



Proceedings The Effect of Green Walls on Humidity, Air Temperature, Co₂ and Well-Being of People ⁺

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Abstract: The experimental study of vegetated walls and their effects on humidity, air temperature and CO₂ is essential. This paper presents an experiment on a green wall to apprehend its thermal and hydrological behavior and its impact inside the building. The experiment is based on a living wall set up in a classroom. Monitoring of temperature, humidity and CO₂ variations within the living wall and a reference case enabled us to analyze the effects of green walls. Measurements were performed in Košice, a city in Slovakia. During the measurements, a set of questions were answered. The data from the respondents were used to achieve goal of this interdisciplinary research, which was to identify the effect of green walls on the well-being of people. It can be stated that women are more sensitive to changes than men. Following the measurements, it can be stated that the green wall is very favorable for indoor environments. The optimum relative air humidity in rooms such as classrooms, hotels and theaters is from 30% to 70%. From a relative humidity perspective, green walls appear to be beneficial for indoor buildings.

Keywords: green wall; experiment; air temperature; humidity; CO2; questionnaire; case study

1. Introduction

Some of the benefits of living green dividers include that they are a surefire approach to upgrade a building's visuals and enhance air quality and also representative sharpness and vitality levels. Over the past 50 years, a remarkable increment of urban-living searchers has prompted an extensive uptick in air contamination and loss of green spaces. Living green dividers (additionally usually alluded to as vertical gardens or living dividers) are a superb answer for any property owner keen on enhancing their space with the characteristic advantages of nature. These dividers offer a moving and tastefully captivating, characteristic lift to worker resolve [1]. Regardless of whether they are introduced on the outside or inside of a building, the structures of absolutely real vegetation give the "wow factor" [2] that such a significant number of inside architects look for while championing manageability.

This paper describes the classroom of the faculty in the TUKE campus in Košice, where an interior green wall is situated. Measurements were carried out in the classroom between 4 January, 2018 and 8 February, 2018 between 08:00 and 09:15 a.m. The paper presents the findings on the effects of green on people and the environment [3].

2. Site

2.1. Košice

Košice (Figure 1) lies at an altitude of 206 m above sea level and covers an area of 242.77 km². It is located in Eastern Slovakia. Košice has a humid continental climate, as the city lies in the North Temperate Zone. The city has four distinct seasons. Precipitation varies little throughout the year, with abundance precipitation that falls during the summer and only a few times during the winter. The coldest month is January, with an average temperature of -2.6 °C and the hottest month is July, with an average temperature of 19.3 °C (Figures 2–6) [4].



Figure 1. Green wall location.

The months May, June, July, August and September have a nice average temperature. The average annual maximum temperature is: 13.0 °C. The average annual minimum temperature is 3.0 °C.



Figure 2. Average minimum and maximum temperature over the year [4].

On average, July is the sunniest. On average, December has the lowest amount of sunshine.



Figure 3. Average monthly hours of sunshine over the year [4].

On average, July is the wettest month. On average, January is the driest month. The average amount of annual precipitation is 619.0 mm.



Figure 4. Average monthly precipitation over the year (rainfall, snow) [4].

Most rainy days are in December. On average, December is the most rainy. On average, September has the fewest rainy days. The average annual amount of rainy days is 147.0 days.



Figure 5. Average monthly rainy days over the year [4].

On average, December is the most humid. On average, May is the least humid month. The average annual percentage of humidity is 62.0%.



Figure 6. Average humidity over the year [4].

2.2. Classroom

The aim of the research was to analyze the impact of a green wall on its environment. The quality may be affected by the materials of the research area. The list of materials, area and percentage of each material is listed in Table 1.

Material	Object	Area	Real Area m ²	Total Area m ²	Percentage %
Engineered wood	OSB board	Floor	59.2	59.2	24.6
Plaster	Wall	Ceiling	61.2	106.0	44.0
		North wall	17.5		
		East wall	9.8		
		South wall	17.5		
Glass	Glass wall + Entrance door	West wall	36.2	56.9	23.6
	Windows	East wall	20.7		
Steel	Heaters	East wall	4.5	4.5	1.8
Wood	Glass wall + Entrance door	West wall	4.1	6.4	2.7

Table 1. Classroom material characteristics.

	Windows		2.3		
Plants	Green wall	7.9 *	3.3	7.9 *	3.3
	TOTAL		236.0	240.9	100

^{*} Real area after calculating leaf areas.

2.3. Green Wall

The size of the one green-wall-bearing construction is $1000 \times 750 \times 1750$ mm (Figure 7). On this bearing construction made of iron bars with a diameter of 50×50 mm (Figure 2), anOSBboard (Oriented strand board) is attached with dimensions of $1000 \times 1500 \times 10$ mm.



Figure 7. TUKE self-made green wall – front and right side view on both green wall designs.

On these OSB boards, plastic drainage pipes with a diameter of 110 mm are attached. The total number of the plastic drainage pipes is 58, 30 on one board and 28 on the second (Figure 7). These plastic drainage pipes were pre-joined into a specific design (Figure 8) and then attached to the board using straps usually used for attaching the downspout to the building facade. The idea of these green walls was to use specific material—plastic, which can be re-used.

Used flowers were pre-grown. In total, six types of flowers were used. The number of each species used is: Dryopteris Erythrosora'Brilliance' – 19 pieces[5], Scindapsus Aureus – 9 pieces [6], Aglaonema 'Silver Queen' – 10 pieces [7], Philodendron Hederaceum – 8 pieces[8], Chlorophytum Comosum'Variegatum' – 4 pieces [9], Anthurium Andraeanum – 8 pieces[10].

These pre-grown flowers were in separate plastic pots. Each pot with its filtration layer, substrate, ceramsite layer and flower was placed in the plastic drainage pipe following the desired design of the green wall.

The big change in the same environment is noticeable in Figure 9. The students were not informed about the installation of these green walls in the classroom. After a week of presence of these green walls in the classroom, the questionnaire [11] was distributed among students and teachers of the faculty.



Figure 8. Plastic pipes used for creating the green wall.



Figure 9. Cass room with and without the green wall.

3. Experiment with 20 Respondents

The aim of this measurement was to find out how the green wall affects the microclimate, environment and well-being [12,13]. The experiment was performed during days when people were in the room from 8:00 a.m. to 9:15 a.m. The respondents were students and teachers. The number of participants was 185,76 of whom were female and 109 male. The first question in the questionnaire was on the perception of the temperature in the room, with potential answers being "cold", "moderately cold", "appropriate temperature", "moderate warm" and "warm". The second was on theodor of the air in the room, with respondents being able to respond that they perceived "no odor", "moderate weak odor", "appropriate odor", "moderate strong odor" and "strong odor". Finally, the last question was to find out whether the given air quality in the room was "satisfactory" or "unsatisfactory" [3,14,15]. This article presents one day of experiments with 20 respondents (6 females, 14 males).

3.1. Effect on Well-Being

3.1.1. Effect on Respondents, Change in Temperature

We can see that men perceived a temperature (Figures 10 and 11) increase at the end of the measurement in both cases, whereas for women, that perceptionis more individualized, thoughthey also perceived a higher temperature at the end of the measurement. The effect of flowers in this measurement did not significantly affecttemperature change.





Figure 10. Change in temperature, classroom with the green wall-4 January 2018.

Figure 11. Change in temperature, classroom without a green wall-18 January 2018.

3.1.2. Effect on Respondents, Change in Odor

While observing odor (Figures 12 and 13) change, we can notice that in the room where there was a green wall with flowers, the respondents perceived the odor change more, and that bothmen and women perceived the odor change.



Figure 12. Change in odor, classroom with the green wall-4 January 2018.



Figure 13. Change in odor, classroom without a green wall-18 January 2018.

3.1.3. Effect on Respondents, Change in Air Quality

With the green wall, 5 respondents rated the air quality (Figures 14 and 15) as unsatisfactory, and without the green wall, only one respondent rated air quality as unsatisfactory.



Figure 15. Change in air quality, classroom without green wall–18 January 2018.

3.2. Change in Relative Humidity

Nochanges in relative humidity in the classroom without a green wall (Figure 16) were detected by 28.7% of the respondents. Nochanges in relative humidity in the classroom with a green wall (Figure 16) were detected by 30.1% of the respondents.



Figure 16. Change in CO2, air temperature and relative humidity, classroom with and without a green wall—18 January 2018.

The maximum air temperature in the classroom without a green wall (Figure 16) during the stay was 37.2 °C according to respondents. The maximum air temperature reached in the classroom with green wall (Figure 16) during the stay was 35.5 °C according to respondents.

3.4. Change in CO2

The CO₂ production of respondents has been calculated, and the effect of green wall: The increase in CO₂ concentration in the classroom without a green wall (Figure 16) during the stay of respondents was 8.29 mg/person. The increase in CO₂ concentration in the classroom with a green wall (Figure 16) during the stay was 7.10 mg/person. In the classroom with a green wall, the increase in CO₂ concentration is 14% lower.

4. Conclusions

The measurement of the effects of a green wall on well-being wascarried out using a subjective method—a questionnaire where respondents evaluated the internal microclimate at the beginning of the stay in the room and at the end of the stay in the room. It can be stated that women are more sensitive to changes than men. Following the measurements, it can be stated that the green wall is very favorable for indoor environments. According to Decree no. 210/2016 Coll. The Decree of the Ministry of Health of the Slovak Republic on the details of the requirements for the indoor environment of buildings and the minimum requirements for apartments of a lower standard and accommodation facilities, the optimum relative air humidity in rooms such as classrooms, hotels and theaters should be from 30% to 70%. In our case, relative air humidity was measured to be 28.7% in the room without the green wall, which is just above the minimum required. In the room with the green wall, the relative air humidity was measured to be 30.1%. From a relative humidity perspective, green walls appear to be beneficial in indoor buildings.

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