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# "AYURVEDIC FUMIGATION AND MODERN INDOOR PLANTS FOR AIR PURIFICATION: A SYSTEMATIC REVIEW BASED ON PRISMA GUIDELINES"

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## ABSTRACT

Indoor air pollution is a growing public health concern linked to respiratory diseases, allergic conditions, and microbial infections. Traditional systems, such as Ayurveda, offer time-tested interventions like *Dhoopana* (medicinal fumigation) and the use of air-purifying herbal plants, which are now gaining renewed attention for their potential in environmental detoxification. **Objective:** To evaluate Ayurvedic practices of *Dhoopana* (medicinal fumigation) and the use of herbal indoor air-purifying plants by correlating references from classical texts with modern scientific evidence, and to establish their role in mitigating indoor air pollution and promoting health. **Data Sources:** Primary references were drawn from classical Ayurvedic texts, including *Charaka Samhita*, *Sushruta Samhita*, and *Kashyapa Samhita* for descriptions of fumigation practices and therapeutic uses. Secondary data were obtained from modern scientific databases such as PubMed, Scopus, and Google Scholar, screening publications from 2000 to 2025. **Review Methods:** A comprehensive literature review was conducted following PRISMA guidelines. Extracted data included pharmacognostical identity, phytochemical constituents, antimicrobial efficacy, and pollutant-removal capacity of the selected medicinal substances and plants. **Conclusion:** Ayurvedic fumigation formulations generally comprised Agni and Vayu-dominant substances such as *Guggulu*, *Nimba*, *Vacha*, and *Agaru*. A total of 40 classical *Dhoopana Yogas* were identified with

specific disease indications in the *Kashyapa Samhita*. Complementary findings from modern research validated 15 herbal plants, including *Sansevieria trifasciata, Chlorophytum comosum,* and *Aloe vera*, which showed measurable reductions in PM2.5, VOCs (benzene, formaldehyde, xylene), and microbial loads, thereby bridging traditional wisdom with environmental health science. The integration of Ayurvedic fumigation and herbal indoor purification strategies provides a holistic, low-cost, and sustainable solution for controlling indoor air pollution. The convergence of traditional Ayurvedic knowledge with modern evidence underscores its dual benefit in health protection and ecological well-being.

**KEYWORDS:** *Dhoopana*, Indoor Air Quality, Ayurvedic Fumigation, VOCs, Air-purifying Plants, Phytoremediation, Classical Formulations, PM2.5.

## INTRODUCTION

Indoor air pollution has emerged as a critical but often underrecognized public health concern. While considerable attention has been directed toward outdoor pollution from industrial emissions and vehicular exhaust,[1] indoor environments where individuals spend the majority of their time can harbour an array of hazardous pollutants. Indoor air contains a complex mixture of contaminants, including volatile organic compounds (VOCs), particulate matter (PM), combustion by-products, biological agents, and harmful gases released from building materials, furnishings, and cleaning agents. Major sources of indoor air pollution are shown in Table 1.[2]

**Table 1: Source and Types of Pollution.**

| Sources of pollution | Types of pollution |
|---|---|
| Outdoor air | PM, nitrogen dioxide, carbon monoxide |
| Buildings' materials, glues, paints, furniture | Alcohols, benzene, formaldehyde and toluene |
| Home ware: carpets, wallpapers | PM, bacteria, fungi, mites dust |
| Electronic equipment: computers, televisions, monitors | Ammonia, benzene, toluene, trichloroethylene and PM |
| Activities of rooms' users: frying meat, using fireplaces, ironing, cigarette smoking, cleaning | PM, nitrogen dioxide, carbon monoxide, benzene, formaldehyde |
| Biological: man, animals, fungi, bacteria | Ammonia, acetone, alcohols, methane, nitrogen oxides, carbon monoxide and Sulphur compounds, PM |

Poor ventilation, high humidity, and modern lifestyle practices further exacerbate indoor air quality (IAQ), leading to acute and chronic health outcomes. According to the World Health

Organisation (WHO), household air pollution contributes to more than three million deaths annually, primarily from respiratory infections, asthma, low birth weight, cardiovascular complications, and certain cancers.[3]

Beyond physical illnesses, deteriorating IAQ has been linked to psychological effects such as fatigue, irritability, impaired cognition, and anxiety. This growing recognition of IAQ's impact has stimulated interest in natural, sustainable interventions, including the use of indoor plants and traditional purification methods. Ayurveda, the ancient Indian system of medicine, provides a rich framework for environmental purification, particularly through the therapeutic use of herbal plants and fumigation practices such as *Dhoopana*.

Herbal plants are increasingly recognised as living biofilters that not only absorb toxic compounds but also regulate oxygen and humidity levels while fostering a biophilic indoor environment that promotes mental well-being. Contemporary scientific studies corroborate the role of indoor plants in improving air quality through multiple mechanisms. These include adsorption of gaseous contaminants and particulate matter (dust and bioaerosols) onto leaf surfaces, microbial degradation of volatile compounds via metabolic pathways, removal of $CO_2$ and production of $O_2$ through photosynthesis, regulation of indoor humidity through leaf transpiration and evaporation from rooting media, and overall reduction of airborne concentrations of dust and bioaerosols.[4] These processes collectively reduce concentrations of dust, bioaerosols, and gaseous contaminants, thereby improving IAQ.

Complementing these modern interventions, the Ayurvedic practice of *Dhoopana* (ritualistic fumigation with medicinal herbs) has been employed since Vedic times and is extensively documented in classical texts such as the *Rigveda*, *Atharvaveda*, and later Ayurvedic compendia. Different terms are used to describe fumigation: *Dhoopana* in *Charaka Samhita* (*Chikitsa Sthana* 10/49–50), *Sushruta Samhita* (*Chikitsa Sthana* 40/52–53), and *Kashyapa Samhita* (*Khil Sthana* 5/5–7); *Yagya* in *Charaka Samhita* (*Vimana Sthana* 3/16), *Sushruta Samhita* (*Sutra Sthana* 1/25), and *Bhavaprakasha*(*Purva Khanda* 6/246); and *Havana* in *Charaka Samhita* (*Sutra Sthana* 25/40–42), *Sushruta Samhita* (*Chikitsa Sthana* 40/52), and *Ashtanga Hridaya* (*Sutra Sthana* 2/50–52). Classical authors emphasised its utility both as a therapeutic intervention in specific clinical conditions and as a preventive practice for maintaining environmental health. Modern pharmacological investigations further substantiate these claims, demonstrating that the combustion of herbs such as *Guggulu*, *Vacha*, *Nimba*, and *Haridra* releases bioactive compounds with antimicrobial,

insecticidal, anti-inflammatory, and mood-enhancing properties. Thus, Ayurvedic fumigation serves a dual function: sanitising indoor air while simultaneously promoting psychosocial and spiritual well-being.

This review aims to systematically evaluate the integration of medicinal plants and Ayurvedic *Dhoopana* as a holistic strategy for indoor air purification. Specifically, it seeks to (i) assess the role of plants as natural air purifiers, (ii) review the efficacy and contemporary relevance of *Dhoopana*, and (iii) propose an integrative, sustainable model for improving indoor environmental quality. By bridging traditional ecological wisdom with modern public health perspectives, this work aims to provide a culturally rooted and environmentally conscious framework for healthier living spaces.

## MATERIALS AND METHODS

1. **Literature Search Strategy**: A comprehensive literature search was conducted to gather relevant information on the role of plants in improving indoor air quality, traditional fumigation methods, and associated health impacts. Scientific databases such as PubMed, Google Scholar, ScienceDirect, and SpringerLink were explored. The systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparent reporting of the study selection process.

2. **Inclusion and Exclusion Criteria**: Articles, preprints, and reports published in English up to July 2025 were considered. Studies involving experimental or review-based evidence on indoor plants, air-purifying capacity, fumigation practices, and plant-based bioactive properties were included. Duplicates, unrelated subject areas, or papers without full-text access were excluded.

3. **Data Compilation and Thematic Classification**: Selected references were classified into themes such as

- Indoor air pollutants and health impact
- Scientific basis of air-purifying plants
- Traditional Ayurvedic fumigation practices (*Dhoopana Karma*)
- Ethnobotanical and Ayurvedic literature
- Antibacterial, insecticidal, and antioxidant properties of specific plants

These themes allowed structured synthesis of findings and enabled a comparative understanding of modern and traditional approaches.

## OBSERVATIONS

### Evaluation of Indoor Herbal Plants Based on Modern Scientific Evidence

A detailed evaluation was carried out on fifteen indoor herbal plants widely recognised for their ability to improve indoor air quality. Selection was based on their prevalence in indoor horticulture, air-purifying properties, and availability of modern scientific studies supporting their efficacy. These plants were assessed for their ability to absorb volatile organic compounds (VOCs), neutralise pollutants, increase relative humidity, and exhibit antimicrobial activity.

Table 2 presents a summary of the phytoremedial potential and scientific findings associated with each plant.

**Table 2: Scientifically Evaluated Indoor Herbal Plants for Air Purification.**

| S.No. | Botanical Name | Common Name | Key Pollutants Removed | Mechanism of Action | Scientific Validation & Findings |
|---|---|---|---|---|---|
| 1. | *Sansevieria trifasciata* Prain., **Family-** Asparagaceae. | Snake Plant | Benzene, Formaldehyde, Xylene | CAM metabolism, VOC absorption | Effective in reducing formaldehyde and improving air quality in sealed spaces (NASA Study)[5-7] |
| 2. | *Chlorophytum comosum* Thunb., **Family –** Asparagaceae | Spider Plant | Formaldehyde, CO, Benzene | VOC metabolism, high transpiration rate | Converts Formaldehyde to non-toxic compounds; improves ambient humidity.[7-8] |
| 3. | *Spathiphyllum wallisii* Regel., **Family –** Araceae | Peace Lily | Toluene, Benzene, Trichloroethylene | VOC absorption, phytoremediation[9] | Known for removal of indoor smoke-based pollutants[10-12] |
| 4. | *Nephrolepis exaltata* L. Schott., **Family -** Lomariopsidaceae | Boston fern or Sword fern | Benzene, Formaldehyde, Xylene, | CAM metabolism, VOC absorption | Highly efficient formaldehyde remover "Best humidifying air-purifier" Top VOC-absorbing fern"NASA-tested pollutant filter[9,13-15] |
| 5. | *Dracaena sanderiana* Mast., **Family –** Asparagaceae | Lucky Bamboo | Formaldehyde, Benzene, Trichloroethylene, Xylene, Toluene | Phytoremediation process, Stomatal gas exchange, Root pollutant uptake, Transpiration-driven humidification, VOC absorption pathway[9,12] | VOC Absorption, Air Detoxifier, Indoor Humidifier, Oxygen Enhancer, Phytoremediation Plant, Pollutant Remover, Respiratory Comfort Enhancer, Low-Light Purifier[16-17] |
| 6. | *Dypsis lutescens* H.Wendl., **Family –** Arecaceae | Areca Palm | TVOCs, $CO_2$, CO, VOCs | Phytoremediation, Transpiration | CSIR-IHBT: Reduced TVOCs, $CO_2$, CO by 88.16% (9 plants); effective in 100–200 sq. ft. spaces.[9,18] |

| | | | | | |
|---|---|---|---|---|---|
| 7. | *Chamaedorea elegans* Mart., **Family–** **A**recaceae | Bamboo Palm | Formaldehyde, Benzene, Trichloroethylene, Xylene | VOC Absorption, Photosynthesis | NASA Clean Air Study (1989): Among top VOC-removing plants[9] |
| 8. | *Ficus benjamina* L. LC. **Family –** Moraceae | Weeping Fig | Formaldehyde, Xylene, Toluene | Broad-leaf VOC Absorption[19] | NASA: Broad leaves help absorb pollutants; best for 100–200 sq. ft. indoor areas[20] |
| 9. | *Aloe barbadensis* Miller., **Family –** Asphodelaceaesis | Aloe Vera | Formaldehyde, Benzene, VOCs | Leaf-Surface Absorption, Transpiration[19] | JEST study: Filters formaldehyde; boosts oxygen levels and indoor humidity[20-22] |
| 10. | *Aglaonema commutatum* Schott., **Family** – Araceae | Aglaonema / Chinese Evergreen | Gaseous pollutants (from incense, mosquito coils,naphthalene) | Phytoremediation, VOC Breakdown | Tested as indoor phytoremediator; effective against common household pollutant gas[23-24] |
| 11. | *Areca catechu* L. **Family-** Arecaceae | Areca Palm | $CO_2$, VOCs | $CO_2$ absorption, transpiration | Enhances oxygen levels and relative humidity[9] |
| 12. | *Epipremnum aureum* (Linden & Andre) G.S. Bunting **Family**-Araceae | Money Plant | Benzene, Xylene, Formaldehyde | Stomatal uptake, metabolic degradation | Air-purifying efficiency supported in indoor air monitoring studies[12] |
| 13. | *Dracaena reflexa* Lam. **Family-** Asparagaceae | Song of India | Formaldehyde, Trichloroethylene | Transpiration and microbial synergy | Reduces eye and respiratory irritants in closed environments[18] |
| 14. | *Dieffenbachia seguine* (Jacq.) Schott. **Family-** Araceae | Dumb Cane | Toluene, Xylene | VOC binding and phytodegradation | Reduces oxidative indoor pollutants[20] |
| 15. | *Hedera helix* Linn. **Family-** Araliaceae | English Ivy | Benzene, Formaldehyde, Mold Spores | VOC breakdown, anti-microbial leaf surface | Demonstrated strong anti-microbial and air-purifying properties[12.25] |

| | | |
|---|---|---|
|  |  |  |
| *Sansevieria trifasciata* Prain. | *Chlorophytum comosum* Thunb. | *Spathiphyllum wallisii* Regel. |

| | | |
|---|---|---|
|  |  |  |
| *Nephrolepis exaltata* L. Schott. | *Dracaena sanderiana* Mast | *Dypsis lutescens* H.Wendl. |
|  |  |  |
| *Chamaedorea elegans* Mart. | *Ficus benjamina* L.LC. | *Aloe barbadensis* Miller. |
|  |  |  |
| *Aglaonema commutatum* Schott. | *Areca catechu* L. | *Epipremnum aureum* (Linden & Andre) G.S.B |
|  |  |  |
| *Dracaena reflexa* Lam. | *Dieffenbachia seguine* (Jacq.) Schott. | *Hedera helix* Linn. |

**Figure 1. Indoor Herbal Plants for Air Purification.**

| | | |
|---|---|---|
|  |  |  |
| *Nardostachys jatamansi* DC | *Commiphora mukul* Hook ex Stocks | *Azadirachta indica* A. Juss. |

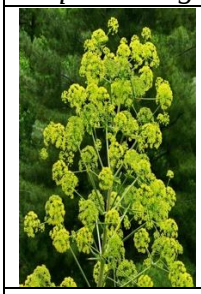
| | | |
|---|---|---|
|   |   |   |
| *Acorus calamus* Linn. | *Brassica compesteris* Linn. | *Curcuma longa* Linn. |
|   |   |   |
| *Santallum album* Linn. | *Viteveria zizanioidis* Linn. | *Eletteria cardamomum* Maton. |
|   |   |   |
| *Aquilaria agallocha* Roxb. | *Acacia catechu* Willd. | *Cedrus deodara (Roxb)* Loud. |
|   |   |   |
| *Ferula assa-foetida* L. | *Solanum virginianum* L. | *Ocimum sanctum* Linn. |

**Figure 2.Herbal Drugs used for Fumigation.**

**Fumigation Practices**

Fumigation involves the use of smoke, vapour, or other gaseous substances derived from specific plants or herbs to cleanse an environment. This practice is rooted in various cultural and spiritual traditions, often employed for purification and healing. The concept of fumigation is exclusively narrated in ancient texts. The *Vedas*, particularly the *Rig Veda*, *Yajur Veda*, and *Atharva Veda*, mention the practices of *Yagya* (or *Yajna*) and *Havana* as central to their ritualistic framework. However, they are more closely associated with *Vedic* rituals and spiritual practices than with the purely medical aspects of *Ayurveda*. The *Yajur Veda* specifically focuses on the rituals of *Yajna* (which includes *Yagya*), with detailed

instructions on the offerings, chants, and procedures for conducting sacrifices. The *Taittiriya Samhita* and *Shatapatha Brahmana* (parts of the *Yajur Veda*) describe various fire rituals performed by priests.[25] *Atharva Veda* discusses the significance of *Homa* (the process of offerings made into the fire), focusing on how it can heal diseases and bring prosperity. The *Homa* rituals are also used for spiritual purification and protecting health.[26] *Ayurvedic* traditional fumigation with natural plant products is used to disinfect the environment. It is termed as *Dhoopana, Yagya, Havana, and Homa* in Ayurvedic texts. Fumigation, referred to as *Dhoopana* in the two fundamental texts of Ayurveda, *Charaka Samhitha* and *Sushrutha Samhitha,* is prescribed for the treatment of various ailments and disinfection of the environment and inanimate objects.[27,28] Classically, *Dhoopana Karma* is indicated in *Janpadodwansha vyadhi,* i.e. epidemic or *Aopsargika Roga*. Ayurveda recommends fumigation as a method of sterilisation and therapeutic procedure for various human diseases, including microbial infections and psychological disorders.[29]

*Homa* and *Yagya* are seen as practices that purify the environment, harmonise the *Dosha* (the three biological energies: *Vata*, *Pitta*, and *Kapha*), and promote both physical and mental health. Ayurvedic literature also mentions *Agnihotra* (a specific form of fire ritual) as beneficial for overall well-being. *Agnihotra* is a form of *Yagya* practised daily, often using specific herbs and ghee, said to purify both the air and the body.[30] Ayurvedic traditional fumigation practices using Garlic (*Allium sativum*) peel, Turmeric (*Curcuma longa),* Carom (*Trachyspermum ammi*) seeds (*Ajwain*) and Loban (resin of *Styrax benzoin* and *Boswellia* species) powders have been mentioned for disinfection.[31]

The study was conducted to scientifically validate the disinfection efficacy of herbal products as an alternative to conventional chemical fumigation. Nautiyal et al. demonstrated that 500 g *Havan Samagri* (a mixture of more than 50 odiferous and medicinal plants) reduced the airborne bacteria by 94% within 1 hour of fumigation.[32] Fumigation with garlic peel, turmeric powder, ajwain seed powder and loban significantly reduces airborne bacteria. In addition, only 3 g of the four herbal materials resulted in nearly 60–70% reduction in airborne bacteria. 15 g of *Devadaru* (*Cedrus deodara*) resulted in around 96% reduction in airborne bacteria. 3 g of garlic peel reduced the airborne bacteria by 71% in a much larger room. Elemental analysis of garlic peel indicates the presence of sulfur, and the ethyl acetate extract of garlic peel exhibits antibacterial activity against *Colletotrichum acutatum*. This data indicates that fumigation with each of these herbal products has significantly improved the

microbiological quality of air by significantly reducing the cfu/m3 of air.[31] Although this study indicates that fumigation with the tested herbs is efficient in disinfection, more research should be carried out to understand the effect of various parameters such as humidity, temperature and exposure time on the disinfection ability.

**Drugs used for fumigation in Ayurveda**

In Ayurveda, the use of a single drug as well as a combination of various drugs is used for fumigation. Like *Dhoopan* with *Agaru* is recommended for *Sheeta Jwara, Sarvgrahhra Dhoopa, Vishamjwara Hra Dhoopa.*[33] Classically, the drugs selected for fumigation are predominant in *Agni* or *Vayu Mahabhoota*. E.g. *Guggul, Nimba, Vacha, Sarshapa, Haridra, Ghee, Chandna, Ushira, Ela, Aguru, Devdaru, Sarjrassa.*[35]

**Classical Ayurvedic References on Fumigation (*Dhoopana*) Practices**

***Atharveda –*** *Guggula, Ajashringi* for *Kriminashana*[35]

***Charaka Samihta –*** *Krimighana Mahakasaya (Guduchi, Karkatshringi, Hingu, Ingudi, Kantakari, Twak, Nimba, Patol, Apamarga, Guggul)*[36,37]

***Shushruta Samhita –*** *Rakshoghna Gana - Guggul, Agaru, Sarjras, Vacha, Gaur Sarshapa, Lavan, Nimbapatra, Ghrut.*[38]

***Kashyapa Samhita –*** *Rakshoghna Drvays* (Capabale of killing demons*)- Ghrita, Hingu, Akshata,* Skin of Reptile (Snake), *Siddhartak (Brassica alba), Dev Nirmalya (*flowers of herbs offered to god), *Akshata* (unbroken rice), *Sarpa tvak* (shed skin snake) and clothes of old Buddhist[39], *Sarvaroghra Dhoopa* (Destroy all diseases)– *Ghrita, Nimba, Tulasi Patra, Ashwagandha Patra,* Cow hair, Aries hair, Goat Hair.[40] Apart from this, Acharya Kashyapa has mentioned 40 Dhoopan*a Yogas,* and various *Dhoopana* formulations, according to clinical conditions, are given by different *Acharyas*. For example, in *Kustha*, fumigation with *Vidanga* and *Khadira,* fumigation with *Guggulu*, *Neemba*, *Sarshapa*, *Vacha,* and *Ghee* is indicated in *Vishamjwara.*[40]

**Table 3: Properties of *Dravya* used for Fumigation.[34]**

| S.No | Dravya | Properties | Part used | Active Principle | Mode of action |
|---|---|---|---|---|---|
| 1. | *Jatamansi* (*Nardostachys jatamansi* DC) **Family- Caprifoliaceae** | *Rasa - Tikta, Kashaya, Madhura Guna - Laghu, Snigdha Vipaka - Katu, Virya - Sheeta* | Root | Essential oil (Sesquiterpnoids) | Insecticidal properties [41] |
| 2. | *Guggula (Commiphora* | *Rasa - Tikta, Katu, Guna - Laghu, Sugandhi* | Gum-resin | Diterpenoids, Alkaloids, | *Krimighna*(Anti-bacterial against |

| | | | | | |
|---|---|---|---|---|---|
| | *mukul* Hook ex Stocks*)* **Family-** Burseraceae | *Vipaka - Katu*<br>*Virya - Ushna* | | Glycosides, Oleo-gum resins, Amino Acids | gram- positive bacteria and gram-negative bacteria) which helps increasing the growth of pathogens by destroying their intracellular fluids |
| 3. | *Neemba (Azadirachta indica* A. Juss) **Family-** Meliaceae | *Rasa - Tikta, Kashaya*<br>*Guna - Laghu*<br>*Vipaka - Katu*<br>*Virya - Sheeta* | Flower, Leaf, Bark, Seeds | Azadirachtin, Nimbin, Nimbinin, Nimbosterol | *Krimighna, Vishgna* (Anti-microbial, Anti-bacterial property of Nimba against pyogenic bacteria e.g. staphylocoocus aureus & staphylocoocus pyogenus and antifungal agent) which helps to dry up the intracellular fluid present inside the bacterial wall& hampers the growth of the bacteria. |
| 4. | *Vacha (Acorus calamus* Linn.*)* **Family-** Acoraceae | *Rasa - Katu, Tikta*<br>*Guna - Laghu, Tikshana*<br>*Vipaka - Katu*<br>*Virya – Ushna* | Rhizome | Asarynidehyde | *Krimighna*(Anti-bacterial agent against bacterial strains of Salmonella typhi, .Pseudomonas .aeruginosa, .Klebsiella pneumonia and Staphylococcusaureus) helps to stop the bacterial growth |
| 5. | *Sarshap (Brassica compesteris* Linn.*)* **Family-** Brassicaceae | *Rasa - Katu, Teekta,*<br>*Guna- Tikshana, Ruksha*<br>*Vipaka - Katu*<br>*Virya - Ushna* | Seed | Allylisothiocyanate | *Krimighna*(Bacteriocidal) |
| 6. | *Haridra (Curcuma longa* Linn.*)* | *Rasa - Tikta, Katu,*<br>*Guna - Laghu, Ruksha*<br>*Vipaka - Katu* | Rhizome | Curcumin, Several curcuminoids | *Krimighna* (Anti-bacterial properties against gm+ve and |

| | | | | | |
|---|---|---|---|---|---|
| | **Family-** Zingiberaceae | *Virya - Ushna* | | | gm-ve bacteria) |
| 7. | *Chandana (Santallum album* Linn.*)* **Family-** Santalaceae | *Rasa- Tikta, Madhura, Guna-Laghu, Ruksha Vipaka - Katu Virya - Sheeta* | Heart wood | Volatile oil Santalol | *Krimighna*(Anti-microbial& Anti-fungal) and increases the effect of Dhoopan karma due to aroma. |
| 8. | *Usheera (Viteveria zizanioidis*Linn*)* **Family**-Poaceae | *Rasa-Tikta, Madhura Guna- Laghu, Ruksha Vipaka- Katu Virya- Sheeta* | Root | Volatile oil | *Krimighna* and increases the effect of Dhoopan karma due to aroma. |
| 9. | *Ela (Eletteria cardamomum* Maton.*)* **Family-** Zingiberaceae | *Rasa-Katu, Madhura Guna- Laghu, Ruksha Vipaka-Madhura Virya- Sheeta* | Seed | Camphene cyaniol | *Krimighana* (Antibacterial) |
| 10. | *Agaru (Aquilaria agallocha*Roxb*)* **Family-** Thymelaeaceae | *Rasa-Katu,, Tikta Guna- Laghu, Ruksha, Tikshna Vipaka- Katu Virya- Ushna* | Heartwood | Agarospirol | *Krimighna* (anti-bacterial & anti-inflammatory) & special use in Sutikagara |
| 11. | *Khadira (Acacia catechu* Willd.*)* **Family-** Fabaceae | *Rasa-Tikta, Kashaya Guna-Laghu, Ruksha Vipaka-Katu Virya- Sheeta* | Bark | Catechin | Bark is Insecticidal [43] |
| 12. | *Devdaru (Cedrus deodara (Roxb)* Loud.*)***Family-** Pinaceae | *Rasa- Tikta Guna- Laghu, Snigdha Vipaka- Katu Virya- Ushna* | Bark | Essential oil Sesquiterpene | Anti-larvicidal[44] Ethanol extracts from cones, leaves, wood anti-viral activity[45] |
| 13. | *Hingu (Ferula assa-foetida* L.*)* **Family-** Apiaceae | *Rasa- Katu Guna- Laghu, Snigdha Vipaka- Katu Virya- Ushna* | Gum-resin | Oleo-resin gum | Anti-microbial[42] |
| 14. | *Kantkari (Solanum virginianum* L.*)* **Family-** Solanaceae | *Rasa- Tikta, Katu Guna- Laghu, Ruksha, TikshnaVipaka- Katu Virya- Ushna* | Whole plants | Alkaloids, Glycosides | Anti-microbial Insecticidal [46] |
| 15. | *Tulsi (Ocimum sanctum* Linn.*)* **Family-** Lamiaceae | *Rasa- Katu, Tikta Guna- Laghu, Ruksha Vipaka- Katu Virya- Ushna* | Whole plants | Eugenol, Methyl eugenol, | Anti-bacterial Anti-microbial Insecticidal [47] |
| 16. | *Karkatshringi (Pistacia integerrima* J.L. Stewart*)* **Family-** Anacardiaceae | *Rasa- Kashaya, Tikta Guna- Laghu, Ruksha Vipaka- Katu Virya- Ushna* | Gall | Camphene Volatile oil | Anti-bacterial[48] |

| | | | | | |
|---|---|---|---|---|---|
| 17. | *Kapoor (Cinnamomum camphora* Nees. & Eberm*)* **Family-** Lauraceae | *Rasa- Tikta, Katu, Madhura*<br>*Guna- Laghu, Tikshna*<br>*Vipaka- Katu*<br>*Virya- Sheeta* | Gum resin | Essential oil | Insecticidal activity [49]<br>Anti-bacterial [50] |
| 18. | *Kapoor Kachri (Hedychium spicatum* Buch-Ham.*)* **Family-** Zingiberaceae | *Rasa- Katu, Tikta, Kashaya*<br>*Guna- Laghu, Tikshna*<br>*Vipaka- Katu*<br>*Virya- Ushna* | Rhizome | Essential oil | Insecticidal[51]<br>Anti-microbial[52] |
| 19. | *Tagar (Tabernaemontana divaricata* (L)R.Br.ex.Roem .&Schult.*)* **Family-** Caprifoliaceae | *Rasa- Tikta, Katu, Kashaya*<br>*Guna- Laghu, Snigdha*<br>*Vipaka- Katu*<br>*Virya- Ushna* | Root | Indole alkaloids | Anti-microbial [53]<br>Anti-bacterial [54] |
| 20. | *Apamarga (Achyranthes aspera* Linn.*)* **Family-** Amaranthaceae | *Rasa- Katu, Tikta*<br>*Guna- Laghu, Ruksha, Tikshna*<br>*Vipaka- Katu*<br>*Virya- Ushna* | Whole plant | Flavonoids<br>Tannins<br>Taxifolin | Anti-bacterial[57]<br>Insecticidal [58] |
| 21. | *Sarjaka (Vateria indica* Linn.*)* **Family-** Dipterocarpaceae | *Rasa- Kashaya, Madhura*<br>*Guna- Ruksha*<br>*Vipaka- Katu*<br>*Virya- Sheeta* | Root | Flavonoids<br>Tannins<br>Volatile oil | Anti-bacterial, larvicidal[59]<br>Anti-microbial[60] |
| 22. | *Kutki (Picrorhiza kurroa* Royle ex Benth.*)* **Family-** Plantaginaceae | *Rasa- Tikta*<br>*Guna- Ruksha, Laghu*<br>*Vipaka- Katu*<br>*Virya- Sheeta* | Rhizome | Kutkiol<br>Kutkin<br>Picrorhizin<br>Picroside Terpenes | Anti-microbial, insecticidal[62] |
| 23. | *Durva (Cynodon dactylon* Pers.) **Family-** Poaceae | *Rasa- Kashaya, Madhura*<br>*Guna- Laghu*<br>*Vipaka- Madhura*<br>*Virya- Sheeta* | Leaves | Cyanidin Glycosides | Anti-microbial, Anti-parasitic [63] |
| 24. | *Chorpushpi (Bidens pilosa* Linn.*)* **Family-** Asteraceae | *Rasa- Katu, Kashaya*<br>*Guna- Laghu, Ruksha*<br>*Vipaka- Katu*<br>*Virya- Ushna* | Whole plant | Flavonoids<br>Terpenoids<br>Aromatic compounds | Insecticial [64]<br>Anti-microbial [65] |
| 25. | *Haritaki (Terminalia chebula* Retz.*)* **Family-** Combretaceae | *Rasa- Pancha-rasa (Except Lavana)*<br>*Guna- Laghu, Ruksha*<br>*Vipaka- Madhura*<br>*Virya- Ushna* | Fruit | Chebulagic acid<br>Chebulinic acid<br>Corilagin | Insecticidal [66] |
| 26. | *Yava (Hordeum vulgare* (L.)*)* **Family-** Poaceae | *Rasa- Kashaya, Madhura*<br>*Guna- Ruksha, Guru*<br>*Vipaka- Katu* | Seed | Hordenine<br>Luteolin glycoside | Anti-bacterial[67] |

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| | | *Virya- Sheeta* | | | |
| 27. | *Ativisha (Aconitum heterophyllum* Wall.*)* **Family-** Ranunculaceae | *Rasa-Katu, Tikta Guna-Laghu, Ruksha Vipaka-Katu Virya-Ushna* | Tuber | Alkaloids, Flavonoids | Anti-microbial[42] |
| 28. | *Arjuna (Terminalia arjuna* (Roxb.) W. & A.*)* **Family-** Combretaceae | *Rasa- Kashaya Guna- Laghu, Ruksha Vipaka- Katu Virya- Sheeta* | Bark | Arjunolic acids, Tannins, Glycosides | Acts as antimicrobial[42] |
| 29. | *Asana (Pterocarpus marsupium* Roxb.*)* **Family-** Fabaceae | *Rasa- Kashaya, Tikta Guna- Laghu-Ruksha Vipaka- Katu Virya- Sheeta* | Bark | Bark; alkaloids, glycosides, flavonoids, phenols, terpinoids | Anti-bacterial, Anti-viral, Anti-fungal[42] |
| 30. | *Bhallataka (Semecrapus anacardium* Linn.*)* **Family-** Anacardiaceae | *Rasa- Katu, Tikta, Kashya Guna- Laghu, Snigdha, Tikshn Vipaka-Madhura Virya- Ushna* | Seed | Biflavonoids, phenolic compounds, bhilawanols | Anti-microbial, Anti-termites[42] |
| 31 | *Vidanga (Embelia ribes* Burm.f.*)* **Family-** Myrsinaceae | *Rasa- Katu, Kashya Guna- Laghu, Ruksha, Tikshana Vipaka- Katu Virya- Ushna* | Seed | Benzoquinone derivative embelin, | Anti-bacterial, Anthelmintic, Anti-fungal[42] |
| 32 | *Kebuka (Costus speciosus* (Koeing) Sm.) **Family-** Costaceae | *Rasa- Tikta, Kashaya Guna- Laghu, Ruksha Vipaka- Katu Virya- Sheeta* | Root | Diosgenins, Benzoquinones | Anti-microbial[42] |
| 33. | *Indravaruni (Citrullus colocynthis* Schrad.*)* **Family-** Cucurbitaceae | *Rasa- Tikta Guna- Laghu, Ruksha, Tikshna Vipaka- Katu Virya- Ushna* | Root Seed | Flavonoids, Tannins, Terpinoids | Anti-microbial [42] |
| 34. | *Ingudi (Balanitis aegyptiaca* Linn.*)***Family-** | *Rasa- Tikta, Katu Guna- Laghu, Snigdha Vipaka- Katu Virya- Ushna* | Seed Bark | Saponins, Glycosides | Anti-bacterial, Anthelmintic [42] |
| 35. | *Kalajaji (Nigella sativa* Linn.*)* **Family-** Ranunculaceae | *Rasa- Katu, Tikta Guna- Laghu, Ruksha, Tikshna Vipaka- Katu Virya- Ushna* | Seed | Thymoquinone | Anti-bacterial [42] |

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| 36. | *Karanja (Pongamia pinnata* Pierre.*)* **Family-** Fabaceae | *Rasa- Tikta, Katu, Kashaya Guna- Laghu, Tikshna Vipaka- Katu Virya- Ushna* | Seed | Flavonoids | Anti-bacterial [42] |
| 37. | *Kosataki (Luffa acutangula* (Linn.) Roxb.*)* **Family-** Cucurbitaceae | *Rasa- Tikta Guna- Laghu, Ruksha, Tikshna Vipaka- Katu Virya- Ushna* | Seed | Terpenoids, Flavonoids, Glycosides | Anti-bacterial, Anti-fungal[42] |
| 38. | *Plakasha (Ficus lacor* Buch. - Ham*)***Family-** Moraceae | *Rasa- Kashaya Guna- Guru, Ruksha Vipaka- Katu Virya- Sheeta* | Bark Root | Aerial root rich in phenolics | Anti-bacterial, latex is Anti-fungal[42] |
| 39. | *Rasona (Allium sativum* Linn.*)* **Family-** Amaryllidaceae | *Rasa- Madhura, Lavana, Katu, Tikta) Guna- Tikshna, Guru Vipaka- Katu .Virya- Ushna* | Bulb | Allicin | Work against bacteria, fungi, viruses, nematodes, insect repellent[42] |
| 40. | *Mallika (Jasminum sambac* Linn.*)* **Family-** Oleaceae | *Rasa- Tikta, Kashaya Guna- Laghu, Snigdha, Mridu Vipaka- Katu Virya- Ushna* | Flower | Alkaloids, Glycosides, Flavonoids, Tri-terpenes, saponin, tannins, resin and salicylic acids | Anti-bacterial, Anti-fungal, Anthelmintic[42] |
| 41. | *Maricha (Piper nigrum* Linn.*)* **Family-** Piperaceae | *Rasa- Katu Guna- Laghu, Tikshna Vipaka- Katu Virya- Ushna* | Seed | Volatile oils | Anti-bacterial[42] |
| 42. | *Nirgundi (Vitex negundo* Linn.*)* **Family-** Lamiaceae | *Rasa- Katu, Tikta Guna- Laghu, Ruksha Vipaka- Katu Virya- Ushna* | Leaves | Alkaloids (Nishindin and Hydrocotylene) | Anti-bacterial[42] |
| 43. | *Pippali (Piper longum* Linn.*)* **Family-** Piperaceae | *Rasa- Katu, Guna- Laghu, Snigdha, TikshnaVipaka- Madhura Virya- Anushnasheeta* | Seed | Resin, Alkaloids, Terpenoids | Anti-bacterial, Anthelmintic[42] |
| 45. | *Tilah (Sesamum indicum* Linn.*)* **Family-** Pedaliaceae | *Rasa- Madhura Guna- Guru, Snigdha Vipaka- Madhura Virya- Ushna* | Seed | Sesamol, sesamolin, sesamin | Anti-bacterial, Anti-fungal[42] |
| 46. | *Dhoopa(Jurinea dolomiaea*Boiss) **Family-** Asteraceae | *Rasa- KatuGuna- Laghu, RukshaVipaka- KatuVirya- Ushna* | Rhizome | Alkaloids, Flavonoids | Anti-microbial[68], Anti-bacterial[69] |

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|  |  |  |
| *Pistacia integerrima* J.L. Stewart | *Cinnamomum camphora* Nees. & Eberm | *Hedychium spicatum* Buch-Ham. |
|  |  |  |
| *Tabernaemontana divaricata* (L)R.Br.ex.Roem.&Schult. | *Achyranthes aspera* Linn. | *Vateria indica* Linn. |
|  |  |  |
| *Picrorhiza kurroa* Royle ex Benth. | *Cynodon dactylon* Pers. | *Bidens pilosa* Linn. |
|  |  |  |
| *Terminalia chebula* Retz. | *Hordeum vulgare* (L.) | *Aconitum heterophyllum* W. |
|  |  |  |
| *Terminalia arjuna* (Roxb.) W. & A. | *Pterocarpus marsupium* Roxb. | *Semecrapus anacardium* Linn. |

**Figure 3. Herbal Drugs used for Fumigation.**

| | | |
|---|---|---|
|  |  |  |
| *Embelia ribes* Burm.f. | *Costus speciosus* (Koeing) Sm. | *Citrullus colocynthis* Schrad. |
|  |  |  |
| *Balanitis aegyptiaca* Linn. | *Nigella sativa* Linn. | *Pongamia pinnata* Pierre. |
|  |  |  |
| *Luffa acutangula* (Linn.) Roxb. | *Ficus lacor* Buch. -Ham. | *Allium sativum* Linn. |
|  |  |  |
| *Jasminum sambac* Linn. | *Piper nigrum* Linn. | *Vitex negundo* Linn. |
|  |  |  |
| *Piper longum* Linn. | *Sesamum indicum* Linn. | *Jurinea dolomiaea* Boiss. |

**Figure 4. Herbal Drugs used for Fumigation.**

## RESULTS

### 1. Literature Search Outcomes

The comprehensive literature search yielded a total of 473 records from databases including PubMed, Google Scholar, ScienceDirect, and SpringerLink. After removing 63 duplicates, 410 records remained for screening. Title and abstract screening excluded 280 articles due to irrelevance or insufficient focus on air purification or traditional practices. Out of the remaining 130 full-text articles assessed for eligibility, 85 studies met the inclusion criteria and were included in the final review. These included both original research and review papers on phytoremediation, Ayurvedic *Dhoopana* practices, and the medicinal use of plants for indoor environmental well-being. The study selection process is summarised in the PRISMA flow diagram **(Figure 5).**

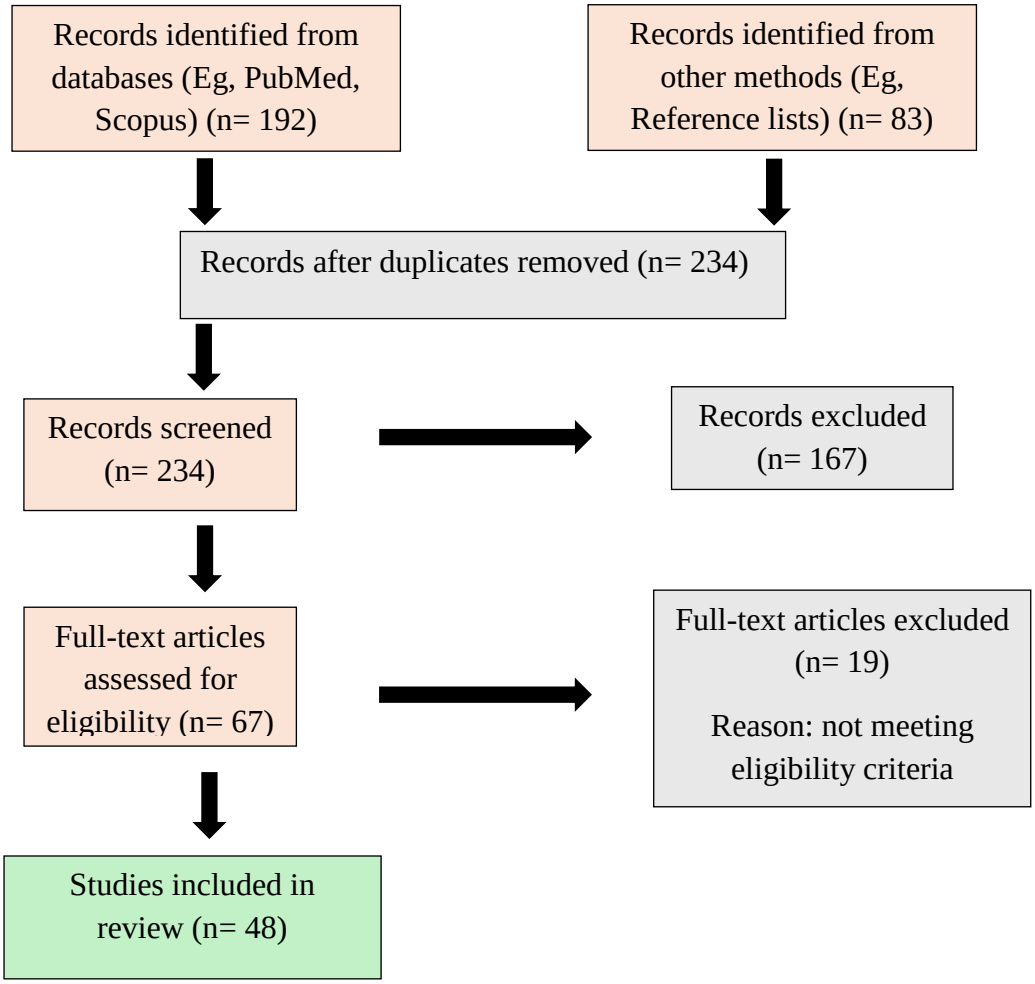


**Figure 5. PRISMA Results.**

### 2. Thematic Classification of Included Studies

The 85 selected articles and sources were grouped thematically into the following categories:

- Indoor Air Pollutants and Health Impact (n=12): Articles highlighted the effects of pollutants such as PM2.5, VOCs, carbon monoxide, and microbial contamination on respiratory and systemic health.
- Scientific Basis of Air-Purifying Plants (n=25): These included NASA studies, phytoremediation research, and plant physiology data showing VOC absorption, microbial neutralisation, and oxygen release mechanisms.
- Traditional Ayurvedic Fumigation Practices (n=20): Studies and classical texts detailing *Dhoopana* formulations, their mode of action, and environmental benefits were reviewed.
- Ethnobotanical and Ayurvedic Literature (n=15): These records provided regional and traditional knowledge of herbs used for purification and ritualistic practices.
- Bioactive Properties of Specific Plants (n=13): This category covered antibacterial, antifungal, antioxidant, and insecticidal activity of key plants such as *Tulsi*, *Neem*, *Tagara*, and *Guggulu*.

**3. Source Composition and Reference Diversity**

Among the 85 studies

- 61 were peer-reviewed scientific papers (45 research articles and 16 reviews),
- 15 were classical Ayurvedic references and commentaries,
- 9 were grey literature, including government reports, theses, and validated online archives.

**4. Integration of Traditional and Modern Evidence**

The review demonstrates a notable convergence between modern scientific findings and traditional Ayurvedic practices. Several herbs traditionally used in *Dhoopana*, such as *Haridra*, *Tagara*, and *Loban*, have shown measurable antimicrobial and air-purifying properties in experimental studies. Furthermore, Ayurvedic fumigation methods align with modern bioaerosol management techniques, providing a valuable bridge between ancient wisdom and contemporary indoor air quality enhancement strategies.

## DISCUSSION

Indoor air quality has emerged as a critical component of environmental and public health, particularly in urban and post-pandemic settings where indoor exposure exceeds 90% of human activity time. This review highlights the unique convergence of classical Ayurvedic knowledge and modern phytoremediation science, offering a holistic approach to indoor air detoxification.

The use of air-purifying plants such as *Sansevieria trifasciata*, *Chlorophytum comosum*, and *Areca catechu* has shown remarkable efficacy in absorbing volatile organic compounds (VOCs) such as formaldehyde, benzene, and xylene. These findings are strongly supported by the NASA Clean Air Study and subsequent phytoremediation trials. The presence of specialised enzymes and CAM (Crassulacean Acid Metabolism) physiology in some species enables continuous air filtration, even during night hours, making them suitable for closed environments like bedrooms, hospitals, and offices.

Ayurvedic *Dhoopana* (fumigation) practices, referenced in texts such as *Charaka Samhita*, *Sushruta Samhita*, and *Rasashastra granthas*, have long emphasised the use of herbal resins, barks, and volatile oils for disinfection, air purification, and spiritual cleansing. This review presents plants such as *Guggulu (Commiphora wightii)*, *Nimba (Azadirachta indica)*, *Haridra (Curcuma longa)*, and *Vacha (Acorus calamus)* as classical components of Dhoopana formulations. Modern microbiological studies have validated the antibacterial, antifungal, antiviral, and insect-repellent properties of such formulations, demonstrating reductions in airborne pathogens and surface microbial load.

Furthermore, the integration of classical Ayurvedic wisdom with modern evidence-based research shows promise for sustainable, low-cost, and culturally relevant air purification systems. However, gaps still exist in terms of standardised protocols, comparative efficacy across environments, and long-term safety assessment. Not all plants or formulations have been thoroughly studied using modern tools such as GC-MS, FTIR, or clinical microbial assays.

This review also identifies a need to re-establish forgotten indigenous practices, revive ethnobotanical knowledge, and promote interdisciplinary research that bridges environmental science, Ayurveda, and pharmacognosy.

The findings of this review underscore a growing convergence between traditional Ayurvedic practices such as *Dhoopana* (medicinal fumigation) and modern phytoremediation science. Indoor air pollution, largely attributed to volatile organic compounds (VOCs), particulate matter (PM2.5), and microbial contaminants, is a pressing global health concern. This review documents how Ayurvedic *Dhoopana* formulations and air-purifying herbal plants offer integrative, natural solutions to address these challenges.

Classical Ayurvedic texts such as the *Charaka Samhita*, *Sushruta Samhita*, and *Ashtanga Hridaya* detail various *Dhoopana Yogas* for environmental purification, disinfection, and disease prevention. Herbs like *Haridra (Curcuma longa)*, *Tagara (Valeriana wallichii)*, *Guggulu (Commiphora wightii)*, and *Vacha (Acorus calamus)* exhibit well-documented antimicrobial, antifungal, and aromatic properties. Modern phytochemical analyses support the presence of active constituents like curcumin, valerenic acid, guggulsterones, and β-asarone, which possess immunomodulatory and detoxifying actions. These formulations, when subjected to fumigation, have demonstrated potential in reducing microbial air load and neutralising airborne irritants.

Simultaneously, several plants evaluated under NASA's Clean Air Study and subsequent environmental research, *Sansevieria trifasciata*, *Aloe vera*, *Areca palm*, and *Spider plant*, are recognised for their ability to absorb pollutants like benzene, xylene, and formaldehyde through stomatal and rhizospheric pathways. Their compatibility with indoor conditions, low maintenance, and health-promoting benefits position them as effective phytoremediation agents.

Importantly, this review identified a category of 10 plants validated both in traditional Ayurvedic texts and contemporary scientific studies. These dual-validated plants hold the most promise for integrative air detoxification systems. However, limitations persist in the form of insufficient randomised clinical trials, a lack of standard protocols for *Dhoopana* preparation and delivery, and minimal inclusion of indoor plant strategies in public health policies.

This integrative approach offers not only environmental benefits but also cultural continuity, psychological wellness, and low-cost interventions particularly relevant for resource-limited settings and urban populations. Future research should focus on developing standardised formulations, conducting comparative indoor air quality studies, and exploring synergistic applications of *Dhoopana* and phytoremediation.

## CONCLUSION

This review consolidates evidence that both Ayurvedic fumigation practices and scientifically validated indoor plants have substantial potential to improve indoor air quality by reducing microbial load, neutralising VOCs, and enhancing ambient oxygenation. By aligning classical Ayurvedic wisdom with modern scientific validation, these practices can offer accessible,

eco-friendly, and culturally rooted alternatives to chemical disinfectants and mechanical air purifiers.

While empirical support is growing, large-scale studies and standardised models are necessary to mainstream these practices into environmental health protocols. The integrative adoption of traditional *Dhoopana* and indoor herbal plants holds promise for sustainable living, preventive health, and environmental harmony.

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**Authors' Contribution**

All authors contributed significantly to the conception, design, and preparation of this review.

- **Dr I. T.:** Conceptualisation, literature review, drafting, and manuscript writing.
- **Dr C. G.:** Analysis of relevant studies and critical revision of the manuscript.

**CONFLICT OF INTEREST**

There is no conflict of interest.

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