: Google Earth Pro, 2019

The information presented in Figure 2 shows the origin and intensity of the wind during one year, towards the selected area of the study sites (where the most popular sites of the Universidad Iberoamericana Torreón are located).

In the last sampled period, it was analyzed by means of the Wind Rose (Fig. 2) and those coming from the South-Southeast were determined as predominant winds. These winds are the most frequent throughout the year. The intensity they present is not very high, but they attract the different types of PST of the aforementioned constructions, reflecting an impact on the interior air quality in Ibero Torreón. The currents with the greatest intensity and / or speed come from the Southwest, where housing complexes have increased considerably in recent years.

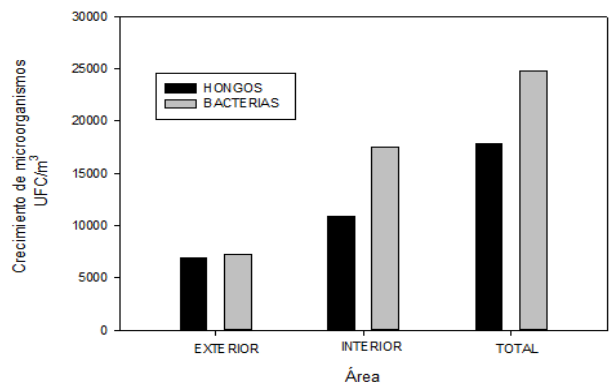
In contrast, the site to which lower concentrations are attributed is the health sciences laboratory, since it is located in a slightly more distant area in the University. The wind that is directed towards this area is not as frequent or intense because it is retained by different buildings and trees that function as biofilters.

Another important factor that can favor the increase of PST indoors, are the so-called dust storms or "lagoon rains". It is one of the typical phenomena in the region that are common throughout the year, intensifying in the first months (from February to March). The dragging of large amounts of dust brings with it a great negative impact on the air quality of the region, and in turn, respiratory and gastrointestinal problems for the population (Ríos, 2019; Macias, *et al.* 2019).

The ISO 14644-1-2015 standard classifies the cleanliness of the air in clean rooms and areas for particles smaller than 5 µm. It is a widely used parameter for analyzing indoor air quality. In Mexico, there are no regulations to measure PST indoors. According to the results obtained in this study, if they are compared with ISO 4644-1-2015, none of the analyzed sites would have adequate air cleanliness at concentrations of 3 µm. Therefore, it represents an environmental alarm about the possibility of generating health problems for users.

Microbiological analysis

The microbiological results presented correspond to the spring of 2019. At the same PST sampling points, the growth of microorganisms was analyzed with the intention of determining the biological quality of the air. Different fungi and bacteria considered pathogenic were found among the isolated strains. Some previous research works describe bacteria, fungi, humidity, temperature and wind as the main factors related to poor indoor air quality and responsible for health problems (Mendes *et al.*, 2015).



Graphic 2 Concentration of Colony Forming Units per m3 of bacteria and fungi in outdoor and indoor spaces

According to the equation proposed by Bogomolova and Kirtsideli (2009), (see Eq. 1), the counts of the microorganisms that were reached were greater than 5000 CFU / m³ in outdoor environments. Likewise, Graphic 2 shows that in the internal spaces of the university there was an average increase of 10,280 CFU / m³ of bacteria and 3,960 CFU / m³ of fungi. To give a context, considering the values of UFC / m³ obtained, no parameter complies with the Spanish regulation UNE 100012: 2005 on System Sanitation (AENOR, 2005), which establishes that both microorganisms must be around 800 UFC / m³. It is important to mention that in Mexico there is also no regulatory parameter for the microbiological quality of indoor air.

Previous studies have carried out counts in the microbiology laboratory of up to 1152.8 CFU / m³ at the District University of Bogotá (Romero *et al.*, 2016). Similarly, in the library of the Universidad de Unión in Peru, an average of 755.6 CFU / m³ were obtained (Tinoco *et al.*, 2016). In classrooms, Enitan *et al.* (2017) found concentrations of 4378.82 CFU / m³ in a private school in the city of Nigeria. In certain households in the southern region of Turkey, up to 176 CFU / m³ of fungal strains could be found and it was linked to asthma problems (Arikoglu *et al.*, 2016). Therefore, when referring to indoor air quality in microbiological matters in the UIA, the figures are well above those established in previous research. The place that showed the least microbiological growth was the health sciences laboratory with 5,630 CFU / m³ for bacteria, and 2,834 CFU / m³ for the case of fungi.

The increase in microorganisms in internal environments is a reflection of the human and anthropogenic activities of users. The low circulation of the wind, together with external currents that enter the building through the access doors, the atmospheric pressure (Vornanen-Winqvist *et al.*, 2018), the mechanical problems in the air units and the lack of extractors benefit the proliferation of microorganisms present in the most frequented places.

Microorganisms can remain inactive for long periods of time on the various surfaces of the place, in dust, windows, etc., and they can be metabolically active as proliferating communities (Konya and Scott, 2014).



According to the findings of Miletto and Lindow (2015), the microorganisms present in the environment can interact with the occupants continuously, causing infections, and some can be originated from the people who enter the site. In the same way, volatile organic compounds produced by microorganisms can be easily inhaled or even penetrate the pores of the skin, which leads to an interaction with the human metabolism, the immune and endocrine systems (Wessén and Schoeps, 1996). Temperature and humidity are essential for the proliferation of bacteria and fungi (Yassin and Almouqatea, 2010). Due to these present characteristics, good ventilation and effective cleaning is opportune in the places frequented daily by university students. In contrast, the situation abroad is different. Wind direction, temperature, building and large trees (Fig. 1) largely stop the proliferation of microorganisms (Goyal and Khare, 2011). On average, less than 6,100 CFU / m<sup>3</sup> of bacterial strains were obtained in the surroundings of the university.

### Identification of microorganisms

For the most part, gram negative bacteria (71%) and to a lesser extent gram positive (29%) were obtained. Bacilli were the predominant morphology in AN. Pathogenic strains of the genera *Salmonella*, *Klebsiella*, *Escherichia* and *Proteus* were identified. Some pathologies of the genus *Proteus* lie in urinary infections, meningitis and pneumonia, in addition to being a frequent secondary invader of burns and wounds, as well as nosocomial infections. The genera of *Salmonella* and *Escherichia* are related to gastrointestinal problems (Umana et al., 2018; Romero et al., 2016; Maldonado-Vega et al., 2014). Similarly, some pathogenic strains with coconut morphology were identified, for example, *Staphylococcus* and *Enterococcus*, which also develop respiratory and gastrointestinal affectations (Madsen et al., 2018; Rivera-Tapia, 2009). Poor hygiene on the part of users could lead to problems that directly affect their health.

Some of these strains isolated in the various busiest sites of the institution have also been identified in the livestock area (Beauvais et al., 2018) and agriculture in the Lagunera region (Chavarría et al., 2019). Wind currents can disperse these microorganisms in the air and become internalized in the UIA.

With regard to fungi, a wide variety of filamentous fungi was found with rough, cottony characteristics, with radial growth and presenting varied shades of green, brown and white. Some yeasts were also obtained in this study.

Lactophenol blue staining determined microscopic characteristics of fungi of the genera: *Aspergillus*, *Penicillium*, *Trichophyton*, *Candida* and *Fusarium* (Umana et al., 2018; Vornanen-Winqvist et al., 2018; Diba et al., 2019). There is a direct association between spores generated by fungi and humans. Exposure could lead to mucosal sensitization, produce different allergies, asthma, activate the immune system, develop respiratory symptoms, chronic cough, laryngitis, sinusitis and urticaria. (Arikoglu et al., 2016; Nitmetawong et al., 2019). Some previous studies have shown that the humidity, temperature and the concentration of the particles suspended in the air, less than 5 microns (Liu et al., 2014); as well as the characteristics of the home, pets, visible mold, ventilation and insects favor the reproduction of fungal strains in internal microenvironments (Arikoglu et al., 2016).

The Commission of the European Communities (1993) establishes concentrations of 1000 CFU / m<sup>3</sup> of fungi in the air as an intermediate level and it is pertinent to take hygiene measures. For this reason, it is important to design a strategy to reduce the concentrations of fungi in university spaces, since all places exceed this parameter.

Of the different microorganisms isolated in the different points of the UIA, the World Health Organization classifies them according to their danger and if they can put users at risk. The bacterial strains of *Klebsiella*, *Salmonella*, *Escherichia* and *Staphylococcus*, as well as the fungi of the genus *Aspergillus*, *Candida* and *Trichophyton*, can cause severe health problems and are classified in group 2 (moderate individual risk, low population risk). This includes pathogenic microorganisms that can cause disease in humans, but are unlikely to cause serious harm to personnel (WHO, 2005).

In turn, the National Institute for Safety and Hygiene at Work (2014) of Spain, details in its section on biological exposures that sanitary measures should be taken when there is a considerable risk from microorganisms.

Among which it establishes not to eat food, protective clothing, toilets and cleaning materials to reduce the risks to workers. In the same way, the institution is responsible for carrying out health surveillance on workers. Although in Mexico there are no protective measures in these terms, it is extremely important to implement adequate cleaning, disinfection and ventilation measures at the University to reduce the concentration of microorganisms and guarantee the health of all users.

Indoor air quality in the UIA's most frequented spaces is in a critical situation. The TSP and microorganisms rose drastically with the considerable increase in buildings in the vicinity of the University in the last year. The poor ventilation of the places constantly visited by students can favor this increase, as well as the proximity of a very busy vehicular road. In the same way, the “dust holes” or earth whirlpools are a very common weather phenomenon in the region that exacerbate the situation. The evening shift is where the highest concentration of fine particles was found, as well as various fungi and pathogenic bacteria. It is important to take immediate measures in terms of hygiene and cleanliness, because a large part of the surveyed population presented problems of allergies, coughs or some other respiratory symptoms. It is convenient to continue monitoring the PSTs and microorganisms in order to improve the indoor microenvironments. Similarly, propose strategies to reduce TSP that provide results in the short and medium term.

Finally, what Hidalgo (2020) raises in his research on social responsibility in educational institutions, it is appropriate to take it into consideration. To be a fully responsible company, the need they must assume to manage their impacts is vital, from different areas, where one of them is the environment. This allows the university to take commitments and actions to respond to the needs and problems of society, as well as users and university staff. Ibero Torreón is an educational institution committed to its social and environmental surroundings and to the region in general. Due to this, it has been recognized by the Mexican Center for Philanthropy (CEMEFI) as a socially responsible company four times. What commits the University to improve the impact on poor indoor air quality in the coming years.

Annexes

TOTAL SUSPENDED PARTICLES (µm)									
YEAR	SCHEDULE	PLACE	THIN					THICK	
			0.3	0.6	1	2	5	10	
2016	M	G	147528 ± 3545 (140066-151939)	13046 ± 355 (12019-13386)	3030 ± 72 (2809-3122)	2014 ± 68 (2044-2946)	419 ± 29 (373-457)	91 ± 17 (60-116)	
		Co	139709 ± 3543 (135113-144968)	13051 ± 296 (13697-14774)	3537 ± 176 (3116-3668)	3191 ± 187 (2790-3514)	468 ± 56 (386-583)	130 ± 39 (94-175)	
		Ca	99020 ± 810 (92659-107070)	9481 ± 217 (9095-9695)	1762 ± 113 (1516-1904)	1473 ± 107 (1349-1712)	244 ± 23 (216-286)	62 ± 12 (46-83)	
		S	139709 ± 3543 (135113-144968)	14111 ± 290 (13697-14774)	3537 ± 176 (3116-3668)	3191 ± 187 (2790-3514)	468 ± 56 (386-583)	130 ± 39 (94-175)	
		L	180164 ± 545 (89256-108965)	27802 ± 1825 (21433-32883)	5372 ± 238 (4686-5788)	2033 ± 33 (1963-2063)	203 ± 42 (237-323)	83 ± 8 (52-77)	
	V	G	44062 ± 511 (43782-45387)	3263 ± 80 (3155-3442)	939 ± 47 (853-1016)	1172 ± 95 (945-1263)	218 ± 28 (176-253)	53 ± 10 (26-67)	
		Co	95089 ± 11029 (49652-15913)	9489 ± 4154 (5533-15887)	ND	ND	486 ± 1245 (168-4067)	124 ± 353 (26-1301)	
		Ca	80501 ± 63631 (36930-261589)	7696 ± 3325 (3488-17099)	ND	ND	275 ± 267 (132-790)	52 ± 41 (26-143)	
		S	14324 ± 90486 (78232-349983)	9569 ± 6932 (5375-25333)	ND	ND	588 ± 413 (271-1307)	191 ± 69 (79-354)	
		L	228828 ± 134892 (77972-490162)	23199 ± 25122 (3462-70716)	ND	ND	66 ± 29 (85-455)	66 ± 29 (29-105)	
2017	M	G	121763 ± 154885 (21802-584777)	7880 ± 6788 (2496-23586)	ND	ND	155 ± 16 (76-282)	45 ± 22 (16-78)	
		Co	59710 ± 17533 (23033-85988)	6483 ± 2773 (4286-14587)	ND	ND	219 ± 219 (96-627)	60 ± 24 (26-100)	
		Ca	9697 ± 94354 (34162-381153)	11493 ± 19887 (9396-44487)	3399 ± 1822 (1926-6114)	3971 ± 1509 (1964-6499)	826 ± 247 (419-1441)	256 ± 117 (105-674)	
		S	107355 ± 56796 (48889-243214)	9993 ± 5846 (4930-20799)	2343 ± 1503 (1018-5749)	2380 ± 2493 (179-18331)	416 ± 580 (172-2270)	122 ± 46 (41-422)	
		L	94637 ± 4398 (52376-517274)	1961 ± 4239 (6499-29634)	4035 ± 1942 (2519-7888)	5896 ± 2338 (4821-18271)	1425 ± 452 (969-5264)	386 ± 184 (111-816)	
	V	G	63184 ± 30026 (40561-97376)	6428 ± 2785 (4686-13883)	1633 ± 608 (917-2788)	1548 ± 607 (949-2621)	361 ± 119 (116-4677)	77 ± 24 (41-113)	
		Co	76727 ± 32491 (32713-137381)	7374 ± 3639 (3211-14333)	1862 ± 792 (917-2788)	1914 ± 1652 (1106-4677)	376 ± 363 (169-1102)	155 ± 127 (39-480)	
		S	188385 ± 107323 (44616-567648)	16719 ± 10369 (1286-57151)	5467 ± 28798 (1314-104153)	4728 ± 14584 (1277-54196)	986 ± 1186 (111-816)	338 ± 231 (111-816)	
		L	132262 ± 69348 (87137-214112)	12548 ± 12888 (1110-43791)	3138 ± 1470 (1723-7072)	2893 ± 1854 (260-5620)	582 ± 217 (226-1825)	134 ± 78 (57-313)	
		G	119288 ± 119714 (28013-481423)	13661 ± 16266 (2057-32345)	3163 ± 2616 (963-10741)	2866 ± 1891 (1186-7672)	516 ± 287 (216-1153)	140 ± 91 (69-306)	
2018	M	G	104187 ± 84114 (39463-27883)	8767 ± 5191 (3443-23454)	1981 ± 1113 (826-5352)	1957 ± 1700 (737-7267)	330 ± 416 (126-968)	94 ± 100 (35-419)	
		Co	78723 ± 32937 (33257-163815)	7339 ± 2687 (3627-11897)	2176 ± 586 (1364-3696)	2461 ± 643 (1433-3451)	568 ± 169 (234-881)	136 ± 58 (61-242)	
		Ca	115942 ± 128888 (21369-54835)	13876 ± 37872 (2365-14006)	2671 ± 5212 (1330-24543)	2356 ± 1127 (1186-4679)	389 ± 110 (220-560)	132 ± 45 (53-206)	
		S	72118 ± 36086 (33019-158893)	6963 ± 3514 (3769-13243)	3719 ± 1418 (756-5863)	1624 ± 783 (1304-3841)	318 ± 139 (128-725)	128 ± 25 (94-182)	
		L	141381 ± 218458 (44867-778874)	16224 ± 68234 (2346-27872)	3178 ± 1418 (756-5863)	2034 ± 6958 (491-21648)	185 ± 265 (83-367)	36 ± 60 (15-230)	
	V	G	74331 ± 15767 (22548-212249)	8023 ± 5813 (576-24088)	2162 ± 1541 (824-7997)	1900 ± 962 (743-3372)	414 ± 294 (111-1136)	116 ± 111 (25-340)	
		Co	453664 ± 3 (120646-6 9999999.9)	3871154 ± 3803132 (893576-9687455.8)	309109 ± 511325 (25323-1236643)	696969 ± 962384 (13487-2762251)	163037 ± 140833 (71731-4741212.8)	41362 ± 62666 (10861-1296953)	
		Ca	40511987 ± 79214844 (1330941-86675056)	3878880 ± 2335699 (1477738-5-8182335)	1913585 ± 2872706 (814841-10754483)	769653 ± 341969 (425441-7-1370668.4)	128226 ± 39877 (84069-220141.3)	43308 ± 115496 (19434-6-433563.1)	
		S	32460878 ± 36818881 (840079-4.6 9214312.3)	4760011 ± 2052005 (1645228-12219088.1)	1249487 ± 2686034 (423861-5-88121201)	864637 ± 504376 (421805-1-1961153.8)	179348 ± 161300 (71731-4-842621.3)	47109 ± 50723 (10864-1-50732.8)	
		L	57434678 ± 29118643 (22873852-9999999.9)	6002024 ± 5152379 (2001413-4-19722614)	719382 ± 846278 (90353-6-2642756.2)	870191 ± 410890 (450303-9-1493038.6)	169582 ± 81059 (85159-347349.8)	56379 ± 25089 (15256-9-125795.1)	
2019	M	G	4388033 ± 3238062 (9773852-88674912)	5468876 ± 2847417 (706754-6974811.3)	1179179 ± 4211245 (319765-15212592.3)	721797 ± 287209 (312314-1-1361484.1)	137910 ± 71788 (38867-2-344735)	47858 ± 20075 (20141-3-109786.7)	
		Co	2871075.09 ± 28487200.22 (8753500-9999999.9)	3396888.75 ± 19999705.29 (786543-9999999.9)	1172933.58 ± 533832.63 (3381625-16755875.2)	855510.75 ± 1999864.34 (138975.7-128141-694699.8)	228833.52 ± 206057.97 (128141-694699.8)	62578.28 ± 353.4233968.2	
		Ca	58806396 ± 2249624 (28487200.22-9999999.9)	1522895 ± 2518804 (881138.86-10999705.29)	1955179 ± 2232336 (425441-7-1035902)	744591 ± 460796 (335595.76-1909864.34)	96389 ± 59356 (30889-3-430995)	28849 ± 17348 (70671-124074)	
		S	4246405 ± 30188828 (1146385-9999999.9)	5844499 ± 19270674 (1496466.4-7588433.5)	365013 ± 407365 (62544-1-7035902)	97400 ± 3626667 (430338-13345334.8)	131549 ± 128035 (308219-1-2520848)	44919 ± 40856 (58537-1-742462.8)	
		L	3418882 ± 30632284 (7493116.5-9999999.9)	3331567 ± 2881406 (1200005-8888884)	756549 ± 444138 (403533-6-1842756.1)	794335 ± 678194 (38219-1-2520848)	122195 ± 187939 (58537-1-742462.8)	30374 ± 55556 (8480-6-205304.4)	
	V	G	40511987 ± 79214844 (1330941-86675056)	3878880 ± 2335699 (1477738-5-8182335)	1913585 ± 2872706 (814841-10754483)	769653 ± 341969 (425441-7-1370668.4)	128226 ± 39877 (84069-220141.3)	43308 ± 115496 (19434-6-433563.1)	
		Co	32460878 ± 36818881 (840079-4.6 9214312.3)	4760011 ± 2052005 (1645228-12219088.1)	1249487 ± 2686034 (423861-5-88121201)	864637 ± 504376 (421805-1-1961153.8)	179348 ± 161300 (71731-4-842621.3)	47109 ± 50723 (10864-1-50732.8)	
		Ca	57434678 ± 29118643 (22873852-9999999.9)	6002024 ± 5152379 (2001413-4-19722614)	719382 ± 846278 (90353-6-2642756.2)	870191 ± 410890 (450303-9-1493038.6)	169582 ± 81059 (85159-347349.8)	56379 ± 25089 (15256-9-125795.1)	
		S	4388033 ± 3238062 (9773852-88674912)	5468876 ± 2847417 (706754-6974811.3)	1179179 ± 4211245 (319765-15212592.3)	721797 ± 287209 (312314-1-1361484.1)	137910 ± 71788 (38867-2-344735)	47858 ± 20075 (20141-3-109786.7)	
		L	2871075.09 ± 28487200.22 (8753500-9999999.9)	3396888.75 ± 19999705.29 (786543-9999999.9)	1172933.58 ± 533832.63 (3381625-16755875.2)	855510.75 ± 1999864.34 (138975.7-128141-694699.8)	228833.52 ± 206057.97 (128141-694699.8)	62578.28 ± 353.4233968.2	

**Annex 1** Results of the concentration of PST in the indoor air of the seven sampling sites of the UIA. n = 12; Geometric mean + standard deviation, the bold values represent the highest concentrations detected by particle size. Values reported in parentheses indicate the range of recorded values. Item (ND) Represents the range of values not detected by the equipment, M (Morning), V (Evening), (A) auditorium, (B) library, (Ca) cafeteria, (Co) computer lab, (G) Gymnasium, (L) health science lab, and (S) study rooms

Acknowledgments

The authors would like to thank Claridad Martínez Mere and Arlette Violeta Flores Guerra undergraduate students in Environmental Engineering for their active participation in the research project. As well as the subject teacher Juan Gualberto Antonio for his support.

Conclusions

It is concluded in this research work that the indoor air quality in the different sampled spaces of the university is related to the increase of the multiple activities in the surroundings of the university campus.

The urban growth, the industrial presence, the wind direction and the typical “terregales” of the region, as well as, the bad ventilation in the most used sites and the constant entrance-exit of the users help to re-suspend the PST and increase the concentration of microorganisms.

Some students have experienced health problems related to indoor air quality issues while in college. At some point, users presented symptoms of allergies, cough and irritation in the eyes and throat without knowing the cause of origin.

In the same way, it is important to make some changes in the ventilation or implementation of exhaust fans in the university facilities. This as a measure to reduce PST concentrations in the sites most visited by users, because the university is located in the area of greatest growth and urbanization of the city.

Finally, since indoor air quality exceeds the two reference standards used, it is intended to implement continuous monitoring after the COVID19 pandemic, especially in sites that presented statistically significant differences, as well as monitor other busy buildings where it predominates. wind direction.

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