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Experimental Assessment of the Indoor Environmental Quality in an educational facility*

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Abstract. *A good indoor environmental quality in educational facilities is important for student's performance, will reduce health problems and absenteeism. Using a detailed experimental campaign we have evaluated the thermal, acoustic, visual comfort and air quality. Air temperature, CO_2 levels, relative humidity, sound pressure levels and daylighting illuminance were recorded and analyzed. It was found that the air temperature during winter period is around 21°C while the CO_2 levels were in acceptable range of 600÷800 ppm. The background sound pressure levels were also in acceptable range with values below 40 dB(A).During this winter cloudy day the illuminance levels from daylighting were measure to be arround 100 lux. It is concluded that the analyzed building offers an acceptable environment for the students.*

Key words: indoor environmental quality, educational facility, experimental measurements

1. Introduction

Nowadays the concept of an acceptable indoor environmental quality (IEQ) as an integral part of the total building performance approach is still not fully studied. It is clear that physical environmental parameters such as air temperature, sound pressure level, relative humidity, CO_2 levels, and luminance levels are all interrelated, and the feeling of comfort is a mixed state of the occupant's that respond to these factors [1–4]. Many studies showed that an occupant's acceptance of an environment is influenced by many environmental parameters [5]. The indoor environmental quality can be divided in four basic components: thermal comfort, indoor air quality, aural and visual comfort. Conventional studies on indoor environment address each of them separately but the approach should be done by studying them together. As mentioned before, the parameters are connected. For example it was reported that at for an operative temperature between 23°C and 29°C, each degree Celsius change would associate the same effect on human comfort with a change in noise level of 3.9 dB [6].

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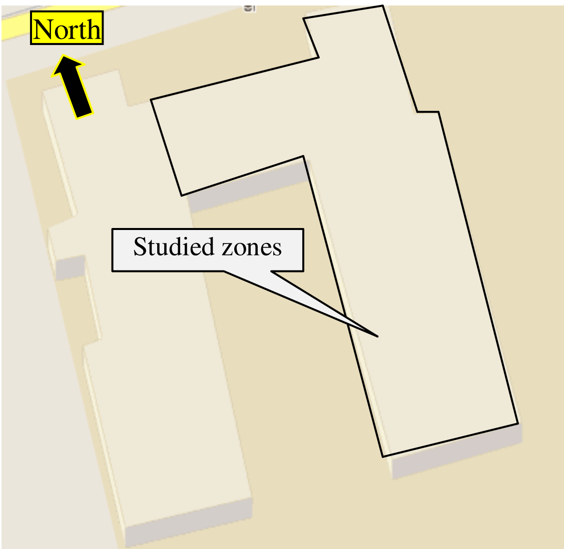
The sick building syndrome (SBS) [11] appears in unacceptable indoor environments. There are several studies [5–9] on the occupants' attitudes towards the air temperature, CO_2 concentration, equivalent noise level and illumination level by various means: surveys and measurements. There are only few research studies on the educational facilities and the IEQ assessment. There is clear evidence that a good IEQ can help the learning process of students and in many cases improving its attributes can also reduce energy use [10]. Moreover a good environment can change the teacher and student performance [11]. In this article we want to check the indoor environmental quality in an educational facility by means of experimental measurements. This expertise can help us understand what the indoor air quality is and what the problems to be solved are.

2. Field measurements

The aim of this part of the campaign was to measure the actual indoor thermal comfort conditions and indoor air quality (IAQ) during a weekday. For this purpose, we have used portable data loggers for the following parameters: the indoor air temperature (±0.3◦C accuracy), the relative humidity (±2% accuracy), sound pressure level (±2 dB(A) accuracy), CO_2 concentration (±50 ppm accuracy) and luminance level (±3% accuracy). These parameters were measured with five separate meters. These measurements were taken between 09:00 am and 13:00 pm during a winter day. The heating system was on and it was functioning in normal parameters. All these measurements were realized in an educational Facility (Faculty of Building Services Engineering). The building architecture and a satellite view (see Figure 1) visually describe the studied building. The studied zones are mainly classrooms and only a part of them are exposed to the traffic noise from Bd. Pache Protopopescu. The classrooms windows are exposed to East and West orientation. The building is composed of four floors but we were interested mainly by the last three as these areas are used as classrooms.



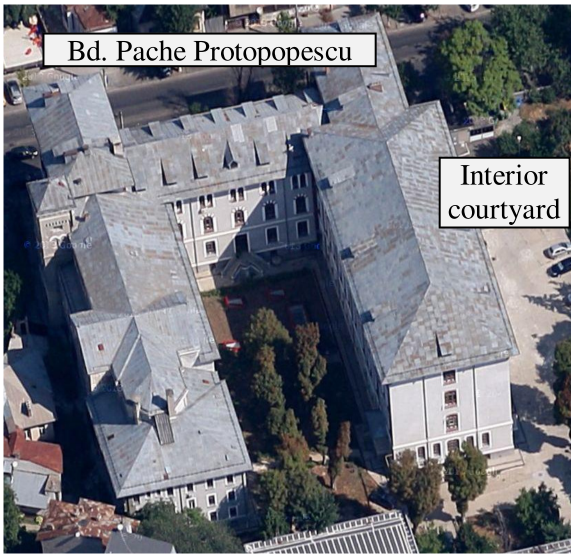


Fig. 1. Faculty of Building Services Engineering (photos source: Google Maps)

3. Experimental results

After the analysis of the taken measurements for the three floors and for all the spaces we were able to realize 3D plots for each measured parameter.

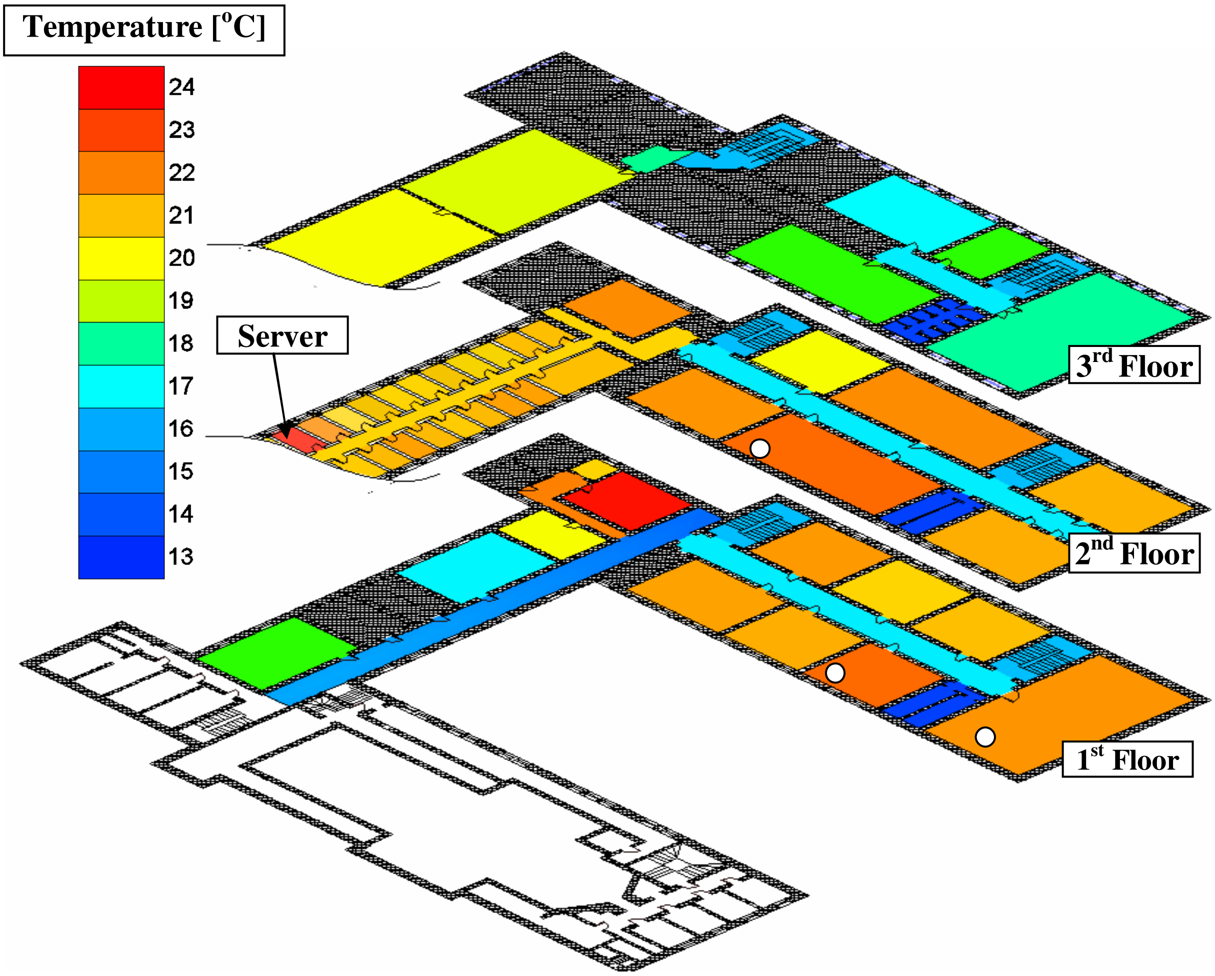


Fig. 2. Air temperature 3D plot for different zones of the building

The air temperature is probably the most important indoor parameter that can change the well being of occupants. In Romania, the indoor set point temperature is usually of 20°C, this being also the heating system design temperature. As it can be noticed from Figure 2 in most of the classrooms the air temperature is higher than 20°C, with a mean value of 21°C. In Figure 2, with white dots, we pointed out the classrooms that were occupied just before the measurements. The heat gains from the occupants influenced the air temperature with at least 1°C. The red zone for the first floor corresponds to the administration room and the value of 24°C is explained by the high amount of internal gains (computers, printers, lighting). The same explanation is done for the red zone of the second floor, this zone being the server room. The air temperature of the corridors and toilets has the smallest values (13°C to 17°C). The explanation is due to the high amount of fresh air entering these areas. We remind that the outside temperature during the measurements was of -5°C. There is one specific classroom where is chilly with a value of 17°C (see 1st Floor). This is explained by the higher amount of air infiltration and old heating radiators that do not have a uniform temperature. The air temperature for 3rd floor classrooms is around 19°C, explained by the higher amount of heat loss surfaces. These zones are in contact with the attic which is a non-heated space and without insulation. In the black hatch areas we did not have access to do the measurements, however those areas are not classrooms and therefore our conclusions on the educational environment were not affected.

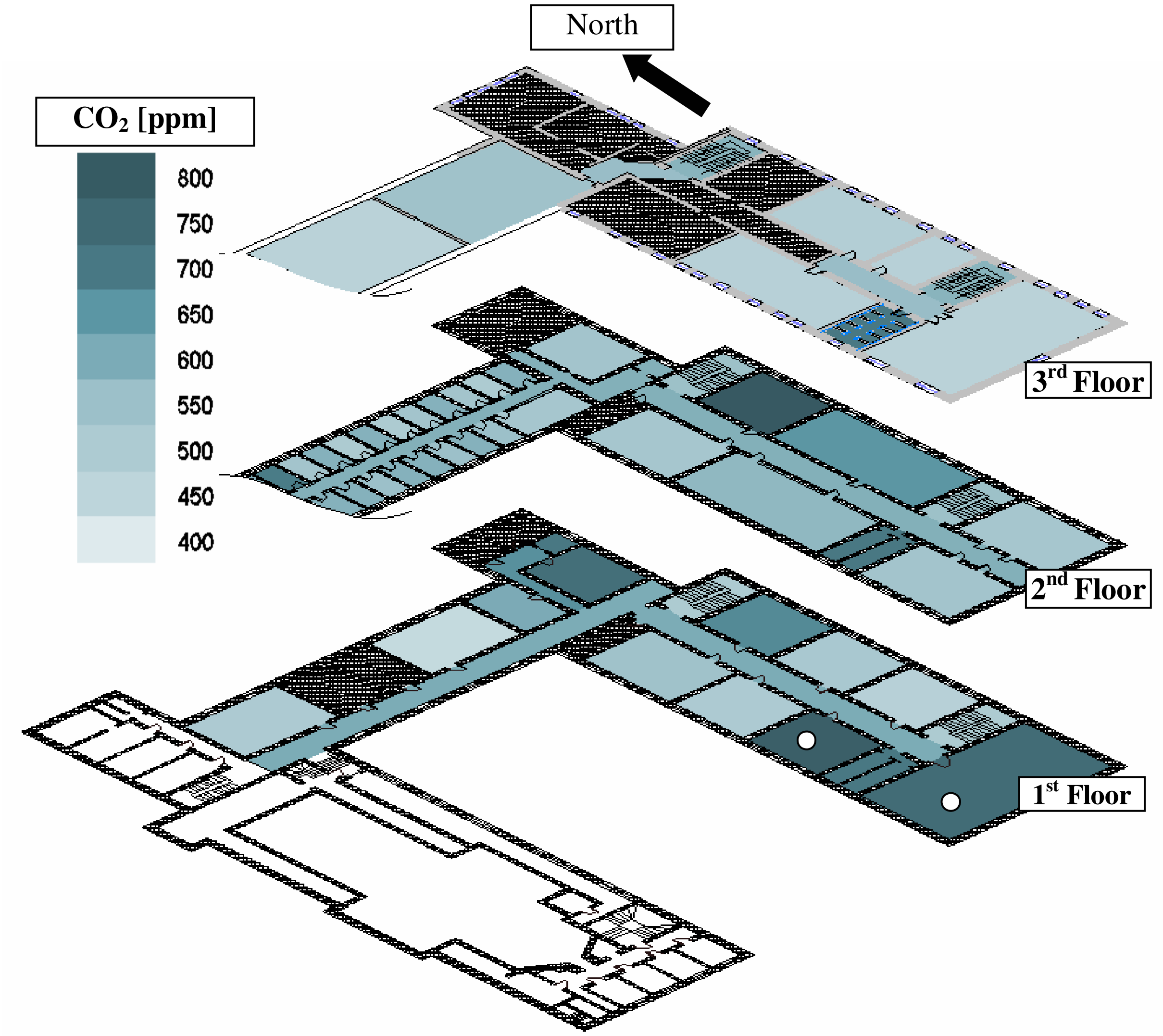


Fig. 3. CO_2 concentration 3D plot for different zones of the building

Carbon dioxide is a normal constituent of exhaled breath from the occupants. The carbon dioxide level is usually greater inside a building than outside, even in buildings with few complaints about indoor air quality. If there is no ventilation system or the air infilitration is not sufficient, then the indoor carbon dioxide levels may be higher than 1,000 ppm and complaints such as headaches and fatigue may be common. Normally, the acceptable levels should be less than 600 ppm. For the studied building (see Figure 3) only in few classrooms the concentration level is higher than 600 ppm. The risk of fatigue may appear in these areas as the values are close to 800 ppm. With white dots are represented the zones occupied by students before the measurements and explain these higher values. The building does not have mechanical ventilation and only the air infiltrated from the windows contributes to a good indoor air quality.

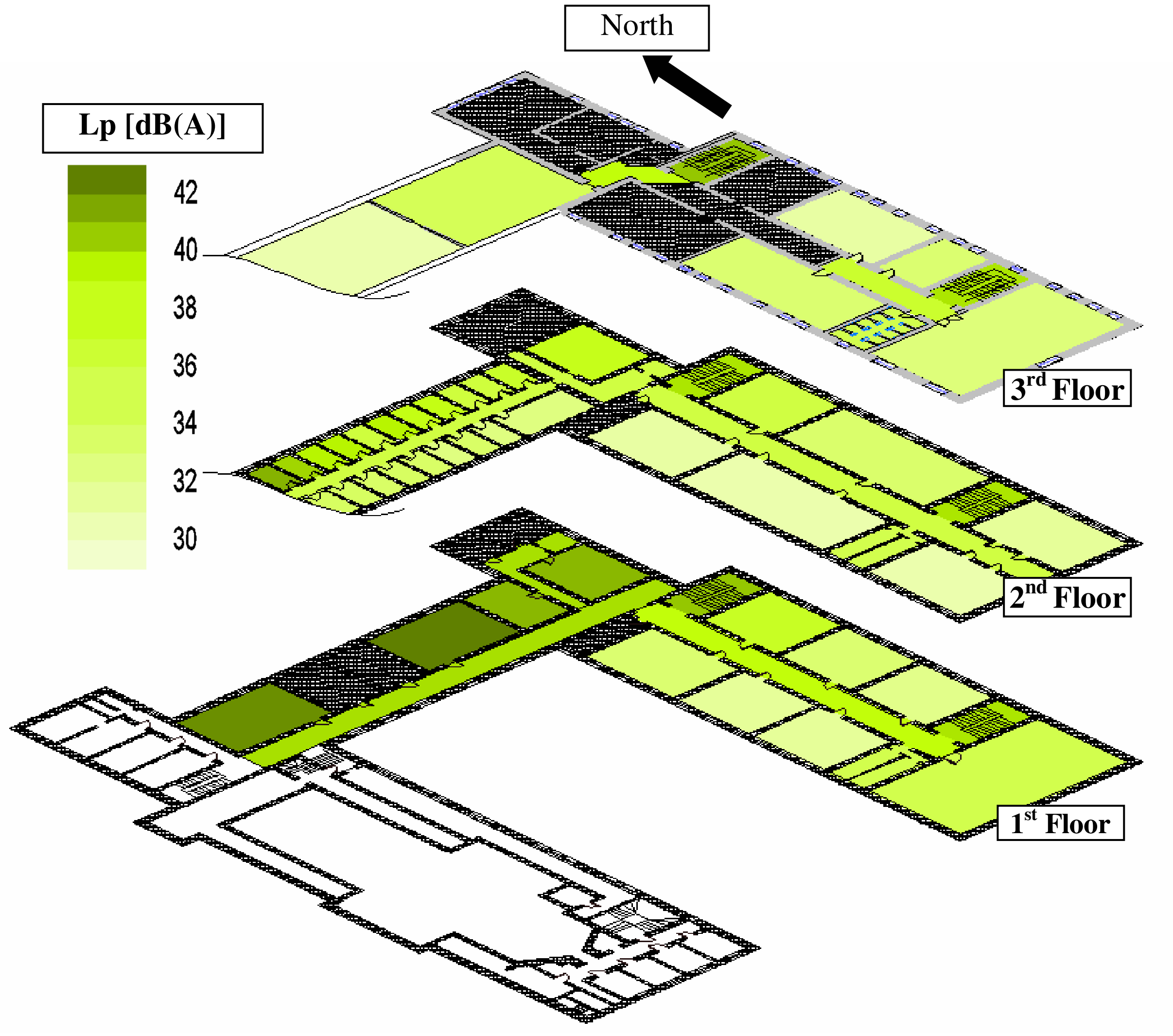


Fig. 4. Sound pressure level 3D plot for different zones of the building

The noise can greatly contribute to the normal learning activities inside an educational facility. Most of the classrooms of the studied building are facing internal courtyards and the sound pressure levels (L_p) are lower than 40 dB(A) which is an acceptable level. The highest measured values were found for the classrooms from 1st floor and which are exposed to the noise traffic. The fenestration of these areas is composed of two simple glazing windows and is not air sealed. The measurements were taken during a week day and the traffic was in normal limits. It is possible that during the day to have peak points when the sound pressure levels are higher than 45 dB(A).

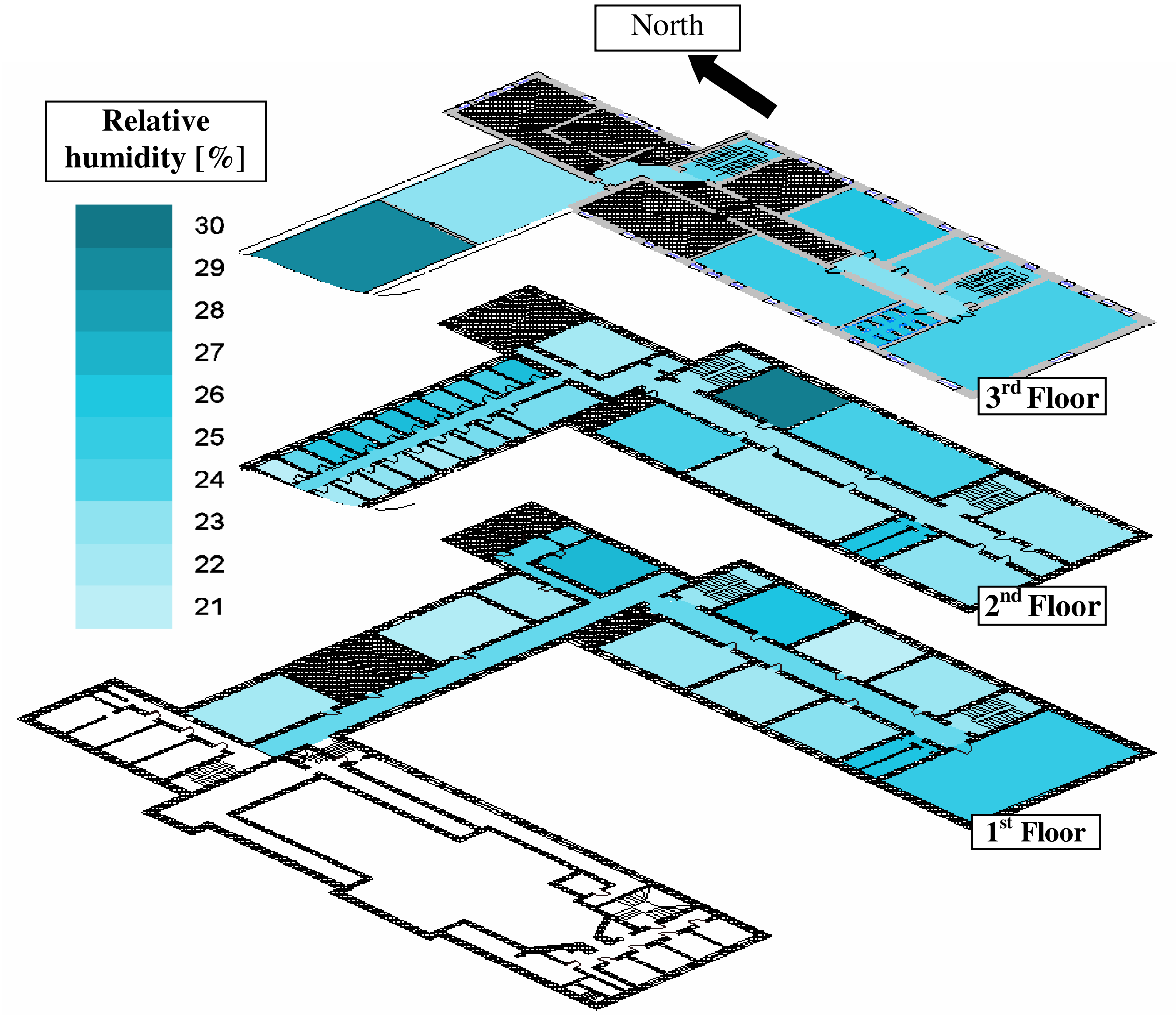


Fig. 5. Relative humidity 3D plot for different zones of the building

There is no "perfect" humidity level and temperature suitable for all the occupants. Among the indoor environment factors there are other, such as personal activity and clothing may affect personal comfort. Acceptable relative humidity levels should range from 20 percent to 60 percent year-round. Figure 4 illustrates the relative humidity measurements. The maximum measured level is 30% while the minimum is recorded in the administration zone which seems logic since the air temperature has the highest value (24°C).

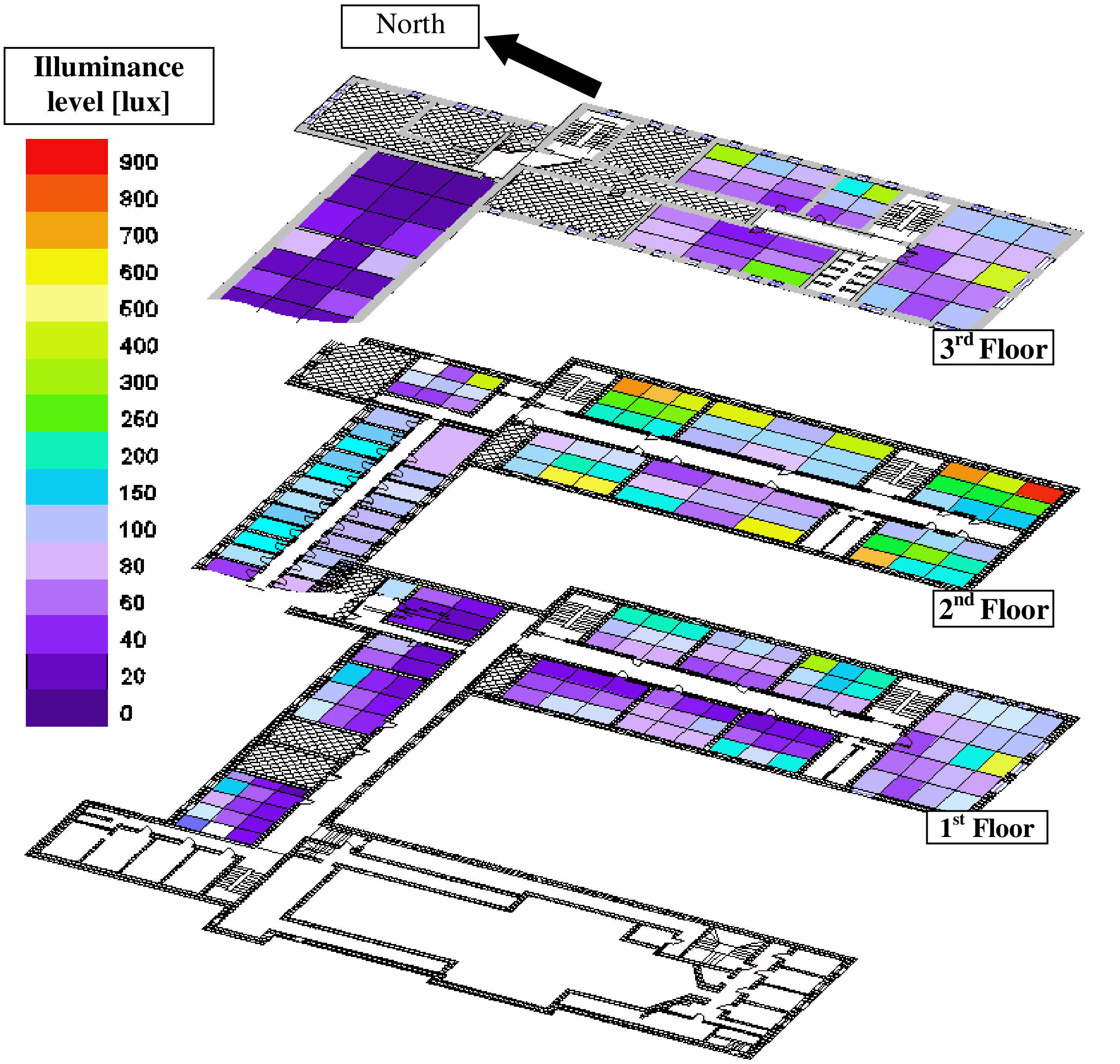


Fig. 6. Illuminance levels 3D plot for different zones of the building

The daylighting illuminance levels are illustrated in Figure 6. The measurements were done under cloudy sky during December for a period of 3-4 hours. In each classroom there were taken 9 measurements of illuminance. These levels were measured directly on the student's tables. It can be observed that the classrooms facing North have lower illuminance levels compared to the ones orientated East. In most of these spaces the indoor visual comfort is not achieved only using the daylighting and the need of an electrical lighting system is mandatory.

6. Conclusions

The Indoor environmental Quality was verified in an educational facility using measurements. In all the classrooms there were taken measurements of air temperature, CO_2, relative humidity, sound pressure level and illuminance. In most the indoor spaces the air temperature is higher than the designed temperature (20^{o}C) with at least 1^{o}C. The CO_2 levels were in acceptable range (600÷800 ppm), probably due to high fresh air infiltrations from the windows. The noise levels were below 40 dB(A) which is translated by a good acoustics. The illuminance levels from daylighting were found to be not enough to ensure a good visual comfort. The mean values of daylighting were around 100 lux.

Acknowledgements

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