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# Green Walls and Vertical Gardens: Ecological Innovation for the Urban Future

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**A B S T R A C T**

Urbanization has significantly contributed to the depletion of green spaces, adversely impacting environmental quality, urban biodiversity, and aesthetic value. As cities continue to expand—particularly in vertical dimensions—integrating sustainable greening solutions has become increasingly vital. Vertical gardens are the tools that can be employed to enhance the quality of air, solve the heat problems in urban areas and at the same time improve aesthetics of our places. This study investigates the implementation, and performance of vertical garden systems within the institutional framework with a particular focus on their environmental, structural purpose, and aesthetic benefits. The study underscores the potential of vertical gardens to transform underutilized vertical surfaces into functional green infrastructure, aligning with sustainable urban development goals. It advocates for the broader integration of vertical gardening into academic establishments and engineering frameworks as a multifaceted solution to contemporary environmental and spatial challenges.

**Keywords: Vertical Garden, energy saving, sustainable development, Air Pollution, Eco-Friendly Architecture, biodiversity, hydroponics**

## 1. LITERATURE REVIEW

The trial revealed that the addition of organic growing media factors and hydrogels significantly enhanced colorful growth parameters, including days to establishment, factory height, number of shoots or branches, shoot circumference, number of leaves, and splint area. Overall, the objectification of hydrogels similar as Stockosorb and Geohumus proved to be more effective than coir pith as a media element. Among the organic complements, vermicompost demonstrated superior performance across all measured growth parameters in the cosmetic shops studied. Especially, treatment T9(Red soil Swash beach Vermicompost (111/2) Stockosorb(25g)) showed the most pronounced positive effect on factory growth, performing in briskly establishment and overall better development. This was nearly followed by treatment T10(Red soil Swash beach Vermicompost (111/2) Geohumus(25g)). The observed enhancement in growth can be attributed to the concerted effect of vermicompost and hydrogels particularly Stockosorb and Geohumus — alongside the standard media factors of red soil and swash beach. (Rameshkumar et al. 2018)

The optimal pH and electrical conductivity (EC) values for the growth of lettuce shops, which were set up to be in the ranges of 6.0 to 6.8 for pH and 1.02 to 1.18 mS/ cm for EC. A trial was conducted to estimate and compare the growth performance of lettuce cultivated in a designed perpendicular theater system versus a conventional marketable hydroponic system. Results showed that the loftiest average factory height was achieved in the conventional hydroponic system, measuring 9.01 cm, compared to 8.45 cm in the perpendicular theater system. also, splint range was slightly lesser in the conventional hydroponic setup (2.84 cm) than in the perpendicular theater system (2.70 cm). still, the perpendicular theater system produced a advanced number of leaves per factory compared to the conventional hydroponic system. ( Hamidona et al. 22019) The perceptions and concerns of citizen regarding vertical gardens, while also emphasizing the significance of design considerations from an architectural perspective. Through comprehensive theoretical and practical analysis, the study developed a checklist of design considerations for vertical gardens, presented in two distinct stages. The first stage involved a theoretical review, covering various types of vertical gardens, their benefits, and a survey of international case studies and applications. The second stage focused on empirical analysis, utilizing frequency distribution, descriptive statistics, and component analysis to evaluate and validate the proposed design considerations for vertical gardens. (Momtaz 2018). Vertical gardening has gained recognition for its environmental benefits, including reducing civic heat islets, perfecting air quality, and enhancing biodiversity. Factory species selection is pivotal for sustainability, with factors like climate, conservation, and aesthetics guiding the choice. In extreme climates, similar as Volgograd, flexible shops are essential for opposing temperature oscillations and pollution. former studies also emphasize the integration of green walls with civic structure to support both ecological and social sustainability. While perpendicular gardening exploration in Volgograd is limited, this study seeks to develop a geography-ecological model acclimatized to the megacity's requirements, fastening on factory selection and civic impact. The generality of architectural planting or sustainable architecture as the style of structures constructed in agreement with the principles of environmental protection. Scientists note that architectural planting seeks to minimize the number of resources consumed during the construction and operation of a structure. Living wall ways can come as a part of a sustainable municipality strategy, and green vertical shells bring significant environmental, social and profitable benefits to communal areas. The issues related to the operation of energy- saving technologies and styles for perfecting the energy effectiveness of structures attract attention when using terrain results, which can reduce energy costs. Vertical gardening is considered also as a unresistant tool for energy saving of a structure. Various aspects of vertical gardens have been focused including their design, implementation, environmental impact, and socio-economic benefits. Researchers have examined different types of vertical garden systems, such as modular panels, green facades, and hydroponic structures, highlighting their suitability for diverse climates and urban settings. Several studies emphasize the ecological advantages of vertical gardens, such as improving air quality, reducing urban heat island effects, enhancing biodiversity, and contributing to energy efficiency in buildings. However, the literature also points to potential challenges, including high installation and maintenance costs, structural limitations, and water management issues. This review of existing research provides a foundational understanding of the topic and helps to contextualize the current analysis of the advantages and risks associated with vertical gardens. (Erdi EKREN et al. 2017).

## 2. Introduction

The modern office is no longer just a place to work—it's a space where design, health, and sustainability intersect. As concerns over indoor air pollution and employee well-being rise, organizations are increasingly looking for solutions that go beyond traditional mechanical systems. One such solution gaining momentum is the installation of vertical gardens—living green walls that bring nature indoors.

Vertical gardens provide more than just visual appeal. They serve as natural air purifiers, space-saving design elements, and even structural barriers that can define areas within open-plan offices. For organizations operating in space-constrained or highly urbanized environments, they offer a way to introduce greenery without sacrificing square footage. Moreover, these systems require minimal energy input, making them a more economically and environmentally sustainable alternative to electric air purifiers.

This paper presents a strong case for why vertical gardens should be adopted in office settings, especially in India where concerns over air quality and space utilization are particularly pressing. Through a combination of literature review, benefit analysis, and a real-world case study of a vertical garden installed in a government office, the paper underscores how these green installations can transform office interiors—not just in form, but in function and impact.

## 3. Why Indoor Air Quality and Office Aesthetics Matters?

In office environments, poor indoor air quality often goes unnoticed, but its effects are far-reaching. Common indoor pollutants—such as volatile organic compounds (VOCs), dust, carbon dioxide buildup, and microbes—can contribute to headaches, respiratory issues, fatigue, and even reduced decision-making performance. This is particularly concerning in urban Indian offices, where external pollution adds to the indoor burden and buildings often lack adequate natural ventilation.

At the same time, the physical appearance and ambiance of a workplace have a direct impact on employee morale, satisfaction, and productivity. Sterile, enclosed spaces can feel impersonal and draining, while workspaces that incorporate natural elements promote mental clarity and reduce stress. This understanding has given rise to **biophilic design**, which integrates nature into the built environment, leading to increased employee engagement and well-being.

While air purifiers may filter out pollutants, they do little to enhance the look and feel of a workspace. This is where vertical gardens emerge as a more holistic solution—improving not just what's in the air, but also how the environment feels to those within it.

## 4. Benefits of Vertical Gardens in Offices

Vertical gardens—also called living walls—are structured panels of plants grown vertically using hydroponics or soil-based systems, often supported on frames. Their benefits go far beyond aesthetics or novelty.

### *4.1 Space-Efficient and Multi-Functional*

One of the most compelling reasons to install a vertical garden in an office is its efficient use of space. Instead of occupying floor space, greenery is mounted on walls or vertical partitions. This allows even compact or high-density office layouts to enjoy the benefits of plants without sacrificing usable workspace.

Vertical gardens can also double as structural barriers, offering visual privacy or separating departments without the need for bulky drywall or cubicle walls. This flexible functionality makes them ideal for modern, open-plan offices.

### *4.2 Natural Air Filtration*

Plants naturally filter the air by absorbing pollutants through their leaves and roots. Studies, including NASA's Clean Air Study, have shown that indoor plants can remove toxins like formaldehyde, benzene, and carbon monoxide. A well-planned vertical garden can significantly enhance perceived air freshness, reduce $CO_2$ levels, and maintain a healthier micro-environment.

### *4.3 Aesthetic Appeal and Psychological Impact*

Greenery brings life into dull, static environments. Employees working around plants report lower stress levels, improved focus, and greater job satisfaction. Vertical gardens become visual landmarks within offices, softening harsh interiors and adding an organic texture that's both calming and stimulating.

### *4.4 Cost-Effective and Low Energy Consumption*

Unlike air purifiers that require electricity and frequent maintenance (e.g., filter replacements), vertical gardens are low-energy systems. Once set up with proper irrigation and lighting (if needed), they incur minimal running costs. Over time, they prove more economical than operating multiple air purifiers, especially for larger spaces.

### *4.5 Environmental and Branding Advantages*

Installing a vertical garden supports sustainability goals by reducing reliance on electrical devices and supporting natural systems. Offices with green design elements often earn better LEED ratings and are seen as environmentally responsible, enhancing brand image and appeal to eco-conscious employees or clients.

## 5. PROCEDURE

### *5.1 Case Study: Vertical Garden at Government Polytechnic, Bhubaneswar*

To practically explore the benefits of vertical garden in the institution, a vertical green wall was installed in January 2025 at Government Polytechnic, Bhubaneswar, Odisha—an educational institution operating under the Government of Odisha. The garden was initially installed inside a classroom to improve indoor air quality, aesthetics, and to evaluate its multifunctional use in academic spaces.

### *5.2 Installation Details*

The vertical garden measures approximately 3 feet by 7 feet, comprising 84 colourful pots neatly arranged on a metal mesh frame. The unit was designed to be mobile and visually appealing while fitting into limited floor space. The vertical frame was placed strategically near the entrance corridor, enhancing visibility and maximizing air circulation.

### *5.3 Plant Selection*

A thoughtfully curated mix of foliage plants, medicinal herbs, and leafy vegetables was chosen to ensure diversity in function and appearance. The selected species included:

| **Category** | **Plant Name** | **Scientific** |
|---|---|---|
| Foliage | Philodendron | Philodendron hederaceum |
| Medicinal | Ajwain (carom) | Trachyspermum ammi |
| Leafy Vegetable | Green Amaranthus | Amaranthus Viridis |
| Foliage | Rhoeo | Tradescantias pathacea |
| Foliage | Coleus | Coleus scutellarioides |
| Foliage | Syngonium | Syngonium podophyllum |

These plants were selected for their air-purifying properties, easy maintenance, and aesthetic variation in leaf shape and colour. Medicinal and edible species like Ajwain and Green Amaranthus also demonstrated how vertical gardens can be both **decorative and functional.**

### *5.4 Staff Feedback and Observations*

Following installation, staff members and students reported an immediate improvement in ambiance, citing a noticeable reduction in indoor heat and stale air. Many appreciated the vibrant color contrast offered by the pots and foliage. Some also mentioned that the installation provided a natural conversation starter and made the institutional atmosphere feel more lively and inviting.

The unit served as an effective semi-partition, subtly separating activity zones within the corridor space. Despite its visual prominence, it did not block movement or light—proving the value of vertical gardens as flexible design tools in constrained interiors.

### *5.5 Cost and Maintenance*

The overall setup cost, including the metal frame, 84 pots, soil mix, and plants, was estimated to be approximately ₹3,000–₹4,000 INR, excluding labor (which was managed in-house by faculty and students). The metal frame was made up of the metal scraps produced from the institution. Maintenance involves weekly watering and occasional trimming, which can be easily handled by staff or student volunteers. Compared to the recurring expenses of electricity and filter replacements in air purifiers, this garden offers a sustainable and budget-friendly alternative.


Visit to CHES, IIHR(ICAR), Aiginia, Bhubaneswar

Research about indoor plants suitable For Vertical Garden from Dr.P.Srinivas, Principal Scientist(Plant Pathology), CHES, IIHR(ICAR), Aiginia

## 6. Notable Locations Featuring Iconic Vertical Gardens:

The picture shows the largest Vertical Garden in the world at Singapore’s Institute of Technical Education College Central. It’s installed on eight blocks of the campus. The wall stands 35 meters tall (115 ft) and it covers 5,300 square meters (57,000 sq. ft).

Vertical Garden setup at Master Canteen Square by BMC(Govt. of Odisha)

## 7. Vertical Gardens vs. Traditional Air Purifiers: A Comparative View

When considering indoor air improvement solutions for offices or institutions, two common options emerge: vertical gardens and air purifiers. While both have their merits, vertical gardens offer several advantages that go beyond just cleaning the air.

| **Parameters** | **Vertical Garden** | **Air Purifier** |
|---|---|---|
| **Air Quality impact** | Filter pollutants, adds humidity and oxygen | Filters Particles and VOCs via mechanical filters |
| **Energy Use** | Passive (no electricity unless for lighting/irrigation) | Requires continuous power to operate |

| | | |
|---|---|---|
| **Aesthetic Value** | Visually enriching; adds color and life to interiors | Neutral or bulky in appearance |
| **Psychological Benefit** | Proven to reduce stress and fatigue | Limited to functional use |
| **Space usage** | Uses vertical surfaces; doubles as partitions | Occupies floor or table space |
| **Maintenance** | Weekly watering, pruning; minimal long-term cost | Filter replacement, Cleaning, electricity bills |
| **Cost Efficiency** | Low setup and negligible running cost | High upfront + recurring costs |
| **Environmental impact** | Eco-friendly, improves biodiversity indoors | Electronic waste over time |

## 8. Application of the vertical green wall

### *8.1. Air Pollutants in Workshops*

Installation of vertical garden in a polytechnic workshop is an innovative and eco-friendly step toward improving air quality and creating a healthier working environment. By utilizing wall space, a vertical garden can host a variety of air-purifying plants such as *Philodendron hederaceum*, *Syngonium podophyllum*, and *Tradescantias pathacea*, which help absorb harmful pollutants like VOCs, dust, and carbon dioxide commonly found in workshops. This green addition not only enhances the aesthetic appeal of the space but also reduces indoor pollution, noise levels, and temperature, promoting a more comfortable and sustainable atmosphere for students and staff.

In workshops, the types of air pollutants which are typically emitted includes:

1. Dust – Generated from cutting, grinding, and sanding operations.
2. Welding Fumes – Emitted during welding processes, which can contain metals such as iron, chromium, and manganese.
3. Volatile Organic Compounds (VOCs) – Released from solvents, paints, adhesives, and other chemicals used in the workshop.
4. Carbon Monoxide (CO) – A byproduct of combustion processes, often from machinery or welding.
5. Nitrogen Oxides (NOx) – Produced by high-temperature processes, including welding and combustion.
6. Sulphur Dioxide ($SO_2$) – Emitted from burning materials that contain sulphur or from chemical processes.
7. Particulate Matter (PM) – Fine particles released from materials during cutting, grinding, or sanding.

### *8.2. Role of the chosen plants in mitigating above problems*

Plants have the ability to absorb pollutants and improve air quality through several processes like absorption, filtration, and respiration. Here's the role of each listed plant in mitigating specific air pollutants:

#### *8.2.1. Philodendron hederaceum (Pothos)*

- Pollutants Removed: VOCs (especially formaldehyde), carbon dioxide, benzene, and xylene.
- Role in Mitigation: Known for its ability to absorb formaldehyde from the air. It helps to purify indoor air by removing various toxic chemicals. It can also contribute to reducing particulate matter and carbon dioxide levels.

#### *8.2.2. Trachyspermum ammi (Ajwain)*

- Pollutants Removed: VOCs, carbon monoxide, particulate matter.
- Role in Mitigation: While primarily used for its aromatic properties, it can also help reduce levels of VOCs and carbon monoxide in the air through its leaves. Additionally, it can contribute to better air circulation in a room, indirectly reducing particulate matter.

#### *8.2.3. Amaranthus viridis (Green Amaranth)*

- Pollutants Removed: Particulate matter, VOCs, carbon dioxide.
- Role in Mitigation: Amaranth is a fast-growing plant that can absorb various air pollutants, particularly particulate matter and VOCs. Its broad leaf structure can capture fine dust and particulate matter effectively.

#### *8.2.4. Tradescantias pathacea (Moses-in-the-Cradle)*

- Pollutants Removed: VOCs, particulate matter, formaldehyde, and carbon dioxide.
- Role in Mitigation: This plant has been shown to help reduce indoor VOCs and particulate matter, making it beneficial for mitigating pollutants like formaldehyde. It also helps absorb excess $CO_2$ in the air and release oxygen.

#### *8.2.5. Coleus scutellarioides (Coleus)*

- Pollutants Removed: VOCs, carbon dioxide, formaldehyde.
- Role in Mitigation: Coleus plants are particularly good at absorbing formaldehyde and reducing VOC concentrations. They also help with the general purification of indoor air by absorbing carbon dioxide and releasing oxygen.

#### *8.2.6. Syngonium podophyllum (Arrowhead Plant)*

- Pollutants Removed: VOCs (especially formaldehyde), carbon dioxide, benzene.
- Role in Mitigation: Known for its air-purifying abilities, the Arrowhead plant is highly effective at removing formaldehyde and benzene from indoor air. It also helps absorb carbon dioxide and release oxygen, improving overall air quality.

| **Plant Name `** | **Pollutants Removed** | **Role in Air Purification** |
|---|---|---|
| *Philodendron hederaceum* | Formaldehyde, $CO_2$, Benzene, Xylene | Absorbs VOCs and $CO_2$; known for high air-purification efficiency |
| *Trachyspermum ammi* | VOCs, Carbon Monoxide, Particulate Matter | Aromatic properties; helps reduce VOC levels and improve air circulation |
| *Amaranthus viridis* | Particulate Matter, VOCs, $CO_2$ | Fast-growing; broad leaves trap fine dust and airborne particles |

| | | |
|---|---|---|
| *Tradescantia spathacea* | Formaldehyde, VOCs, $CO_2$, Particulate Matter | Attractive foliage; helps absorb common workshop pollutants |
| *Coleus scutellarioides* | VOCs, $CO_2$, Formaldehyde | Aesthetic and effective in filtering harmful indoor gases |
| *Syngonium podophyllum* | Formaldehyde, Benzene, $CO_2$ | One of the most effective plants for removing airborne toxins |

### *8.3. Observed Impact and Feedback*

After the installation of the vertical garden in January 2025 at the Government Polytechnic, Bhubaneswar, its presence has sparked curiosity, appreciation, and visible behavioral change among both staff and students. Despite being a modest 3' x 7' setup, the garden quickly became a focal point in the classroom and surrounding corridors.

#### *8.3.1. Positive Reactions*

Many staff members noted an immediate improvement in the atmosphere of the space. The greenery introduced a sense of freshness and vitality, making the room feel more alive and welcoming. Teachers who regularly conducted classes nearby reported feeling less fatigued, especially during long academic hours. Several others appreciated its dual function—aesthetic enhancement and spatial partition. The vertical setup subtly separated the entryway from the classroom area, creating a more focused zone for teaching without enclosing the space like a typical partition wall would.

#### *8.3.2. Student Engagement*

Students, too, responded positively. Many were curious about the plant types and even began discussing names, categories, and uses (especially medicinal ones like Ajwain). A few took initiative in watering and minor upkeep, creating a shared sense of responsibility. The garden served as an informal learning aid, especially for students in environmental, architectural, or civil disciplines.

#### *8.3.3. Health and Mood Benefits*

Although no formal survey was conducted, anecdotal observations suggested fewer complaints of eye strain and headaches, often associated with dry, stale indoor environments. Some attributed this to the subtle humidity regulation and air freshness contributed by the plants.

#### *8.3.4. Broader Interest*

Inspired by the installation, several other departments have inquired about replicating the model in their own offices. The minimal cost, ease of setup, and high visual impact have encouraged wider acceptance. The administration has even considered developing a standardized vertical garden model for various blocks in the campus, making this one a prototype for future adoption.

#### *8.3.5. A Living Landmark*

Within months, the vertical garden has transitioned from being a ‘decorative experiment’ to a functional, admired landmark—a small change that has made a big difference in how the workplace feels. The installation has proven to be more than just a decorative addition—it has become a symbol of environmental awareness, innovation, and institutional pride.

Findings indicate that vertical gardens can effectively enhance air quality, reduce urban heat island effects, improve thermal insulation, and contribute to noise attenuation. Moreover, they serve as educational tools and promote psychological well-being by enhancing the visual and ecological character of urban spaces.

Air purifiers might be ideal for high-risk medical environments, but in general office or academic spaces, vertical gardens offer a multi-dimensional advantage—clean air, reduced stress, improved decor, and an environmentally responsible approach. They enhance both physical well-being and emotional satisfaction, combination modern workspaces desperately need.

## 9. CONCLUSION

Several plants can help reduce harmful gases and improve air quality in a workshop or indoor environment. These plants work through the process of **phytoremediation**, which involves absorbing or neutralizing pollutants and improving the indoor condition.

**VOC Removal:** Many of these plants are effective at absorbing volatile organic compounds, including formaldehyde, benzene, and xylene, commonly found in workshop environments.

**Particulate Matter Absorption:** Plants like *Amaranthus viridis* and *Tradescantia spathacea* help trap and remove fine dust and particulate matter from the air.

**Carbon Dioxide Absorption and Oxygen Production**: These plants also contribute to reducing carbon dioxide levels and improving oxygen levels through photosynthesis.

The vertical garden installed at Government Polytechnic Bhubaneswar stands as a compelling example of how a small, thoughtful intervention can spark a ripple of positive change in an institutional environment. What began as a simple initiative to beautify a classroom has evolved into a multi-dimensional solution—enhancing air quality, promoting mental well-being, encouraging informal learning, and reinforcing the principles of sustainability.

Unlike traditional indoor methods such as air purifiers or artificial décor, the vertical garden provides real, living benefits. It cools and purifies the air, supports biodiversity, requires minimal resources, and creates a natural space divider—making it a versatile and economical option for offices, classrooms, and even public spaces. Its success at Government Polytechnic suggests that vertical gardens are not just decorative—they are functional, educational, and transformative.

The project also serves as a prototype for future installations in institutional, governmental, and corporate spaces. With Bhubaneswar steadily growing as an urban hub—and projects like the proposed Bhubaneswar Metro gaining attention—the timing is ideal to embed such green practices into the city's development narrative. From administrative blocks to staff lounges, waiting areas, and corridors, the scalability and flexibility of vertical gardens make them an ideal fit for modern, sustainable infrastructure.

## 10. Future Scope and Recommendations

1. Expansion across Campus: Similar vertical gardens can be installed in the library, staff rooms, and canteens. Students can be involved in design, installation, and maintenance, fostering a sense of community and ownership.

2. Integration into Curriculum: Vertical gardens can be introduced as interdisciplinary mini-projects in civil, architecture, and environmental engineering courses—blending theory with hands-on application.

3. Data Monitoring: Future versions could integrate simple sensors to monitor humidity, temperature, and air quality changes—turning the garden into a living lab.

4. Collaboration with Local Nurseries or Self-Help Groups: This can support women-led green entrepreneurship and local plant diversity, while reducing costs.

5. Government Support and Replication: With support from state urban departments or municipal green initiatives, vertical gardens can be promoted across other institutions in Odisha and bey.

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