Potential of Improving Air Quality and Thermal Comfort Via Green Boundary Walls

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Abstract: *World is facing many problem due to increasing atmospheric temperature and air pollution. Excess of waste, heat release, lack of vegetation, high thermal capacity material in urban areas are several reasons for global warming.*
The green spaces are a sustainable solution for this problem. Out of all green spaces green wall is a better option considering the space limitations in urban areas.
Green walls are of two types as green facades and living walls. In this research the living type wall is experimented for its capacity to improve thermal comfort and air quality. Also the varying abilities of different plant species in heat control and air quality control is studied. By this research most effective plants for a detached green wall and effective distance of the wall are identified

Keywords: *thermal comfort, air quality, green boundary wall, microclimate*

1. INTRODUCTION

Industrialization and Urbanization has led to the increase of atmospheric temperature and air pollutants in the atmosphere. The severity of this condition is increasing day by day.
Due to local effects like urban growth, irrigation, desertification, and variations in local land use, the global mean surface air temperature has risen about 0.5°C during the 20th century. Analysis has shown that this rise has resulted, in the daily minimum temperature to increase at a faster rate or decrease at a slower rate than the daily maximum. (Easterling et al, 1997)
According to a survey "Air Quality and Thermal Comfort in Office Buildings" conducted by the center for built environment in University of California, only 11% of the surveyed buildings are under proper thermal comfort zones while only 26% are under proper air quality. Those results show that the indoor environmental conditions in urban areas are not satisfactory even in developed countries. (Huizenga et al, 2006)
To maintain thermal comfort in indoors various measures are taken. As a result of air conditioning directly and indirectly the outdoor temperature and air pollutants increase. Urban climate can have severe impacts on people who use outdoor spaces, thus the thermal comfort and air quality of outdoor environment is very important. Worldwide attention is currently drawn towards sustainable urban planning. (Krüger et al, 2011)

2. LITERATURE REVIEW

2.1. Thermal Comfort

Thermal comfort can be defined as "that condition of mind which expresses satisfaction with the thermal environment". There are both environmental factors and personal factors that affect this condition of mind. (Kunkel et al, 2015)

2.1.1 Environmental factors

The four environmental factors are air temperature, Radiant Temperature, Air velocity and Humidity.
Air temperature-The degree Celsius (°C) value of temperature of the air surrounding a body is known as air temperature.
Radiant temperature - The heat that radiates from a heat source is called as Thermal radiation. Radiant temperature has a greater influence on how heat is lost or gained to the environment.
Air velocity-It is the measure of speed of air moving across a certain point. Still or stagnant air will build up heat and odour .But moving air reduce heat through convection.
Humidity-Humidity is the amount of moisture in the air (Oxford Dictionary). Relative humidity is given by the ratio between the actual amount of water vapour in the atmosphere and the maximum amount of water vapour that it can hold at a particular air temperature. Humidity affects the evaporation of sweat which is the main method of heat reduction. (Thermal comfort: The six basic factors, 2015)

2.1.2 Personal factors

Two personal factors affect thermal comfort. **Clothing insulation-** Clothing is both a potential cause of thermal discomfort as well as a control for it depending on the working environment.
Work rate/metabolic heat- The impact of metabolic rate on thermal comfort is critical. Factors such as their size and weight, age, fitness level and sex have an impact on a person's physical characteristics. (Thermal comfort: The six basic factors, 2015)

2.2. Air Quality

Air quality irrespective of whether indoors or outdoors is one of the major environmental health concerns. Since people spend 60--90 % of their life in indoor environment, indoor air quality has a direct influence on people. Vulnerable groups like babies, children and elderly people are major victims of health issues due to poor air quality. According to the World Health Organization, in 2012, 99,000 deaths in Europe and 19,000 in non-European high income countries were attributable to household (indoor) air pollution (Kunkel et al, 2015).
Parameters such as, carbon dioxide (CO_2), sulphur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), respirable particulate matter (PM10), formaldehyde (HCHO) and bacteria are major air pollutants.(Lee and Chang, 2000)

2.3. Green Walls

Green walls are the vertical structures covered with vegetation. Even in the historical times there has been natural plant growth over walls and buildings. In the present times, modern technology and techniques are developed to improve and control the growth of different types of plants to obtain a more intentional and controlled vegetation covering on walls (UK green wall association, 2014).
Green walls not only improve aesthetic aspects but also perform sustainable strategies of urban rehabilitation and building retrofitting.

2.3.1. Classification of green walls based on construction characteristics

According to Manso et al (2015) green walls are of two types as green facades and living walls. Green facades are sub divided as direct and indirect where traditional facades are of direct type and facades grown in continuous guides and modular trellis are called indirect type. Lightweight screens are in the category of continuous living walls and trays, vessels, planter tiles and flexible bags are modular living walls.

2.3.2. Classification of green walls based on plant type

As defined in Team and Technology (2016) there are four green wall categories based on plant types. Vines that have the ability to climb by its own are called **Extensive** green walls. It has low installation and maintenance cost. **Semi-intensive** type green walls have cable or wire meshes to support the plants to climb. **Intensive** green walls consist of a planter cell style. They typically compose of plastic grid like components or large sheets of felt like material with pockets for soil. **Free standing** green walls are independent of an architectural structure. Hedges and shrubs used as screens for privacy come under this category.

2.4. Research Aim

Many studies and investigations show that it requires a sustainable solution for the problem of thermal discomfort and air pollution. Green walls have been identified as a successful solution.
There are two aims in this research. They are, to identify the potential ability of a detached green boundary wall to increase **thermal comfort** and to identify the potential ability of a detached green boundary wall to increase **air quality**

3. METHODOLOGY

This research uses a series of experiments to quantitatively measure the thermal comfort and air quality parameters. In the experiment Temperature and Humidity variations were considered as representative parameters of thermal comfort and carbon dioxide for the representation of air quality.

3.1. Research Design

In this research a model of detached green wall system was prepared. It helped in identifying the impacts of different parameters quantitatively. The two critical variables Temperature, humidity impacting microclimate and plant life are chosen to study the impact of green walls on increasing thermal comfort. This research mainly focuses on improving thermal comfort over air quality.
Carbon dioxide levels were measured as an air quality measurement parameter.

3.2. Experiment Procedure

3.2.1. Pre-identification experiment to select plants

An initial experiment was conducted to identify better performing plants for the green wall. A sample of 30 plant types was selected considering their characteristics relevant to a detached green [illegible]. Relative temperature and relative humidity were obtained from a series of experiments. The [illegible] were ranked according to their performance and then the best performing varieties were selected for the prototype model preparation. Figure 1 shows the four types of plants selected for the experiment

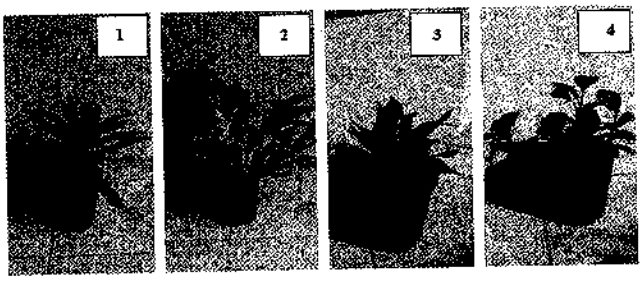

Figure 1 *Tradescathus spathacea*, 2-*Xiphidium caeruleum*, 3-*Sansevieria trifasciata*, 4-*Peperomia obtusifolia*

2.2.2 Experiment setup

A 1m x 1m size detached green wall model was used to conduct the final set of experiments. It was a rack arrangement where pots could be placed at an angled position. A boundary wall at an urban location was selected which is clear from vegetation and gain sunlight throughout the day. The selected wall was a block wall which was not painted or plastered. This structure was used to collect data.

2.3. Instruments

There were three parameters considered in the experiment. To measure temperature a digital thermometer was used. Humidity measurement was taken using digital thermometer hygrometer (model-VICTOR VC 330).The CO_2 meter (model-TIM-10) was used to measure carbon dioxide.

2.4. Data Collection and Analysis

2.4.1 Data Collection

The final experiment was conducted for the four selected plant species. Temperature, Humidity and carbon dioxide data were collected during the experiment. The green wall microclimate was set with a control wall where readings were taken up to five meters either sides of the wall for both green wall and control wall. The readings are taken at distance gaps of 1m. Also within 30 minute intervals readings were taken throughout the day (10.00a.m. to 3.00p.m.). The data points are clearly shown in Figure 2.

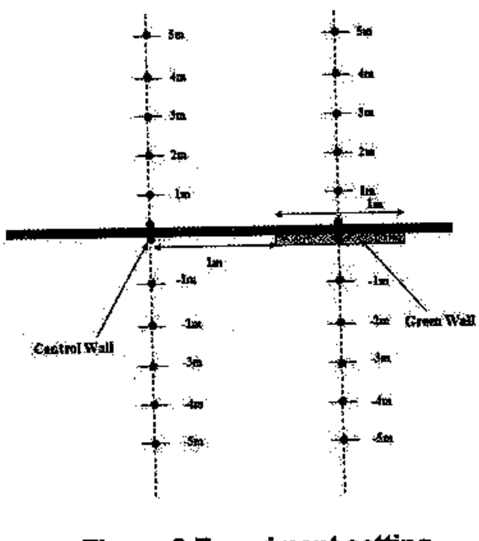

Figure 2 Experiment setting

3.4.2. Data Analysis

Graphs are drawn for each parameter with respect to time and distance. Data were a
considering two approaches

(i) Comparison of data between green wall surface and control wall surface
(ii) Data variation perpendicular to green wall

4. RESULTS AND DISCUSSION

4.1. Variation of Comfort Parameters between Green Wall Surface and Control Wall Surface

4.1.1. Temperature variation

All plants 2, 3, 4 shows gradual linear increase in temperature. The green wall has always l
temperature than control wall throughout the day. Plant number 1 doesn't show a gradual variatio
after 12.30p.m it shows higher temperature reduction ability. The graphs of temperature variation
with time of the day for green walls with different species are shown in Figure 3

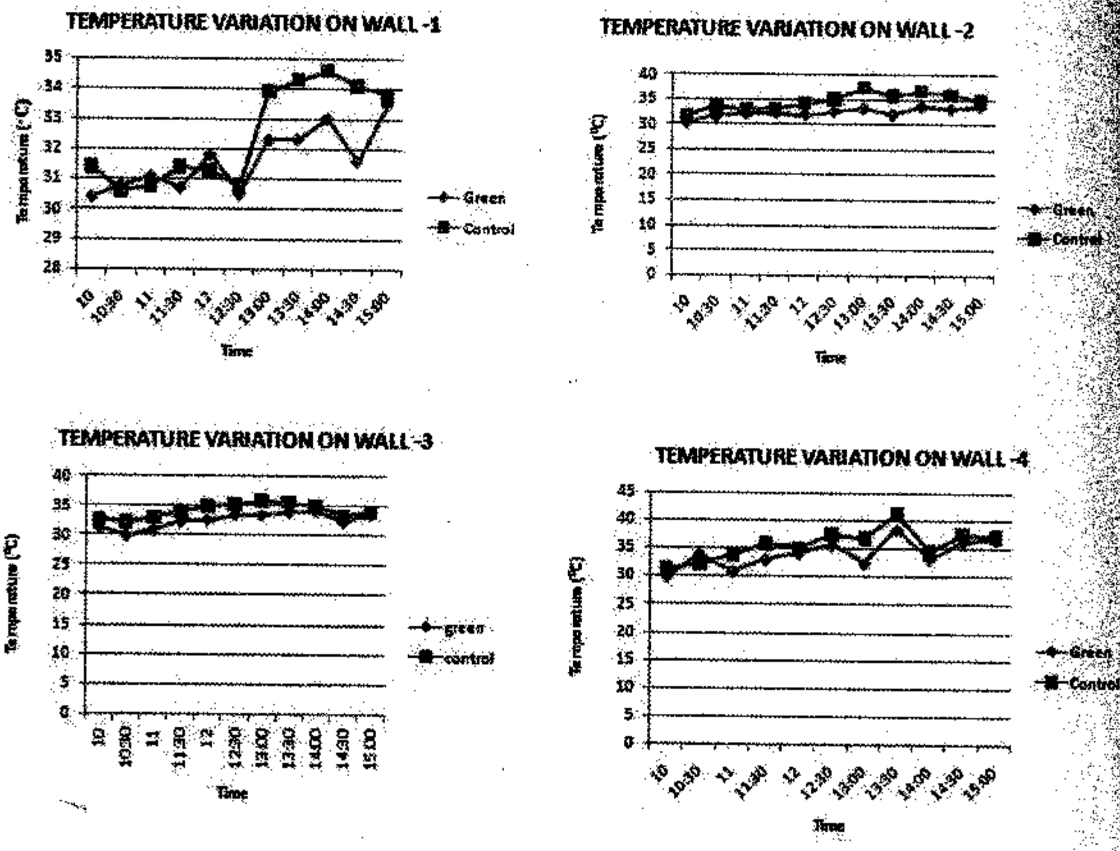

Figure 3 Variation of Temperature over with time of the day for green walls with different species 1-*Tradescathus spathacea*, 2-*Xiphidium caeruleum*, 3-*Sansevieria trifasciata*, 4-*Peperomia obtusifolia*

4.1.2. Humidity variation

When comparing the humidity variation of plants between green wall and control wall it shows a minute variation between them. But still the green wall shows a higher relative humidity than control wall. Throughout the day, humidity shows a gradual decrease. Figure 4 shows the humidity variation with time in the four types of plants.

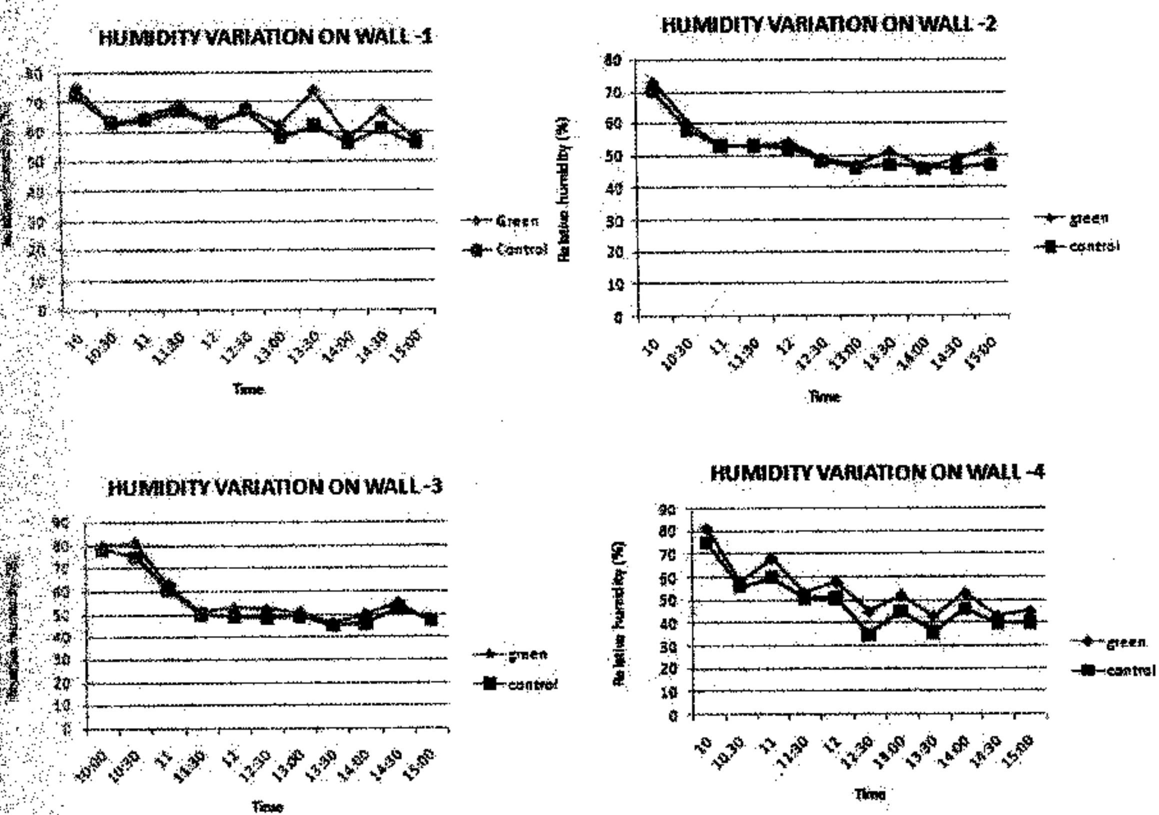

Figure 4 Variation of Humidity over with time of the day for green walls with different species 1-*Tradescathus spathacea*, 2-*Xiphidium caeruleum*, 3-*Sansevieria trifasciata*, 4-*Peperomia obtusifolia*

4.1.3. Carbon dioxide variation

As shown in Figure 5, the carbon dioxide shows a scattered variation. Therefore a proper affect of green wall on Carbon dioxide level cannot be identified.

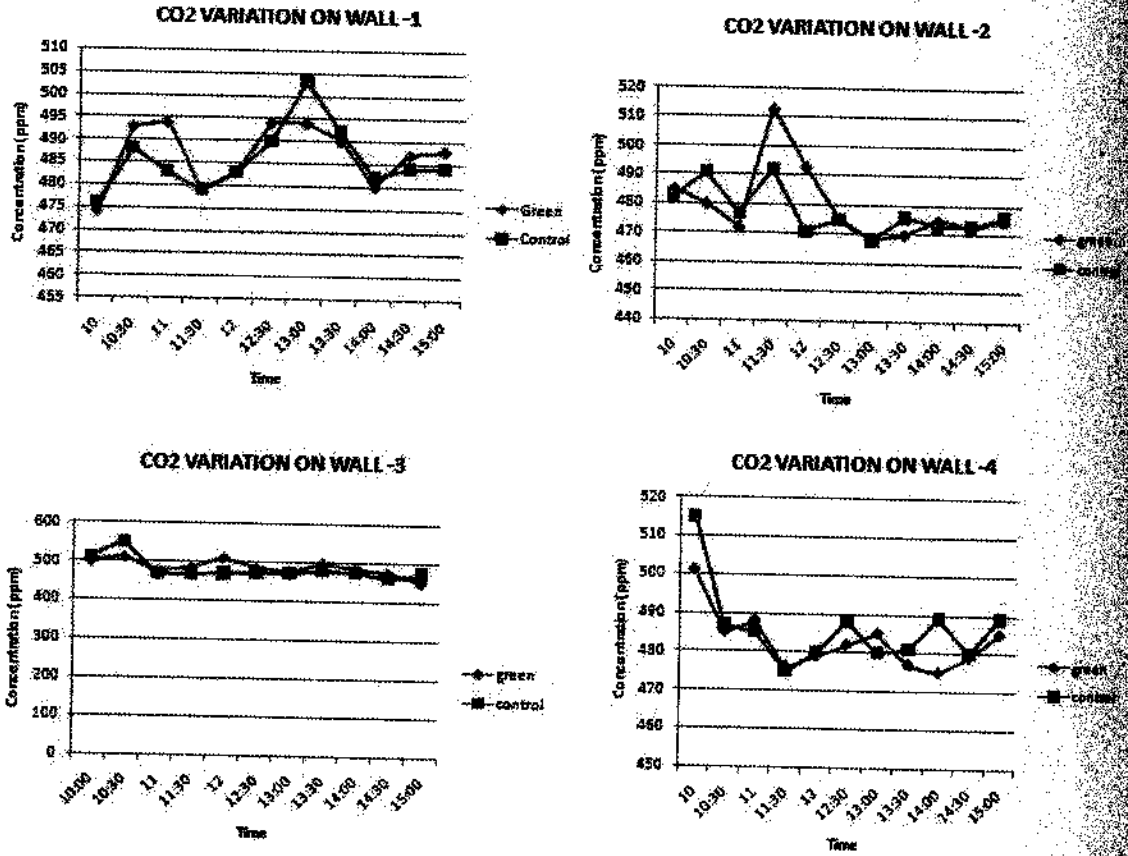

Figure 5 Variation of Carbon dioxide over with time of the day for green walls with different species 1-*Tradescathus spathacea*, 2-*Xiphidium caeruleum*, 3-*Sansevieria trifasciata*, 4-*Peperomia obtusifolia*

4.2. Temperature Variation Perpendicular to Green Wall

The temperature is lesser in green wall than control wall during the peak time. But the difference reduces with the increasing distance from the wall.

Humidity of green wall gives a higher value than control wall but the variation is lesser.

The Carbon dioxide variation does not show a proper pattern. The wall is located in an urban area, so the vehicular emissions cause oscillating Carbon dioxide levels.

5. CONCLUSIONS

This research was conducted to understand the potential of four species used in detached green boundary walls can improve the thermal comfort of urban residential settings. The main findings were, Plant ***Sansevieria trifasciata*** shows the best temperature performance and the detached green wall has shown a reduction potential of up to Temperature up to **2.3°C.**

Plant ***Peperomia obtusifolia*** shows the best humidity performance and the detached boundary wall can increase humidity by **5.8%.**

None of the plants showed an evidence of Carbon dioxide reduction potential.

The effect of green wall is felt even beyond 5m.

6. ACKNOWLEDGMENTS

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