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AIR QUALITY IN INTERNAL ENVIRONMENTS AND ANALYSIS OF CURRENT LEGISLATION: CASE STUDY IN A EDUCATIONAL INSTITUTION

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Abstract. *In the present work, the greatest interest and concern about the indoor air quality arises due to the tendency of increasingly occluded buildings, due to the control of air conditioning, noise, and for aesthetic reasons. Therefore, the sick buildings syndrome (SED) emerges, which associates with the relation between cause and effect of indoor air quality conditions, characterized by poor air renewal which allows the accumulation of pollutants inside those spaces being these chemicals and microbiological pollutants, capable of foment adverse effects to the health of the occupants. In this context, the objective of this research is to investigate the air quality of six indoor environments in an education institution - Instituto Federal do Espírito Santo – IFES – Campus Vitória and critically analyze the main Brazilian legislation in the topic – ANVISA Resolution No. 9 of 2003. For the characterization of indoor air, temperature, relative humidity and bioaerosols (fungi suspended in the air) were sampled and quantified, and the results were confronted with the maximum values allowed by the resolution. The analysis of fungal growth and the concentration of bioaerosols in the environments and their use conditions. The parameter analyzed, bioaerosols, no result was higher than the recommended by the resolution. The critical analysis of the legislation indicated some defaults and shortcomings in the requirements, such as the as the inexistence of exhibition limits to pollutant in short or in long period, the lack of microbiological parameters for concentration of bacteria in the air, and the lack of recommendations for monitoring growth of fungi in Petri plate. Thus, from the responses achieved, improvement proposals were made for the environments, the ventilation system and in the resolution in order to improve the internal air quality and therefore, to ensure the well-being and comfort to the occupants.*

Keywords*: Indoor air quality. ANVISA Resolution. Bioaerosols, Sick buildings.*

1. INTRODUCTION

Air pollution affects the health of the population even when the measured levels are within the limits imposed by current legislation, with children and the elderly being the groups more susceptible to the harmful effects of atmospheric contamination (Bakonyi et al., 2004).

Since the 1970s, the study of air quality in Internal Environments (Schirmer et al., 2011). Interest in the subject emerged in the context of the trend of building sealed buildings due to the control of air conditioning and noise, as well as for aesthetic reasons in the construction (Gioda, 2003; Lee; Awbi, 2004; De Oliveira; Guimarães; Lorenzetti, 2015).

The discussion was further enhanced by the discovery that the reduction in changes in ambient air results in a biological and non-biological pollutants such as Carbon Dioxide, Total Particles Suspension, Volatile Organic Compounds and Bioaerosols - Suspension of microorganisms (viable organisms) in the air (Brickus; Neto, 1999; Lee, Awbi, 2004; Turiel et al., 1983; Amorim; Silva; Almeida, 2014).

Nowdays, some studies have been developed in this subject related to the contamination in indoor environments, such as microbiological environments, investigations regarding the association between hospital air quality in air-

conditioned rooms and the effect of pollutants on the health of children (Ferreira, Cardoso, 2014, Da Costa, Machado, 2015, Da Silva, 2014). Some researchers have been conducted in school institutions, evaluating the indoor air quality in the classrooms and associating with the characteristics of the ventilation systems present in such enclosures, as well as the relationship of certain levels of pollutants on student and teacher productivity (Stabile et al., 2017; Toftum et al., 2015).

In Brazil there are standards that regulate air quality, but to deal withThere is only one internal environment, established by the Agencia Nacionl de Vigilância Sanitária (ANVISA), Resolution No. 9 of January 16, 2003. This from the revision and updating of Resolution No. 176, dated October 24, 2000, and standards for indoor air quality in artificially heated for public and collective use (BRASIL, 2003). The Institutions of Public Education (IE), one of which will be done the case study of this work, ifunder this resolution.

In this study, were measured bioaerosols. In addition, physical parameters of temperature and relative humidity. The presence of bioaerosols is mainly in humid environments, in organic porous materials, in the interior of conditioners and ducts with little or no maintenance (Brasil, 2003) and can cause irritations, allergies, respiratory diseases and other toxic effects, when present indoors (Lisboa, 2014).

Therefore, the main objective of study is the quantitative analysis of parameters of the indoor air quality in order to evaluate compliance with recommended concentration standards current legislation. Also, analyze the relationship of fungal growth and bioaerosol concentrations in the environments with their conditions and characteristics of use the evaluation. Finally, the study may be added to the Program of Environmental Management of IFES, in order to give greater and inspire improvements in the institute.

2. METHODOLOGY AND METHODOS

The biological pollutants, it has been that the main ones are the bacteria, mites, fungi, spores and pollen grains, the study of which is extremely relevant, since they can cause numerous allergic and infectious diseases. Many Sometimes, diseases are caused by toxins produced by microorganisms that mainly grow in ventilation systems (Schirmer et al., 2011). Some microorganisms can cause allergic reactions, being that cough, sneezing, watery eyes, respiratory failure, lethargy and fever are among the symptoms. Jarvis and Miller (2005) studied the microtoxins as air pollutants and investigated the ability of production of mycotoxins, which can enter the human body through the dermis, oral or inhalation, causing different reactions in the host.

Several factors allow the growth, proliferation and release of agents such as poor ventilation, high humidity, ventilation and air conditioning systems that have cooling towers. Among these, The high humidity of the air is one of the most significant factors, since it allows the of the mite population and the increase of fungi. Indoors, with large physical activity and high number of people like sports courts and gyms is quite common, as observed in the study by Dacarro et al. (2003) who evaluated the microbiological quality of indoor air in school gymnasiums, investigating the students' exposition.

Bioaerosols can be defined according to ANVISA Resolution No. 9 of 2003, as a suspension of microorganisms (viable organisms) dispersed in the air (Brasil, 2003). Another concept is that they are determined as particles whose origin are suspended in the air, and their origin may be both natural and artificial, existing in the form of a single cell, agglomerates of microorganisms viable or non-viable particles of varying sizes (Pastuska, 2000).

The physical factors of temperature and humidity are one of the most important factors influence the development of fungi, with the ideal temperature range for the growth of most colonies between 18 ° C and 32 ° C. However, the physical parameters of temperature and relative humidity, as well as the physical factors of circulation rate and air renewal rate, do not only affect the development of microorganisms in internal environments, but also the comfort conditions to which the occupants are subject the dispersion and dilution of pollutants in the air (Lisboa, 2014).

The best way to maintain a healthy environment is by controlling pollutants, for example by avoiding the use of Construction Materials. However, in some situations, effective control of emissions is not practiced. In these terms, it is assumed that ventilation, natural or mechanics, is the second most effective mechanism in maintaining air quality. internal. But, it is worth mentioning that this option can lead to higher costs with energy in the affected buildings (Carmo, Prado, 1999, Cho et al., 2015).

The criteria on indoor air quality in air-conditioned environments, deals with the technical responsibility and instrumentalization of teams regarding quality control, planning, preparation, analysis and execution of physical projects and inspection of air-conditioned environments. This Resolution also provides analytical methods for the monitoring of viable fungi, carbon dioxide, temperature, humidity and air velocity and total aerodispersoids, referring to Technical Norms 001, 002, 003 and 004, respectively (Brasil, 2003) as shown in the table below.

Table 1. Maximum Allowable Values by Resolution No. 9 - 2003 -ANVISA

Carbon dioxide	≤ 1.000 ppm
Aerosols	≤ 80 g/m³
Temperature (Summer/Winter)	23 – 26 °C/ 20 – 22 °C
Relative humidity	40 – 65 %/35 – 65 %
Renovation rate	27 m³/h/pessoa
Air velocity	0,25 m/s
Funghi	≤ 750 UFC/m³
Ratio I/E	I/E ≤ 1,5

Note: I / E = Relation between the amount of fungi of the internal environment and the external environment.

There is also a public consultation, carried out by ANVISA, 2003), also dealing with indoor air quality, but in this case, being more specific for health environments (QUADROS,2008). One point at which such a document differs from Resolution 9 is that are classified at different levels of risk, and microbiological references are set out separately for each of these levels.

2.1 - Environments in which measurements were taken

The Federal Institute of Espírito Santo (IFES) Campus Vitória, is a public institution, which offers technical courses integrated to secondary education and subsequent courses of higher education and postgraduate studies (Figure 1).

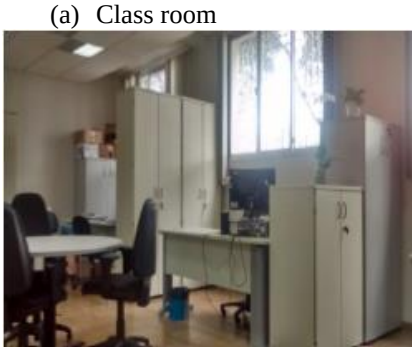
The study was carried out in the internal environments of IFES (classrooms, offices, laboratories, workshops), where samples were taken and subsequent measurements of concentrations of pollutants of interest. These are justifications for choosing IFES as environment for case study: (i) ease of access to different environments, (ii) sampling safety, (iii) large number and variety of environments classified as internal and (iv) large circulation of people in all shifts. The Table 5 below details the ventilation system environments (quantity, brand and / or model).

Figura 1: Location of the internal environments analyzed at IFES

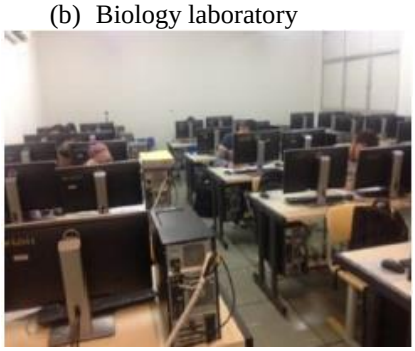
(a) Class room

(b) Biology laboratory

(c) Teacher´s room



(d) Administrative office



(e) Computer laboratory

(f) Meeting room

2.2 - Bioaerosol sampling and UFC counting

Therefore, for the sampling of bioaerosols, specifically the CF-6 Sampler Kit Andersen Type One Impact Criffer Instrumentos de Medição Ltda, which can also be called the Microorganism Sampler, shown in Figure 2 (a) and (b).

The method consists of installing a Petri dish, containing a culture medium suitable for microorganisms. Thus, the air is drawn through the impactor with the aid of a constant flow pump, and the larger particles are, then, impacted and retained on the plaque with the agar, while the smallest particles through the outlet at the base of the impactor and pump hose. After this process is completed, the plate is removed with the sample, which should be incubated and then counted, with the aid of the colony counter FANEM – SP BRASIL, ED 550A shown in the Figure 2(c).

Figure 2: Bioaerossois Sampler and Colony counter Bioaerossois Sampler: (a) and (b) Bioaerossois Sampler and (c) colony counter

As microbial cells often occur in clusters, possible to establish a direct relation between the number of colonies and the number of cells, this correlation is made between the number of colonies and the number of Colony Formation Units (CFUs), which can be either individual cells as clusters that are characteristic of some microorganisms. In this way, for plaques with number of colonies between 25 and 250, colonies with the aid of the counter magnifying glass presented above. However, for plates with more than 250 colonies and up to 10 colonies / cm², counts the number in 12 squares of 1 cm², being 6 consecutive horizontally and 6 consecutive vertically, using counter markings to assist. Thus, the average number of colonies per cm², and this result is multiplied by the Petri dish area.

The analytical method for carrying out this measurement was according to the methodology found in Technical Standard 001 of ANVISA's Resolution 9, in which defines at least one sample for a constructed area of up to 1,000 m². Also, specifies the possible culture media to be used in the analysis, such Ágar Extrato de Malte, Ágar Sabouraud Dextrose a 4%, Ágar Batata Dextrose or other, since it is scientifically validated.

Figure 3: Sabouraud dextrose agar (ASD) and Petri plates: (a) ASD and (b)Petri plates

The sampling time recommended by ANVISA Resolution 9 is between five and fifteen minutes and the air suction rate from 25 to 35 L / min. In this experiment, a sampling time of 10 minutes - this being measured with the help of a chronometer - and a flow rate of 28.3 L / min (Figure 4 (a) and (b). The sample points were uniformly distributed and collected with the sampler 1.5 meters from the floor, which is located centrally in the environment or in the occupied zone (BRASIL, 2003). Thus, having the time of sampling, the airflow and the number of colonies, the concentration of airspeed in UFC / m³, calculated according to the following Equation 1, in which N is the number of colonies counted in the Petri plate (UFC) and V is the volume of air sampled in m³.

Figura 4: (a) Counting of colonies with the aid of the counter and (b) (b) Parts properly disinfected and packed in Kraft paper before measurements

$$C = N/V(UFC/M3) \quad (1)$$

3. RESULTS AND DISCUSSIONS

The bioaerosol samples were taken on consecutive days by the starting on 10/17/2017 and ending on 10/25/2017, the medium being previously prepared on the day prior to the start of measurements, on the day 10/16/2017. It should be noted that on the day of each bioaerosols sampling, measurements, were measured temperature and relative humidity of the air. The table 2 shows the results of concentration of bioaerosols

Table 2: Results of concentration of bioaerosols	
Room	Colon count (UFC)
Techer´s room	184
Microbiology laboratory	280
Administrative office	435
Class room	361
Meeting room	343
Computer laboratory	156
External environment	541

During the follow-up of the incubation period, it was observed that in most of Petri plates, the growth of colonies of microorganisms became visible from the second day after collection. However, in some cases, as in the case of sampling in the classroom and in the external environment, it was possible to verify the fungal growth after only 24 hours of incubation.

We also studied the relationship between the concentration of bioaerosols between the internal environment (I) and the external environment (E), as established in the Resolution. In the Table 3, the results obtained for this I / E ratio were shown.

Table 3: Results regarding the relationship I/E	
Room	Ratio I/E
Teacher´s room	0,34
Microbiology laboratory	0,32
Administrative office	0,80
Meeting room	0,67
Class room	0,63
Computer laboratory	0,29

Note: I: internal environment and E: external environment

The maximum value recommended by ANVISA Resolution 9 for the I / E ratio is 1.5. Thus, it is noted that the results were much lower. It is understood that, and I / E ratio whose result was greater than 1 would indicate an accumulation of microorganisms in the indoor environment, however, the results shown do not indicate accumulation.

The Figure 5 shows the growth of colonies in administrative office.

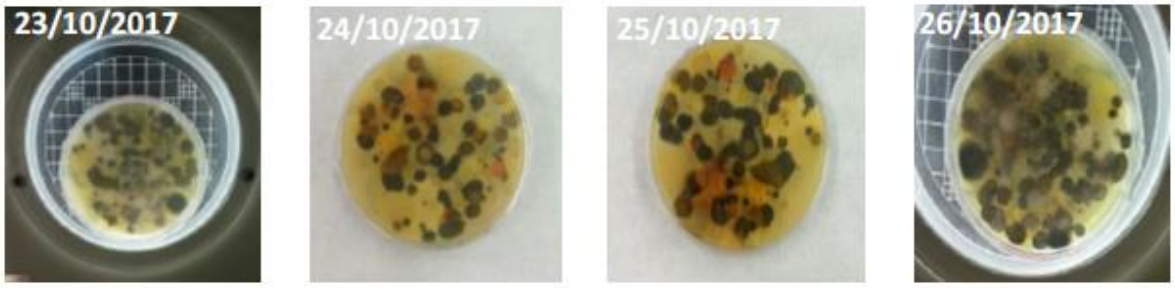


Figura 5: Increase of colonies in sample 3: administrative office

4. CONCLUSIONS

In this study, it was observed that the different results obtained were consequence of the characteristics of the use and occupation of the environment, in the environment and poor conditions of the enclosures. It was not possible to assess whether accumulation in the bioaerosol concentration was increasing over time in environments.

Although all the studied environments agree with the Brazilian legislation for internal environments with regard to contamination microbiological perspective, a perspective that cannot be ignored is that there are still few studies on the detection and measurement of chemical pollutants in indoor environments, so that an enclosure that has a good air quality, considering the microbiological aspect, may have high concentrations of chemical contaminants.

There could still be cases where the high level of chemical contamination can inhibit the growth of microorganisms in the so that this environment would be framed as an environment with a good air quality at microbiological level. In this sense, we conclude that the analysis of only one parameter is insufficient to support a monitoring analysis the air quality of indoor environments, making it essential to use a data set that is capable of reliably reflecting the circumstances and conditions.

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