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Altering Micro-Climatic Conditions with Green Landscaping Elements in Office Buildings

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Abstract
Experiments were conducted to determine whether vegetation can favourably affect micro-climatic conditions. The experimentation area contained a significant amount of computer and printer equipment, which generated higher temperatures and increased levels of Volatile Organic Compounds (VOCs), creating health hazards for workers. The high summer temperature of 45°C significantly reduced work efficiency. The experiments strategically positioned vegetation to assess whether micro-climatic parameters could be brought closer to a comfortable range. It was found that micro-climatic conditions can be monitored and regulated by placing plants at crucial positions.

Keywords: Micro-climate, volatile organic compounds, vegetation, comfort zone

Introduction
Controlling the micro-climate positively using plants, an element of landscape design, without mechanical systems is an innovative idea. Indoor plants and foliage within or around the work area are soothing to the human eye. Experimenting with the strategic placement of an increasing number of indoor plants to monitor micro-climatic factors and VOC levels in industrial indoor environments is worthwhile. This idea was validated through experimentation at Enviro LTD, Nagpur.

Objective
Methods to control micro-climate with placement of plants in indoor industrial environment

Parameter
The micro-climatic measurements were done at every three hours interval so as to coincide with meteorological data. The parameters considered for the experimentation are as under:

- Wet Bulb Temperature (WBT)
- Relative Humidity (RH)
- Air Velocity
- Illumination (LUX)
- Volatile Organic Compound (VOC)

Site Details
The unit situated at Enviro Ltd, near Somalwar School Khamla, Nagpur. The unit deals with the environmental treatment of waste disposal in various industries. The unit operates in two shifts with

around 40-42 employees. The site is identified for the experimentation to examine the effect of vegetation on micro-climate control with emphasis on temperature, humidity and VOC control in indoor environment.

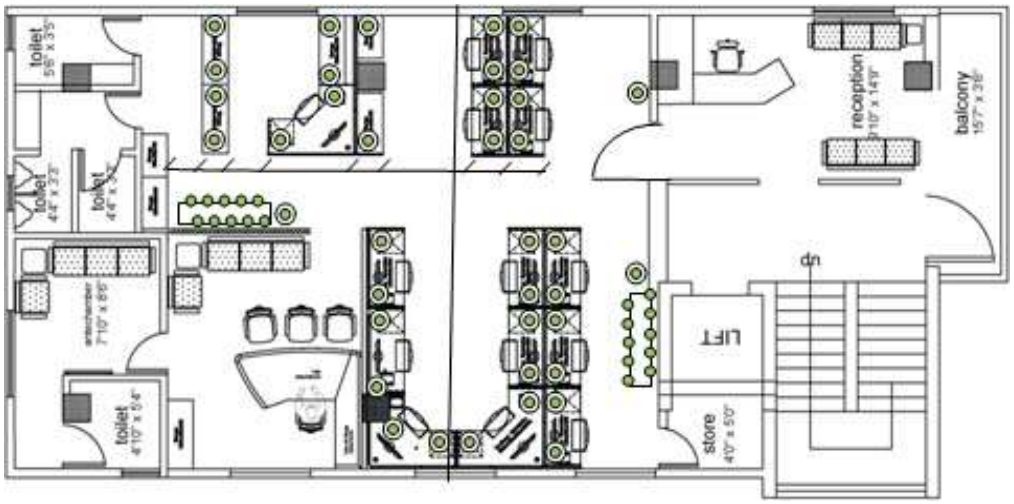

Fig. 1 Experimentation area marked on the typical floor plan of Enviro Ltd, Nagpur

Processes

The areas of the office were mapped cautiously such as areas of high temperature zone, noisy spaces and computer printers and plotters are located. Identification of critical area for experimentation includes spaces with computer operation, printing, heat generated due to computer operation, printers and electronic gadgets.

In order to reduce the temperature thereby increasing the humidity and getting the aerial pollution within the comfort zone the planters were arranged. The planters filled half way with activated charcoal and remaining half with micro-nutrients and compost. So as to facilitate the absorption of VOC's not only by plants but also by the activated charcoal and the compost.

<table>
<tr>
<td> 
Zamioculcas zamiifolia</td>
<td> 
Dracaena marginata</td>
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<tr>
<td> 
Epipremnum AureumGolden Pathos</td>
<td> 
Epipremnum aureum (marble queen) variegated</td>
</tr>
</table>

Epipremnum aureum

Fig. 2 Plant suitability for experimentation in Enviro Ltd., Nagpur

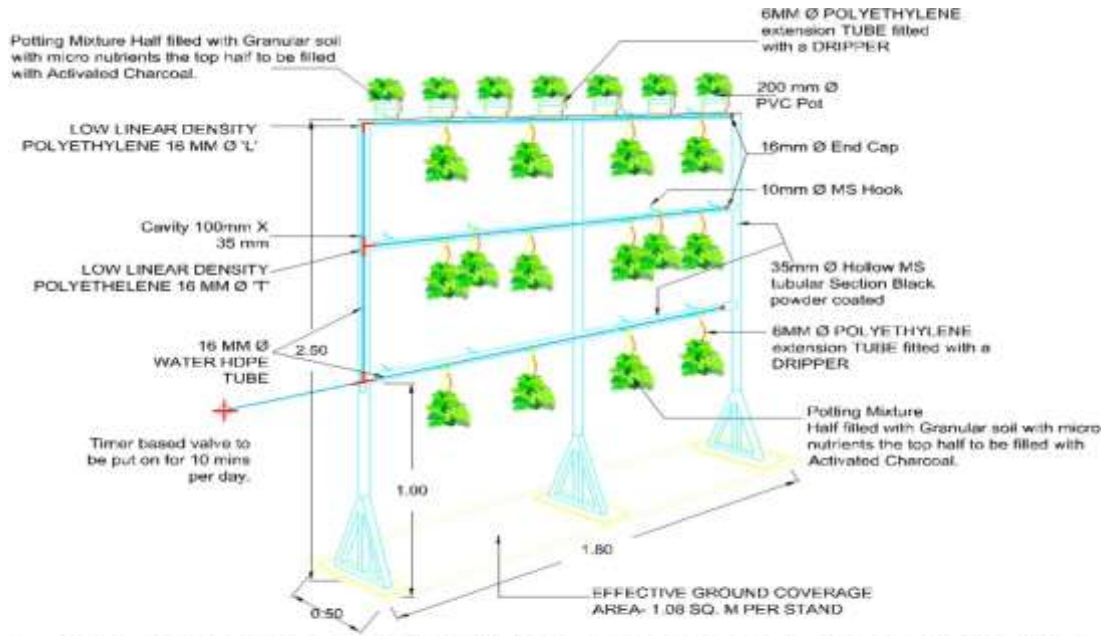
- Placement of planter needs to be located at the breathing level of mankind either at sitting position (1.10m) or at standing position (1.40m).
- Planting arrangement design and placement of vertical stands need to be worked out so as to assure lighting levels can be maintained in the indoor environment.
- Proper maintains and irrigation of hanging baskets is secured as observed in the figure 4

Micro-climate factors measuring equipment

Equipment Used for the Experiment

- Volatile organic compound (VOC) meter: It provides
- Indoor temperature in Degree Celsius,
- Relative humidity in percentage- VOC count in ppm.
-

Fig.3 Mounting of measuring equipment



- In the experimental area of(14.70 X 7.01) **103.05 sq. m** the effective area under 10 nos. plantation stands is equal to 1.08 x 10 sq. m= **10.8 sq. m**
- The area of vertical plantation stands would be in 1: 10 ratio with the experimental area.

Fig. 4 Isometric view of M.S. fabricated stand with inlay of drip irrigation system along with placement of hanging baskets of shortlisted plants.

The experiments were conducted under the artificial source of light12 lumen.

Histogram was used for calculating effective temperature (ET) to find out whether the value of ET lies closer to the comfort zone. The chart given above provides values of dry bulb measurements of 31.2° C and Wet bulb temperature is 27.4° C on 10th day of May, 2016. These observations intersect air velocity curve for the value of 1 m/sec and the resultant intersection is referred to as effective temperature (ET) at the level of 28.10° C.

The comfort zone indicates temperature in range of 22°C–26°C and the readings available are 27.3°C. This suggests that the indoor temperature of the industrial unit at 11.30 AM was higher by 3.5°C. The entire micro-climatic data at the time of experimentation was tabulated at every three hours per day and analysed as per the meteorological data.

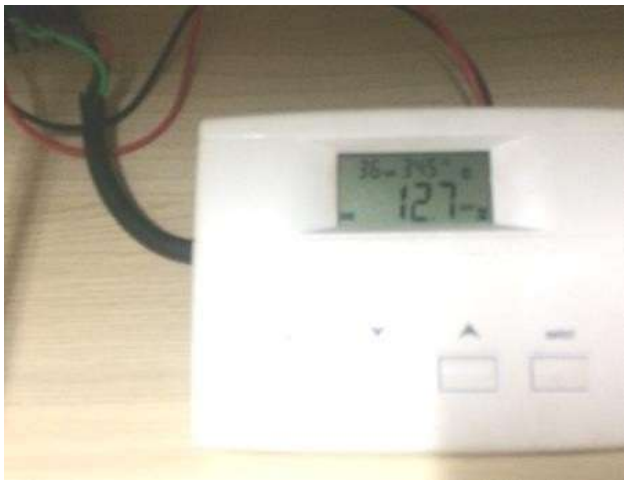


Fig.5 Volatile Organic Compound (VOC) meter

Fig 6. Zamioculcas zamiifolia plants arranged in the cubical

Fig. 8 Golden pathos plant baskets in three rows on M.S. Stand

Fig. 9 Table top plants are used in office interior

Table 1. Experimentation Inside ENVIRO LTD., Nagpur 1St and 10th Day of May 2016

	Data from MET. Dept. Nagpur		**Data from MET. Dept. Nagpur**		**Indoor- Dry Bulb Thermometer**		**V O C METER (READINGS WITHIN THE EXPERIMENTATIONZONE)**					
Time	Outdoor Temperature 0_C		Humidity %		Indoor Temperature 0_C		Temperature 0_C		Humidity %		OC count(PPM)	
	Day1	Day 10	Day1	Day10	Day1	Day10	Day1	Day10	Day1	Day10	Day1	Day10
08:30 am	16.6	17	57%	56%	28.6	28	27.9	27.4	42%	45%	4.9	3.5
11.30 am	26.5	27.9	37%	36%	28.1	27	27.8	27.8	43%	46%	5.7	2.1
2:30 pm	31.2	30.2	28%	32%	24.9	27.8	23.7	23.7	48%	46%	6.0	3.9
5:30 pm	19.6	21.2	58%	62%	24.4	27.3	23.3	24.7	43%	41%	5.8	3.2
8:30 pm	16.2	17.8	73%	67%	28.2	27.1	27.9	26.9	44%	49%	4.9	2.1

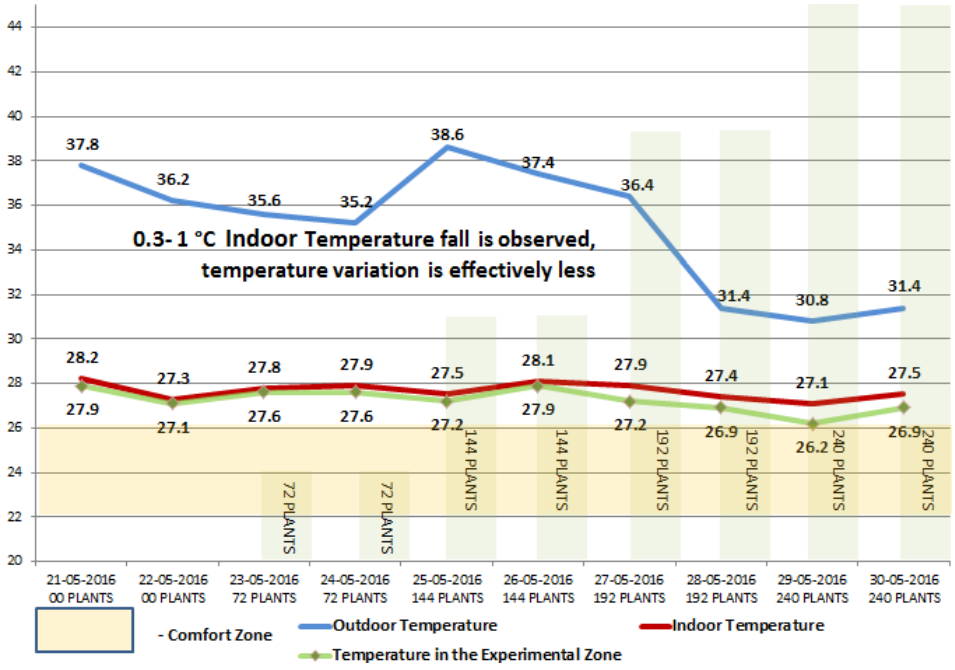


Fig. 10 Temperature graph during May (summer) 2016

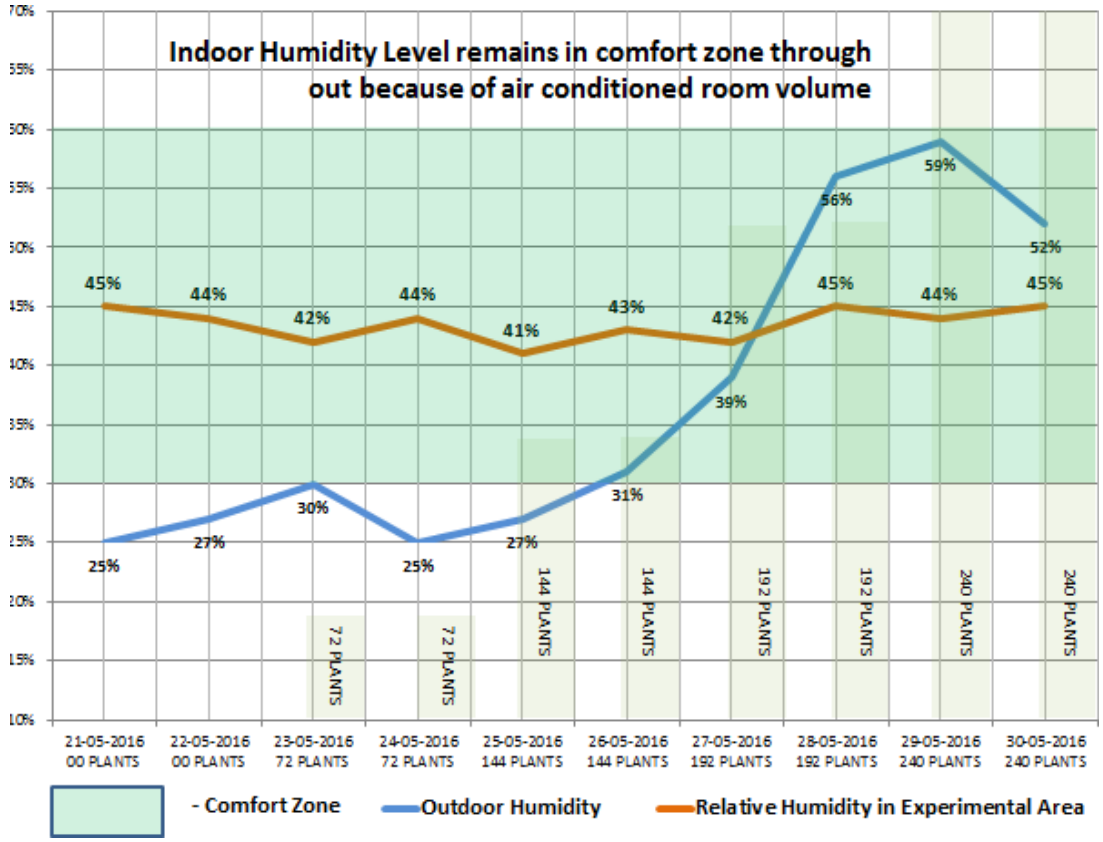


Fig. 11 Humidity graph during May at 08:30 PM. (summer) 2016 at 08:30 PM

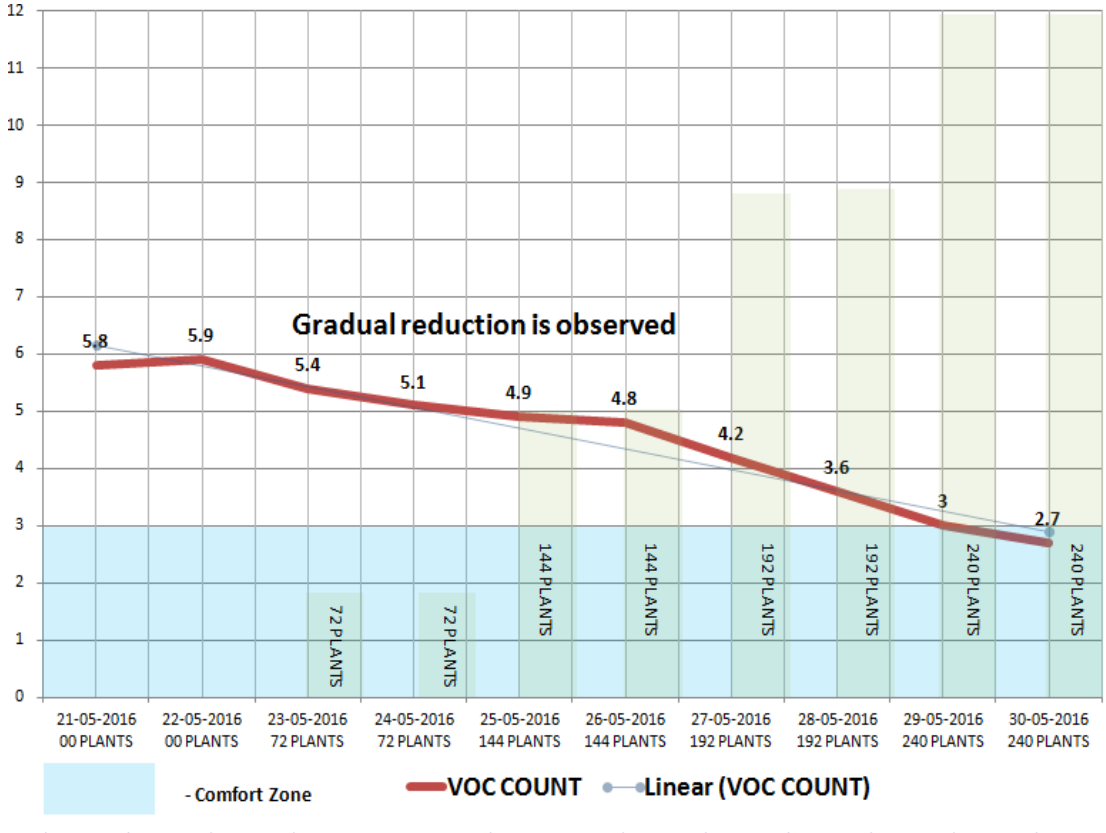


Fig.12 VOC graph during May (summer) 2016 at 08:30 PM.

Table 2. Experimentation Inside ENVIRO LTD., Nagpur 1St and 10th Day of July 2016

	Data from MET. Dept. Nagpur		**Data from MET. Dept. Nagpur**		**Indoor- Dry Bulb Thermometer**		**V O C METER (READINGS WITHIN THE EXPERIMENTATIONZONE)**					
Time	Outdoor Temperature ^0C		Humidity %		Indoor Temperature ^0C		Temperature ^0C		Humidity %		VOC count (PPM)	
	Day 1	Day 10	Day1	Day10	Day1	Day10	Day1	Day10	Day1	Day10	Day1	Day10
08:30 am	27.9	28.7	97%	97%	27.2	26.2	26.9	25.9	54%	55%	5.3	2.5
11.30 am	30.0	30.8	98%	97%	27.1	27.1	27	27	57%	54%	6.1	2.4
2:30 pm	31	28	98%	98%	29.3	28.8	28.1	25.9	61%	58%	3.9	4.1
5:30 pm	29.5	26.5	78%	73%	28.8	28.3	27.7	25.7	59%	56%	3.6	3.6
8:30 pm	26	26.3	96%	89%	27.8	27.1	27.5	26.9	54%	53%	5.4	2.1

From the table, it could be inferred that inside the building in Experimental area of ENVIRO Ltd. on 10thday of July, 2016:

Temperature at 11:30 am

The outdoor temperature 30.8°C is less than the indoor temperature that is 27.1°C.

The indoor temperature in experimental zone as per VOC meter is 27.0°C and the indoor temperature is 27.1°C.

The temperature in experimental zone is increased by 0.1°C.

From the graph, we could infer that in the month of May, the temperature is increased by 0.1°C and brings it closer to comfort zone.

Humidity at 11:30 am

The outdoor humidity on first day is 98% and on the 10th day, it is 97%. In experimentation zone on first day is 57% and on the 10th day it is 54%.It can be inferred that the humidity level decreases by 3%

The decreased 3% humidity level brings it closer to the comfort zone.

VOC (Volatile Organic Compound) at 08:30 pm

The VOC is reduced from 6.1ppm to 2.4 ppm in 10 days. By putting 250 numbers of potted plants/hanging basket.

AIR CONDITIONED ROOM

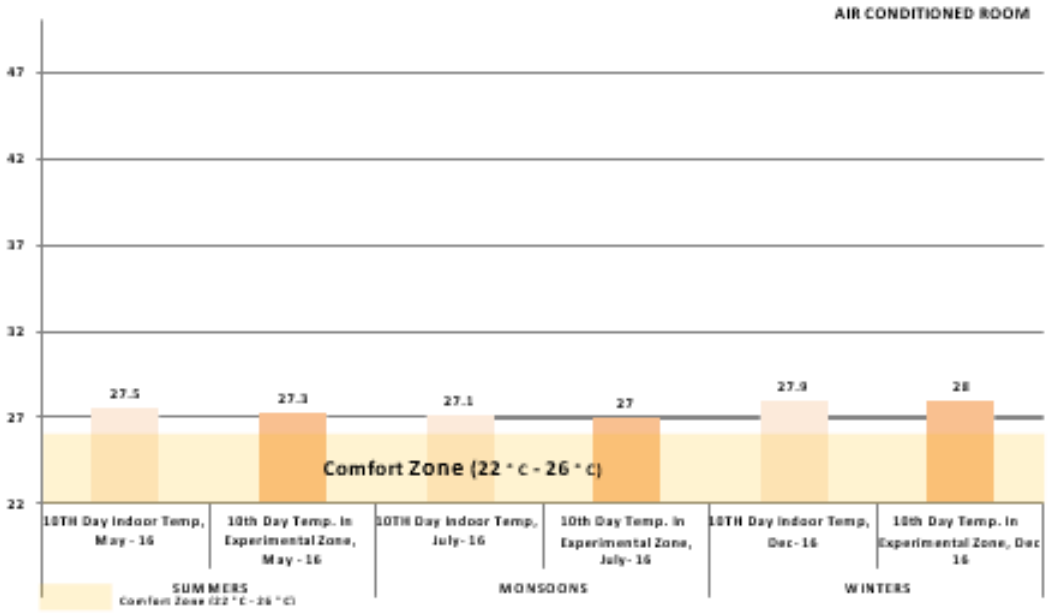


Fig. 13 Comparative Analysis of temperature at Enviro Limited, Nagpur

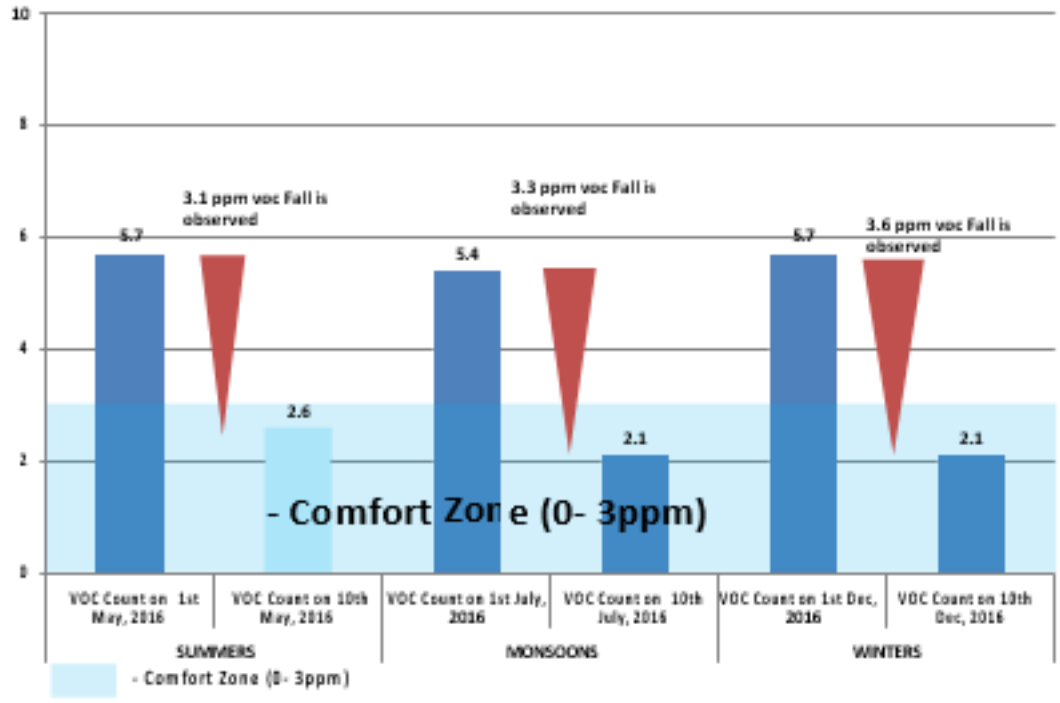


Fig. 14 Comparative Analysis of VOC at Enviro Limited, Nagpur

Inferences

The experiments carried out within the industrial interiors of Enviro Ltd, Khamla, Nagpur, in the month of May -2016, it is noticed that indoor temperature reduced with the vegetation density of 240 hanging

baskets, the effective temperature falls closer to comfort zone (22° C - 27° C) by 0.1°**C.**

- May -2016 temperature variation shows reduction from 27.9 ° C to 27.8 ° C that is 0.1°C at noon.
- July -2016 temperature variation shows reduction from 30.8° C to 27.1° C that is 3.7°C at noon.

From the above it can be inferred that the effective temperature falls closer to comfort zone that is 0.1°C in May, 3.7°C in July.

Relative Humidity with placement of 240 number of hanging baskets with vegetation at noon.

-May -2016 humidity variations recorded is 3% that is from 46% to 43%.

-July -2016 humidity variations recorded is 3% that is from 54% to 57%.

From the above it can be inferred that the relative humidity level falls closer to comfort zone (30-60) that is 3% in May, 3% in July

The Volatile Organic Compound (VOC) an inherent component of the indoor air within the industrial envelope.

- May -2016 VOC level falls from 4.9 ppm to 2.1 ppm that is 2.8 ppm at noon.
- July -2016 VOC level falls from 5.4 ppm to 2.1 ppm that is 3.3 ppm at noon.

From the above it can be inferred that the VOC levels fall closer to comfort zone that is 2.8 ppm in May, 3.3 ppm in July.

Recommended Strategies to control and improve micro-climatic conditions, inside Industrial units, withthe help of green elements are as follows:

- Identification and adoption of the appropriate plants for different environments and pollutants is crucialfor optimum result.
- The usage of plants of various species would help increase the comfort levels within the industrial unitand the landscape structure can be designed with customization.
- Looking into the encouraging results of the field experimentation, the concept is worth the recommendation for universal application.
- Research processes are seen to be applicable in industrial units where the hazardous VOCs are prevailing.

Conclusions

- Innovative landscape interventions similar to this can be adopted in all work environments to enhancemicro-climatic comfort levels resulting into the operational efficiency.
- Through experiments are conducted in tropical compost climate of several industries the final recommendation can also be implemented in other industries of similar nature in other type of climate region with alternative species of plant species keeping in mind special feature of climate.
- From the questionnaire survey conducted in this unit to a great extent establishes that the workers working in this type of indoor environment suffer from Sick Building Syndrome (SBS) which affect their health resulting from causes such as drowsiness, irritations, fatigue, nausea, loss of concentration andappetite etc. Beside this survey also established that persons working within indoor spaces prefer an interaction (may be visual only) with natural elements such as vegetation.

Acknowledgements

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