P2 Project Report

Futuristic Air Purifying solution for Premium Users in Metro Cities

Guided by
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Approval form

This is to certify that the Industrial Design Project entitled "Futuristic Air Purifying solution for Premium Users in Metro Cities" by Harish Hemanth D is approved for partial fulfillment for the Master of Design degree inIndustrial Design.

Prof . B.K.Chakravarthy
[Project Guide]

Signature of the
Chair Person

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Declaration Form

I, declare that this written report represents my ideas in my own words, and where others' ideas or words have been included I have adequately cited and referenced the original sources.

I also declare that I have adhered to all principles of academic honesty and integrity and have not falsified, misinterpreted or fabricated any idea, data, facts or source in my submission.

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Signature:
Name of the Student: Harish Hemanth D
Roll No.:22M2230

Acknowledgement

I would like to express my heartfelt gratitude to my guide, Prof. B.K.Chakravarthy, for his essential assistance throughout the project. Special thanks to the professors of Industrial Design Department for their critics and guidance . I am also grateful to all of the instructors, staff, and students at the Industrial Design Centre (IDC) for their assistance, advice, and suggestions. Finally I'd like to express my gratitude to my family and friends for their unwavering support.

Abstract

This project pioneers a futuristic air purifying solution tailored for premium users in metro cities. We merge speculative design theories with NASA's plant-based indoor air purifier tech, envisioning a harmonious integration of aesthetics and functionality. The result is a user-centric, sustainable system that not only combats urban air challenges but also enhances the overall living experience for the discerning urban dweller.

Contents

1.Introduction *Why Purifying Air?*

In the rapidly evolving landscape of modern urban living, the quality of air has emerged as a critical concern, particularly for premium users in densely populated metro cities. Recognizing the need for a revolutionary solution, this industrial design project embarks on a journey to reimagine air purification through the lens of speculative design and the groundbreaking technology developed by NASA in the realm of plant-based indoor air purification.

As urbanization continues to soar, so does the demand for innovative solutions that not only address the functional aspects of air purification but also seamlessly integrate with the lifestyles and preferences of premium users. The convergence of speculative design theories and NASA's advancements in plant-based air purifiers forms the nucleus of our approach, promising a paradigm shift in the way we perceive and engage with indoor air quality.

This introduction sets the stage for a comprehensive exploration of our futuristic air purifying solution, showcasing a harmonious fusion of aesthetics, functionality, and sustainability. By delving into the unique challenges faced by premium urban dwellers, we lay the groundwork for a design that goes beyond mere purification, redefining the very essence of air quality in metropolitan living.

1.1 Current Market

The current market for air purification solutions is marked by a growing awareness of the adverse effects of air pollution on health and well-being. In densely populated metro cities, premium users are increasingly seeking sophisticated and effective air purifiers that not only address air quality concerns but also seamlessly integrate into their modern lifestyles.

The market is characterized by a demand for innovative designs, sustainable technologies, and user-centric features that go beyond traditional filtration systems.
Existing air purifiers often prioritize functionality over aesthetics, presenting an opportunity for our project to disrupt the market by merging cutting-edge technology with speculative design theories. Premium users are not only looking for efficient air purification but also for solutions that enhance the overall ambiance of their living spaces.

Furthermore, there is a growing interest in sustainable practices, reflected in the market's receptivity to environmentally friendly technologies.

Competitive analysis reveals a gap in the market for a holistic air purification system tailored to the specific needs of premium urban dwellers. By leveraging the current market dynamics and integrating the best practices observed in existing products, our project aims to position itself as a trailblazer in the premium air purification segment, catering to the evolving demands of the discerning consumer.

1.2 Target Area

The primary focus of our futuristic air purifying solution is the dynamic landscape of metro cities, where premium users reside and face distinct challenges associated with air quality. Our target area encompasses cosmopolitan environments characterized by high population density, elevated pollution levels, and a demand for innovative, high-end solutions that complement contemporary lifestyles.

Key considerations for this target area include the integration of the air purifying solution into the architectural and design aesthetics of premium urban residences. As the urban population seeks more than just functional appliances, our design caters to the desire for aesthetically pleasing, space-efficient, and seamlessly integrated solutions that enhance the overall ambiance of living spaces.

Additionally, the target area recognizes the specific preferences and lifestyle patterns of premium users, emphasizing features such as user-friendly interfaces, smart connectivity, and a low-maintenance design. These considerations aim to align the air purifying solution with the sophisticated needs of our target demographic, ensuring a seamless and delightful user experience.

By tailoring our project to the unique challenges and preferences of premium users in metro cities, we aim to position our futuristic air purifying solution as an indispensable element of modern, urban living, addressing the distinct nuances of this target area with precision and innovation.

2.Causes of Poor Air Quality

2.1 Traffic-Related air pollution (TARP)

various forms of carbon, nitrogen oxides, sulfur oxides, volatile organic compounds, polycyclic aromatic hydrocarbons, and fine particulate matter..

2.2 Industrial Emissions

Both cities have a large number of industries, factories, and power plants, which release various pollutants into the air, including sulfur dioxide (SO2), particulate matter, and other hazardous substances.

2.3 Meteorological conditions

Weather patterns can exacerbate air quality issues. Inversions and stagnant air masses can trap pollutants near the ground, leading to higher concentrations of harmful substances.

2.4 Volatile organic compounds (VOC)

vaporize at or near room temperature—hence, the designation volatile. They are called organic because they contain carbon. VOCs are given off by paints, cleaning supplies, pesticides, some furnishings, and even craft materials like glue. Gasoline and natural gas are major sources of VOCs, which are released during combustion.

2.5 Urban heat island effect

The dense urban landscape and excessive concrete surfaces in metro cities can lead to the urban heat island effect, which can influence weather patterns and exacerbate air pollution.

2.6 Secondary Aerosols

Some pollutants emitted by vehicles and industries undergo chemical reactions in the atmosphere and form secondary aerosols, further worsening air quality.

2.7 Ozone

An atmospheric gas, is often called smog when at ground level. It is created when pollutants emitted by cars, power plants, industrial boilers, refineries, and other sources chemically react in the presence of sunlight.

2.8 Inadequate Ventilation

Improper and Inefficient air flow in the interior spaces of the houses and residence spaces around polluted spaces.

2.9 Moisture and Mold

Metro cities with high humidity levels or buildings with water leaks can lead to mold growth, which releases spores and mycotoxins into the air, potentially affecting indoor air quality.

2.10 Pet Dander and Allergens

Pet ownership in urban areas can introduce pet dander and other allergens into indoor spaces, impacting individuals with allergies or asthma.

2.11 Building Materials and Furnishings

Some building materials, furniture, and furnishings can emit volatile organic compounds (VOCs), formaldehyde, and other chemicals into the air, especially in newly constructed or renovated buildings.

2.12 Particulate matter (PM)

(PM) is composed of chemicals such as sulfates, nitrates, carbon, or mineral dusts. Vehicle and industrial emissions from fossil fuel combustion, cigarette smoke, and burning organic matter, such as wildfires, all contain PM.

A subset of PM, fine particulate matter (PM 2.5) is 30 times thinner than a human hair. It can be inhaled deeply into lung tissue and contribute to serious health problems. PM 2.5 accounts for most health effects due to air pollution

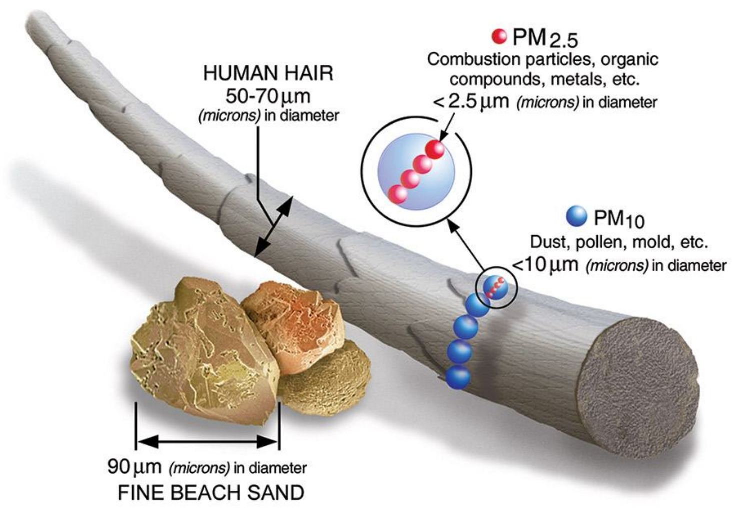


Image Courtesy of the U.S EPA

3. Air Purifying Technologies

3.1 UV air purifier

UV air purifiers are devices that use UV light technology to capture air and pass it through a filter. The air then goes through a small internal chamber where it becomes exposed to UV-C light. Some air purifiers then filter the air again before releasing it back into the room.

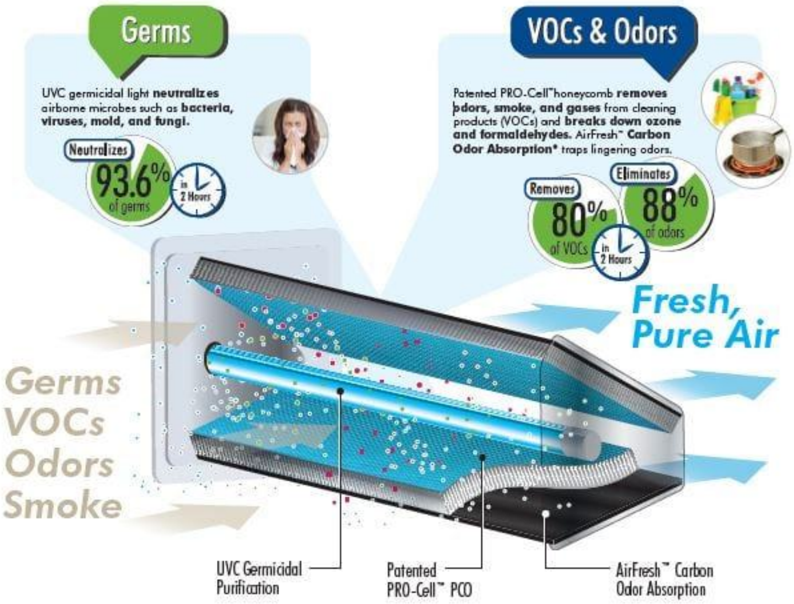


Image Courtesy Field Controls

Pros:

Have a quiet operation and may be effective at removing bacteria from the air if a person uses them with HEPA filters

Cons:

Can emit ozone
Cannot remove VOCs

3.2 HEPA air purifier

HEPA is a type of pleated mechanical air filter. It is an acronym for "high efficiency particulate air [filter]" (as officially defined by the U.S. Dept. of Energy). This type of air filter can theoretically remove at least 99.97% of dust, pollen, mold, bacteria, and any airborne particles with a size of 0.3 microns (μm).

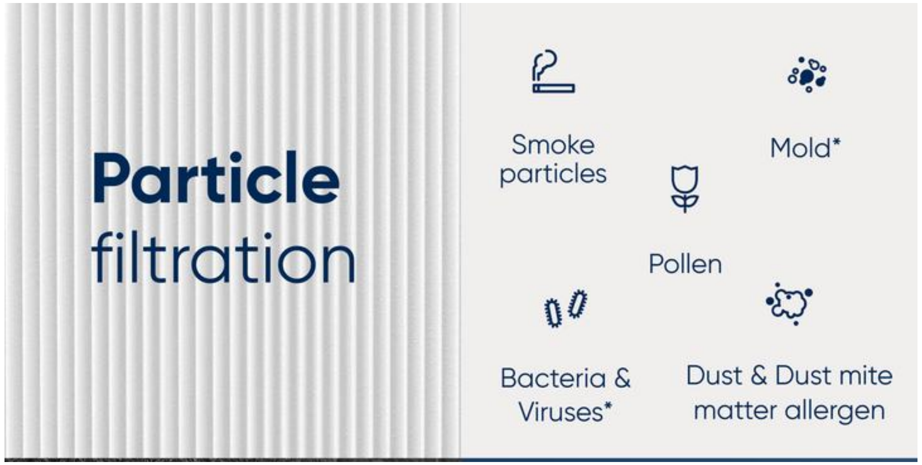


Image Courtesy Blue Air

Pros:

Reduces allergy and asthma symptoms
Produces no byproducts
Commonly available

Cons:

Won't remove every particle
Requires frequent replacement
Can be difficult to clean
Molds might build up

3.3 Carbon activated air purifier

Activated carbon air purifiers are effective at removing smoke, odors, fumes, and gasses from the air inside your home. People who are sensitive to odors like smoke or natural gas should consider an activated carbon air purifier.

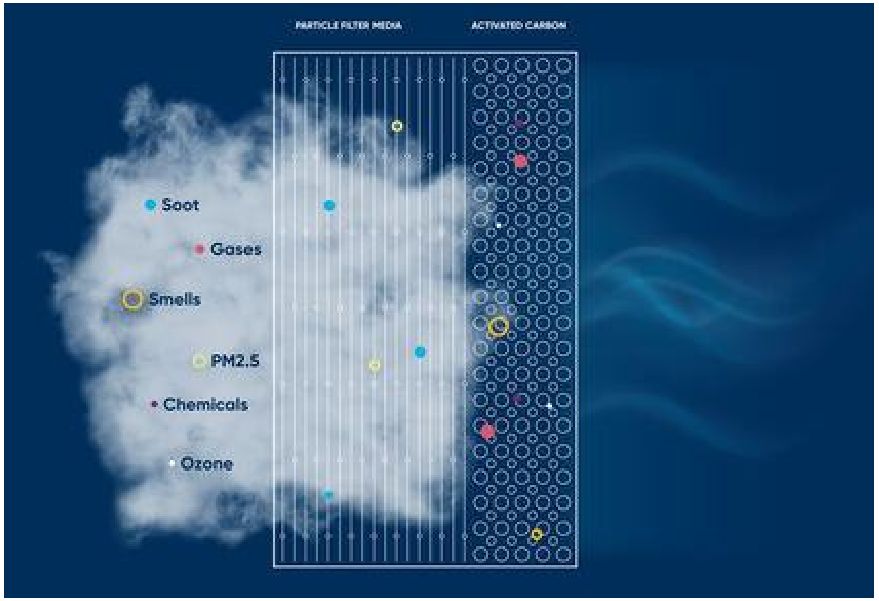


Image Courtesy Blue Air

Pros:

- *Reduces allergy and asthma symptoms*
- *Produces no byproducts*
- *Commonly available*

Cons:

- *Won't remove every particle*
- *Requires frequent replacement*
- *Can be difficult to clean*
- *Molds might build up*

3.4 Ionic air purifier

Ionic air purifiers are extremely quiet and operate without a motor. They emit negative ions into the air, which bond with positively charged, airborne particles like dust, making these particles so heavy that they eventually fall out of the air. Some ionic air purifiers have electrostatic precipitators that trap positively charged particles to a metal plate inside the air purifier.

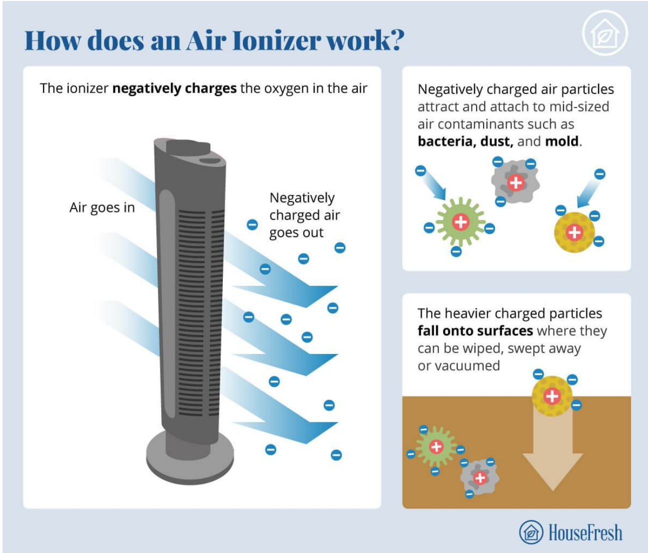


Image Courtesy House Fresh

Pros:

No need to replace filters
Effective in removing odors and outside pollutants as small as .01 microns

Cons:

Ionizers create low levels of ozone
Some ionizers can produce a foul smell
Not effective in removing dander, pollen, dust, dirt, and other large particles
It likely won't neutralize all particles, especially those on surfaces
Some ionizers (without collection plates) will leave dirty particles on your surfaces

4. Current Market Analysis

4.1 Current Market Products

Image Courtesy IKEA & MI

4.2 Wearable Varients

Image Courtesy Dyson & Google Images

4.3 Added Values

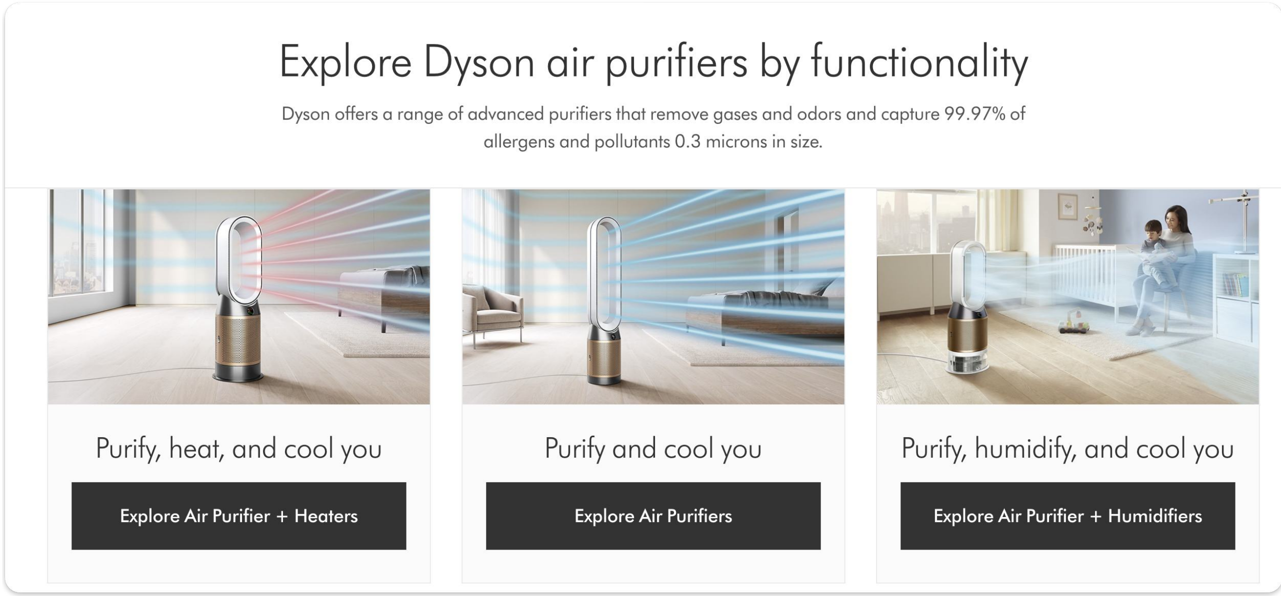


Image Courtesy Dyson

4.4 Natural relations

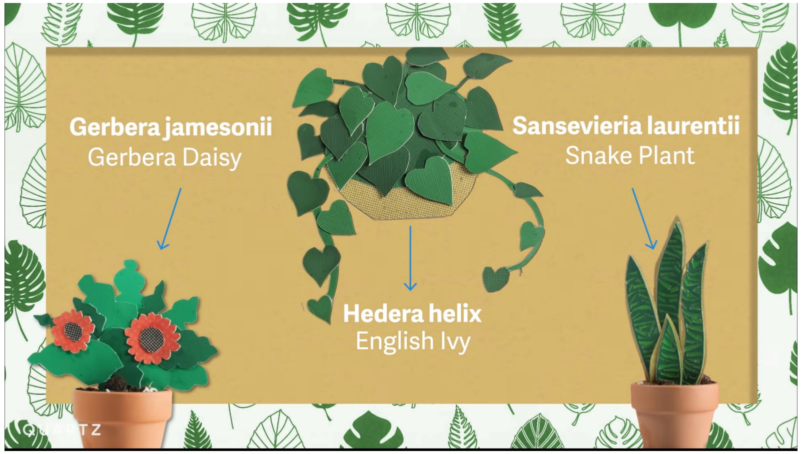
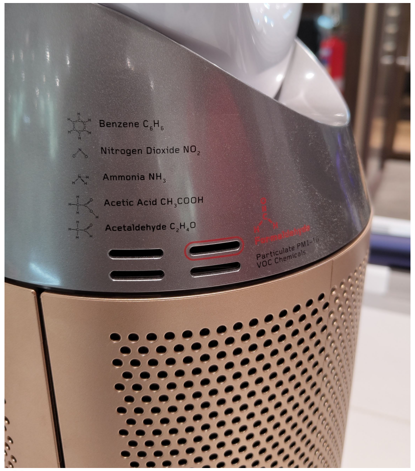


Image Courtesy Google Images

4.5 Showroom exploration



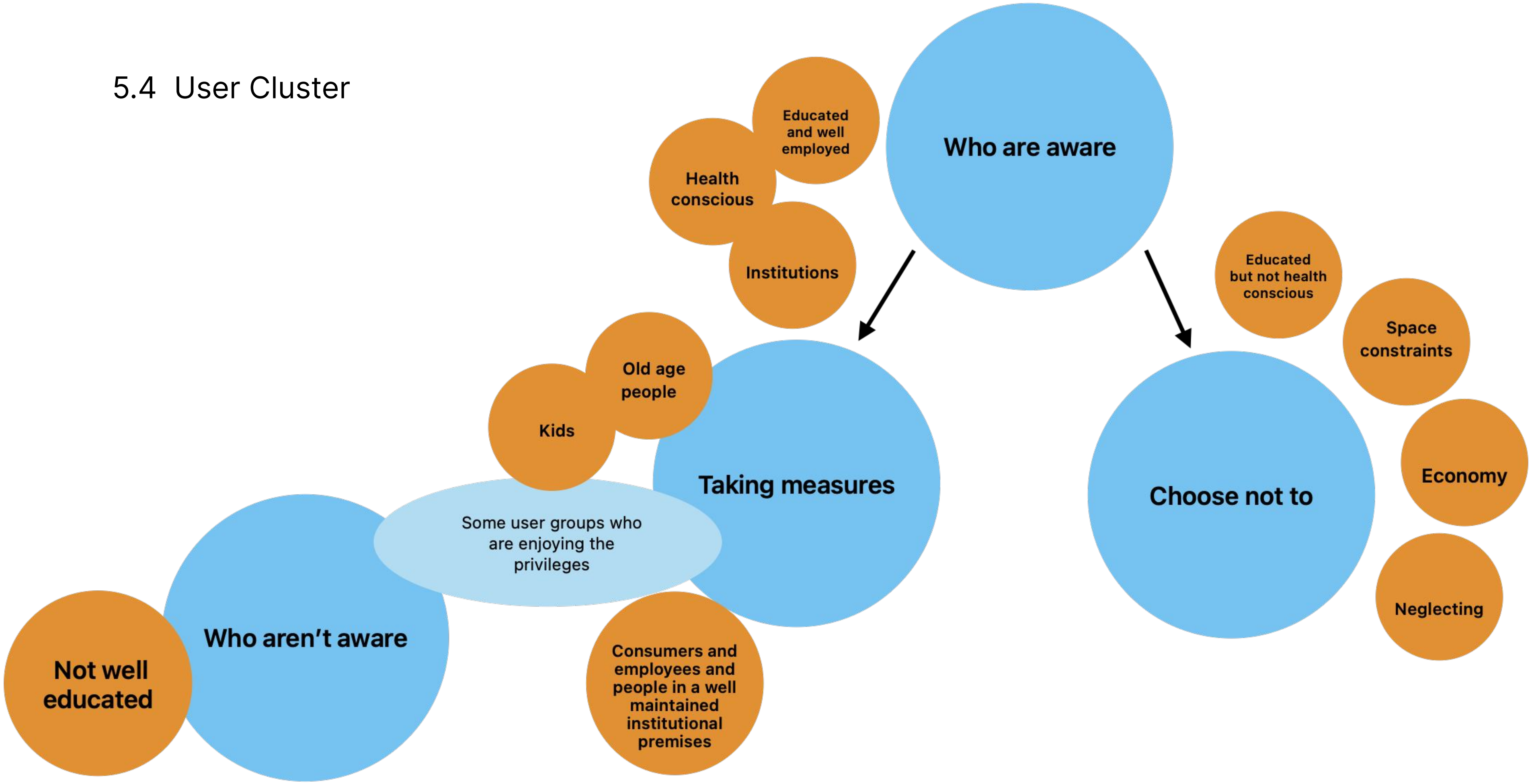
5.Field Visit and User Study

5.1 Field Location

5.2 User Interior context

5.3 Product Placement

5.4 User Cluster



5.5 Observations

This product is 5 Years old and it's still relevant to current Design trend.

There Maybe some ambiguities in the semantics related to Fan.

Also the user limits its purpose as only a fan

Users tends to loose interest in interacting with the solution over a period

6. Future Synthesis

6.1 Synthesising a desired future

In envisioning the future synthesis of our air purifying solution, we embark on a speculative journey that transcends conventional boundaries. Our project redefines the trajectory of indoor air quality by embracing the imaginative intersection of emerging technologies, avant-garde design philosophies, and a profound commitment to sustainable living.

Technology, in this speculative future, evolves beyond the constraints of the present, incorporating advancements that extend the capabilities of NASA's plant-based purification system. The synthesis of state-of-the-art technology anticipates breakthroughs, ensuring our solution remains at the forefront of innovation, pushing the boundaries of what is currently achievable.

Design in the speculated future is a fusion of artistry and functionality, breaking free from traditional norms. It involves the creation of an immersive and adaptive experience, where the air purifying solution seamlessly integrates with dynamic, ever-changing living spaces. The synthesis of form and flexibility ensures that our solution evolves alongside the fluid nature of future urban lifestyles.

Sustainability takes center stage in the speculated future synthesis, transcending mere environmental consciousness. It involves a radical shift towards regenerative practices, with materials that not only minimize ecological impact but actively contribute to a positive environmental footprint. Our solution is envisioned as a catalyst for sustainable living, inspiring a harmonious relationship between technology and nature.

In this speculative future, our air purifying solution becomes more than a product; it becomes a transformative force shaping the way we perceive and interact with our living environments. By pushing the boundaries of technology, design, and sustainability, our project sets the stage for a future where indoor air quality is not just improved but elevated to an unprecedented realm of possibilities, fostering a truly visionary synthesis that anticipates the needs of the ever-evolving urban landscape.

7. Design Brief

In metro cities across India, rapidly increasing urbanization and industrialization have led to severe air quality challenges, resulting in adverse effects on public health and well-being.
The goal is to address these issues by designing a cutting-edge air purifier that not only ensures the highest standards of indoor air quality but also enhances user wellness, usability, and value addition.
This project aims to create a futuristic air purification solution that responds to the unique challenges faced by Premium range residents in metro cities.

8. NASA's Speculation

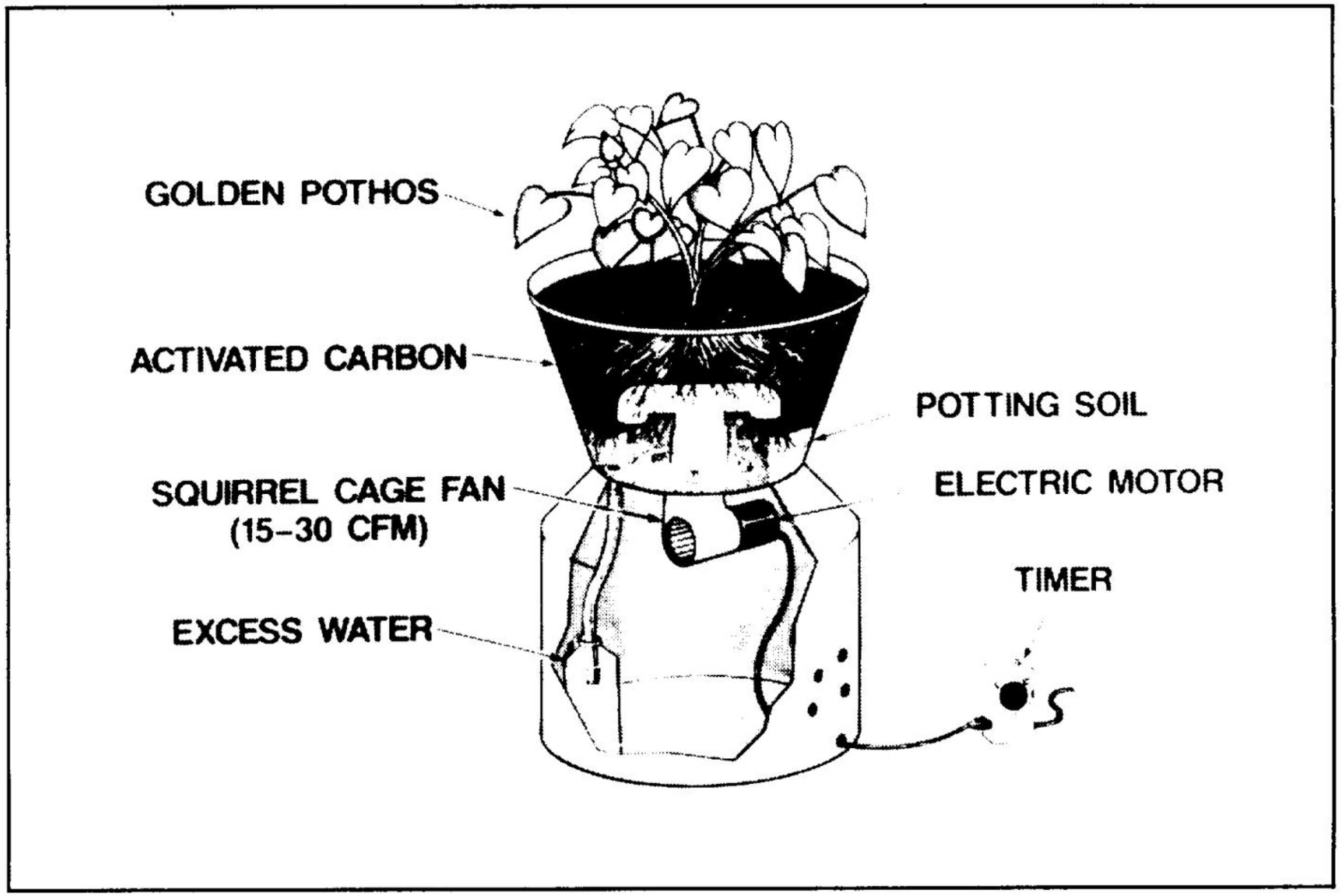


Figure 1. Indoor air purification system combining houseplants and activated carbon.

Image courtesy Interior Landscape plants for Indoor Air pollution abatement report by B.C. Wolverton, Ph.D

Image courtesy Interior Landscape plants for Indoor Air pollution abatement report by B.C. Wolverton, Ph.D

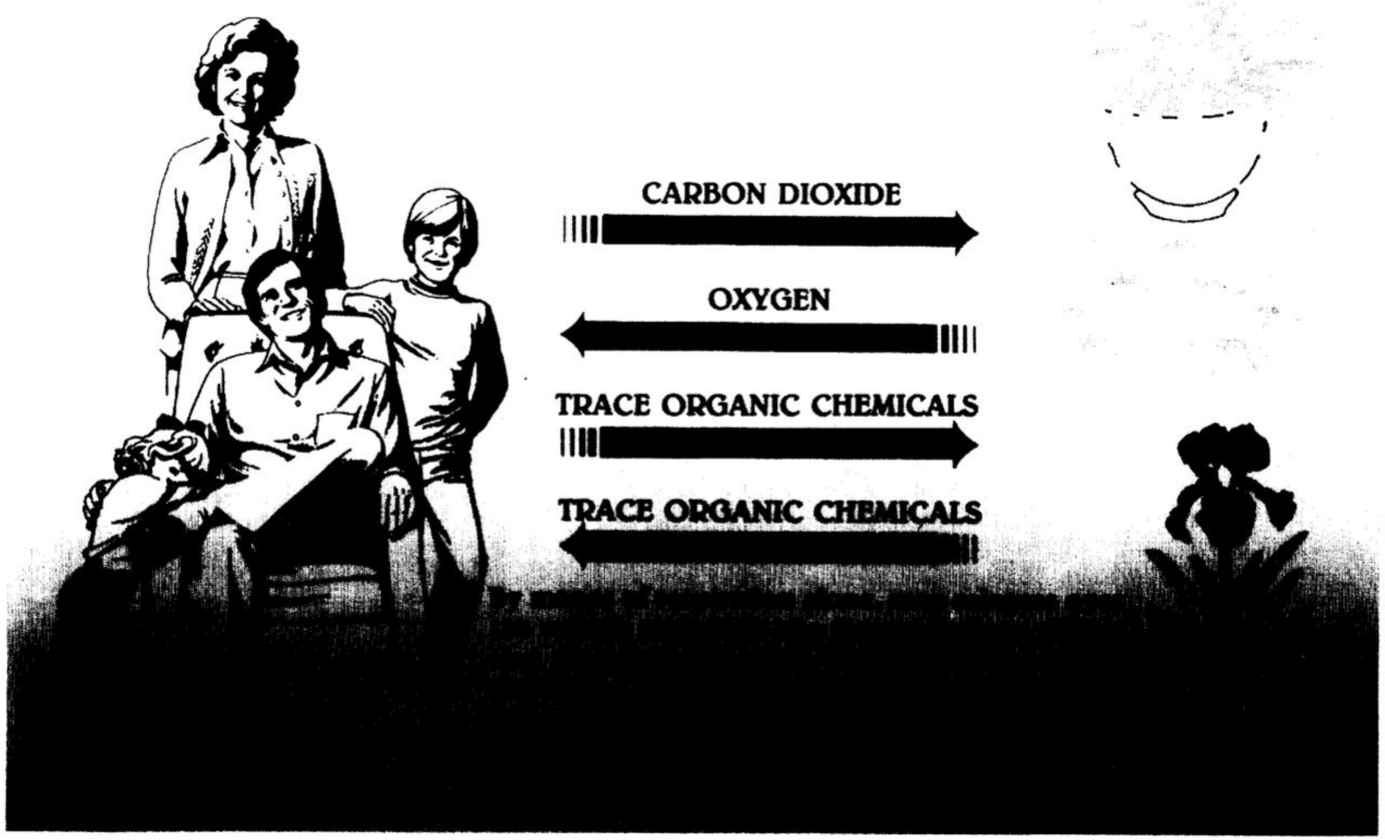


Figure 2. Man's interaction with his environment—plants, soil, microorganisms, and water.

Image courtesy Interior Landscape plants for Indoor Air pollution abatement report by B.C. Wolverton, Ph.D

MATERIALS AND METHODS

The following ALCA plants were screened:

Common Name	Scientific Name
Bamboo palm	*Chamaedorea seifritzii*
Chinese evergreen	*Aglaonema modestum*
English ivy	*Hedera helix*
Ficus	*Ficus benjamina*
Gerbera daisy	*Gerbera jamesonii*
Janet Craig	*Dracaena deremensis "Janet Craig"*
Marginata	*Dracaena marginata*
Mass cane/Corn cane	*Dracaena massangeana*
Mother-in-law's tongue	*Sansevieria laurentii*
Peace lily	*Spathiphyllum "Mauna Loa"*
Pot mum	*Chrysanthemum morifolium*
Warneckei	*Dracaena deremensis "Warneckei"*

All plants tested were obtained from nurseries in our local area. They were kept in their original pots and potting soil, just as they were received from the nursery, and were maintained in a greenhouse between tests. Stern's Miracle-Gro fertilizer was used to keep the plants in a healthy condition for the project.

Chemical contamination tests were conducted in four Plexiglas chambers, which were constructed to the following dimensions:

	Width*	Depth*	Height*
Two chambers measuring	0.76 (30)	0.76 (30)	0.76 (30)
Two larger chambers measuring	0.76 (30)	0.76 (30)	1.53 (60.5)

The tops of the small chambers and side sections of the large chambers were removed to allow entry. Bolts and wing-nuts ensured complete sealing of the lids and created airtight chambers for testing. Constant illumination was provided during the testing from a bank of Damar Gro-lights that encircled the outside of each chamber. Mounted on the inside of each chamber has a coil of copper tubing through which water at a temperature of 7 °C was circulated. This cooling coil prevented the Gro-lights from causing excessive heat buildup inside the chambers and minimized any fogging from plant respiration in the chambers. The chambers also contained two small removable ports, each 0.6 cm (1/4 in.) in diameter, through which contaminants could be introduced and air samples could be obtained. A small fan was used to circulate air within each chamber.

*Each dimension is given in meters (m); the equivalent in inches (in.) is given in parentheses.

All tests were conducted for a period of 24 h. Experimental testing included sealing a selected plant in the Plexiglas chamber, injecting one of the three chemicals into the chamber in the method described below, and collecting air samples immediately following chemical introduction, at 6 h and, finally, 24 h later. Leak test controls, wherein the same chemicals were injected into an empty, sealed chamber, were conducted periodically throughout the study. In addition, soil controls without plants were tested to determine if the potting soil and associated microorganisms were effective in removing the different chemicals. These control tests were conducted by using pots of the same size containing the same potting soil as the potted plants used in actual testing. Experimental procedure then followed the same order as described above.

Benzene testing at high concentrations was performed by introducing 35 μL of benzene into the chamber using a 50 μL microsyringe. The benzene was injected onto a small metal tray attached to the chamber wall just below the introduction port and allowed to evaporate with the help of the fan inside the chamber. A period of 30 min was allowed for complete evaporation of the benzene prior to withdrawing the initial sample.

Sampling was done with a Sensidyne-Gastec air sampling pump and gas detector tubes specific for benzene concentrations ranging between 1 and 100 p/m. In sampling, a 200-mL volume of air from the chamber was drawn through a Gastec tube. Detection of a color change in the benzene-specific indicator reagent present in the tube measured the concentration of benzene.

Introduction and sampling of TCE was performed in a similar manner, except that the indicating reagent in the Gastec tubes was specific for TCE. The levels of TCE that could be detected ranged from 1 to 25 p/m.

Because formaldehyde is a water-soluble chemical and is routinely supplied as a 37.9 percent solution in water, it was necessary to utilize a different method to introduce this chemical into the test chambers. The formaldehyde solution was placed into a gas scrubber apparatus, which was attached to both an air pump and to the chamber sample inlet using pieces of Tygon tubing. Air was bubbled through the formaldehyde solution and introduced into the chamber as a gas. The time necessary to achieve the desired concentrations of formaldehyde in the two chambers was determined experimentally to be 50 s for the small chamber and 120 s for the large chamber. Sampling was performed in the same manner as that used for benzene and TCE using a Sensidyne-Gastec air pump and formaldehyde-specific tubes. The detection range of the formaldehyde-specific tubes was 2 to 20 p/m.

Because the Sensidyne-Gastec equipment was not sensitive enough for testing less than 1 p/m concentrations, a gas chromatographic method was developed for low-concentration analysis of benzene and TCE simultaneously in single sample. For the low-concentration benzene-TCE studies, two chambers of similar size were used, having volumes of 0.868 and 0.694 m^3. Benzene and TCE were introduced into the chambers using a 1-μL volume of an equal volume mixture of benzene and TCE. The sample was injected onto a Kimwipe tissue and allowed to evaporate for a 30-min period before the initial sampling. Sampling was performed by using the air pump to withdraw 200 mL of air through a glass tube containing

Image courtesy Interior Landscape plants for Indoor Air pollution abatement report by B.C. Wolverton, Ph.D

Tenax adsorbent. The samples were analyzed promptly using a Supelco air desorption unit interfaced to a Hewlett-Packard (HP) Model 5890 gas chromatograph (GC) equipped with an HP Ultra 2 capillary column and flame ionization detector.

GAS CHROMATOGRAPH-MASS SELECTIVE DETECTOR ANALYSIS FOR TRACE METABOLITES

After chemical injection, 500-mL air samples were collected from the chambers onto 18-cm (7-in.) by 0.6-cm (1/4-in.) outside diameter stainless steel tubes packed with Tenax adsorbent, using the Sensidyne-Gastec air pump. Trace chemical contaminants were desorbed from the Tenax tubes using a Tekmar Model 5000 automatic desorber into a HP 5890 GC equipped with a 30-m, 0.32 mm inside diameter, Restek Rt_X—volatiles capillary column. The GC oven was initially cooled to 0 °C using carbon dioxide, and then followed a temperature program beginning at 0 °C, with a 30-s hold at 0 °C, and a rise in temperature of 8 °C/min. The program ended when the temperature reached 200 °C, for a total run time of 25.5 min. After separation on the GC, the sample entered an HP 5970 mass selective detector. Analysis of the sample was conducted using a scanning range of 35 to 400 atomic mass units.

MICROBIOLOGICAL ANALYSIS

Using both potted plants and potting soil controls, 1-g samples of soil were taken from surface and subsurface regions (approximately 10 cm in depth). Samples were subsequently analyzed by means of the pour plate technique to determine the number of "colony forming units" per gram of sample (cfu/g). Plate count agar (PCA) was utilized as the primary microbiological medium. Plate count data reflect bacteriological counts.

Triplicate samples were taken both before and after exposure of the plants and soil to benzene and TCE. Following incubation at 25 °C for 24 h, samples were examined for the presence of bacteria. Due to the inherently slower growth rate of fungi and actinomycetes, these microorganisms cannot be detected until three to five days of incubation have elapsed. After plate count data were recorded, both bacterial and fungal samples were isolated. Stock cultures were maintained on PCA and Sabouraud's dextrose agar, respectively. Bacterial isolates were then subjected to a series of biochemical tests in order to aid in preliminary identification. Fungal isolates were examined by light microscopy to search for the presence of asexual and sexual spores.

ACTIVATED CARBON-HOUSEPLANT AIR FILTER SYSTEM

Air filters designed as shown in Figure 1 were tested in one of the large Plexiglas chambers for simultaneous removal of benzene and TCE. Benzene and TCE in 500 μL volumes were injected onto a Kimwipe tissue taped inside the chamber and were allowed to evaporate for 5-min. Complete volatilization occurred and 100-mL air samples were drawn, using a Tenax tube and air pump. Analysis followed on the Supelco desorber and HP GC that have been previously described. Samples were drawn initially and at 15-min intervals for a minimum of 2 h, or until all trace chemicals were removed.

RESULTS AND DISCUSSION

The ability of houseplants or potting soil to remove benzene, TCE, and formaldehyde from sealed experimental chambers is demonstrated in Tables 1 through 8. The screening of plants shown in Tables 1 through 3 was accomplished during the first year of studies, while data shown in Tables 4 through 8 were collected during the second and final year of this project.

Plants in Tables 1 through 4 were exposed to high concentrations of chemicals, in the 15 to 20 p/m range. Although these exposures gave a good indication of which plants might be particularly suited to the removal of one or more of these chemicals, they are far above the levels commonly found in indoor atmospheres. During the final year of this project, investigations were conducted using low concentrations of benzene and TCE (less than 1 p/m) and more sophisticated analytical methods. Results from these studies are shown in Tables 5 through 8.

Table 1. Trichloroethylene (TCE) Removed from a Sealed Experimental Chamber by Houseplants During a 24-h Exposure Period

	Total Plant Leaf Surface Area (cm^2)	Total Micrograms Removed per Plant
Gerbera daisy *(Gerbera jamesonii)*	4,581	38,938
English ivy *(Hedera helix)*	981	7,161
Marginata *(Dracaena marginata)*	7,581	27,292
Peace lily *(Spathiphyllum "Mauna Loa")*	7,960	27,064
Mother-in-law's tongue *(Sansevieria laurentii)*	3,474	9,727
Warneckei *(Dracaena deremensis "Warneckei")*	7,242	13,760
Bamboo palm *(Chamaedorea seifritzii)*	10,325	16,520
Mass cane *(Dracaena massangeana)*	7,215	10,101
Janet Craig *(Dracaena deremensis "Janet Craig")*	15,275	18,330

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Image courtesy Interior Landscape plants for Indoor Air pollution abatement report by B.C. Wolverton, Ph.D

Table 2. Benzene Removed from a Sealed Experimental Chamber by Houseplants During a 24-h Exposure Period

	Total Plant Leaf Surface Area (cm^2)	Total Micrograms Removed per Plant
Gerbera daisy *(Gerbera jamesonii)*	4,581	107,653
Pot mum *(Chrysanthemum morifolium)*	4,227	76,931
English ivy *(Hedera helix)*	1,336	13,894
Mother-in-law's tongue *(Sansevieria laurentii)*	2,871	28,710
Warneckei *(Dracaena deremensis "Warneckei")*	7,242	39,107
Peace lily *(Spathiphyllum "Mauna Loa")*	7,960	41,392
Chinese evergreen *(Aglaonema "Silver Queen")*	3,085	14,500
Marginata *(Dracaena marginata)*	7,581	30,324
Bamboo palm *(Chamaedorea seifritzii)*	10,325	34,073
Janet Craig *(Dracaena deremensis "Janet Craig")*	15,275	25,968

Table 3. Formaldehyde Removed from a Sealed Experimental Chamber by Houseplants and Soil During a 24-h Exposure Period

	Total Plant Leaf Surface Area (cm^2)	Total Micrograms Removed per Plant
Banana *(Musa oriana)*	1,000	11,700
Mother-in-law's tongue *(Sansevieria laurentii)*	2,871	31,294
English ivy *(Hedera helix)*	985	9,653
Bamboo palm *(Chamaedorea seifrizii)*	14,205	76,707
Heart leaf philodendron *(Philodendron oxycardium)*	1,696	8,480
Elephant ear philodendron *(Philodendron domesticum)*	2,323	9,989
Green spider plant *(Chlorophytum elatum)*	2,471	10,378
Golden pothos *(Scindapsus aureus)*	2,723	8,986
Janet Craig *(Dracaena deremensis "Janet Craig")*	15,275	48,880
Marginata *(Dracaena marginata)*	7,581	20,469
Peace lily *(Spathiphyllum "Mauna Loa")*	8,509	16,167
Lacy tree philodendron *(Philodendron selloum)*	2,373	8,656
Chinese evergreen *(Aglonema modestum)*	1,894	4,382
Aloe vera	713	1,555

Image courtesy Interior Landscape plants for Indoor Air pollution abatement report by B.C. Wolverton, Ph.D

Table 4. Chemicals Removed by Household Plants from a Sealed Experimental Chamber During a 24-h Exposure Period

	Formaldehyde			Benzene			Trichloroethylene		
	Initial (p/m)	Final (p/m)	Percent Removed	Initial (p/m)	Final (p/m)	Percent Removed	Initial (p/m)	Final (p/m)	Percent Removed
Mass cane	20	6	70	14	11	21.4	16	14	12.5
Pot mum	18	7	61	58	27	53	17	10	41.2
Gerber daisy	16	8	50	65	21	67.7	20	13	35
Warneckei	8	4	50	27	13	52	20	18	10
Ficus	19	10	47.4	20	14	30	19	17	10.5
Leak control	18	17.5	2.8	20	19	5	20	18	10

Note: Plants were maintained in a commercial-type greenhouse until ready for testing. Each test, 24-h in duration, was conducted in a sealed chamber with temperature and light intensity of 30 °C ±1 and 125 footcandles ±5, respectively.

Table 5. Benzene Removal from a Sealed Experimental Chamber by Houseplants During a 24-h Exposure Period

	Initial (p/m)	Final (p/m)	Percent Removed
English ivy	0.235	0.024	89.8
Janet Craig	0.432	0.097	77.6
Golden pothos	0.127	0.034	73.2
Peace lily	0.166	0.034	79.5
Chinese evergreen	0.204	0.107	47.6
Marginata	0.176	0.037	79.0
Mother-in-law's tongue	0.156	0.074	52.6
Warneckei	0.182	0.055	70.0
Leak test control	0.171	0.162	5.3
Soil control	0.119	0.095	20.1

Table 6. Trichloroethylene (TCE) Removal from a Sealed Experimental Chamber by Houseplants During a 24-h Exposure Period

	Initial (p/m)	Final (p/m)	Percent Removed
English ivy	0.174	0.155	10.9
Janet Craig	0.321	0.265	17.5
Golden pothos	0.207	0.188	9.2
Peace lily	0.126	0.097	23.0
Warneckei	0.114	0.091	20.2
Marginata	0.136	0.118	13.2
Mother-in-law's tongue	0.269	0.233	13.4
Leak test control	0.121	0.120	<1.0
Soil control	0.141	0.128	9.2

During the first-year studies, the only controls used were chambers free of plants to test for loss of chemicals from chamber leakage and pots with fresh potting soil without plants. It was then assumed that after correcting for controls, the removal of chemicals from the sealed chambers could be attributed to the plant leaves. Because of the low photosynthetic and metabolic rates expected from these plants at light levels of 125 to 150 footcandles, the high chemical removal rates attributed to these low-light-requiring houseplants were puzzling.

In an effort to determine the exact mechanism(s) involved in chemical removal from the plant-soil system, plants were tested with foliage and then the same pots and soil were tested again after removing all foliage. Controls using full plant foliage with pea gravel covering the soil were also tested (Table 7). A microbiologist was brought into these studies to determine themicrobial profile found in the potting soils.

Early tests demonstrated that potting soil, after all foliage had been removed, was more effective in removing benzene than pots containing full foliage and soil. However, further studies and careful observation determined that this phenomenon occurred only when large amounts of foliage covered the potting soil surface, reducing contact between the soil and the air inside the chamber. Thus, some of the lower leaves were removed, allowing maximum contact between the soil-root zone and the chamber air containing toxic chemicals. Results of these new studies are shown in Tables 7 and 8.

Image courtesy Interior Landscape plants for Indoor Air pollution abatement report by B.C. Wolverton, Ph.D

Table 7. Benzene Removal from a Sealed Experimental Chamber by Houseplants in Potting Soil and the Same Potting Soil After Removing all Plant Foliage During 24-h Exposure Periods

	Initial (p/m)	Final (p/m)	Percent Removed
Marginata			
Full foliage	0.343	0.144	58.0
Foliage removed	0.348	0.175	49.7
Fresh potting soil control	0.206	0.164	20.4
Leak test, empty chamber control	0.215	0.199	7.4
Marginata			
Full foliage	0.176	0.037	79.0
Full foliage and soil covered with pea gravel	0.205	0.069	66.3
Janet Craig			
Full foliage	0.369	0.077	79.1
Foliage removed	0.321	0.176	45.2
Golden pothos			
Full foliage	0.122	0.040	67.2
Foliage removed	0.175	0.062	64.6
Fresh potting soil control	0.099	0.091	8.1
Leak test, empty chamber control	0.262	0.254	3.1

Table 8. Benzene Removal and Soil Bacterial Counts of a Chinese Evergreen Plant After Being Exposed for Several 24-h Periods to Benzene in a Sealed Experimental Chamber

	Percent Removed	Soil Bacterial Counts (cfu/g)
Initial exposure	47.6	3.1×10^4
After six weeks of intermittent exposure	85.8	5.1×10^4

Although the bacterial counts correlated with increased chemical removal in some of the studies as shown in Table 8, this finding was not consistent. Therefore, other yet unidentified biological factors may also be important. Data from this two-year study indicate that when the same plants and potting soil are constantly exposed to air containing such toxic chemicals as benzene, their capacity to continuously clean the air improves as shown in Table 8. This is not surprising, since it is a well-established fact that microorganisms have the ability to genetically adapt, thereby increasing their ability to utilize toxic chemicals as a food source when continuously exposed to such chemicals. This phenomenon is currently used to remove toxic chemicals from wastewater.[31-37]

Bacterial isolates found in the soil in which mother-in-law's tongue had been growing for a long period were *Alcaligenes, Bacillus, Curtobacterium, Flavobacterium, Micrococcus, Myxococcus,* and *Pseudomonas. Arthrobacter, Bacillus,* and *Leuconostoc* were found in marginata root soil. Bacteria such as *Bacillus, Flavobacterium, Leuconostoc,* and *Micrococcus* were also found in the Chinese evergreen potting soil. The peace lily potting soil contained *Aureobacterium, Bacillus, Curtobacterium, Micrococcus, Pseudomonas,* and *Streptomyces*. These are common soil microorganisms and most are known to be capable of biodegrading toxic chemicals when activated by plant root growth.

Results of the activated carbon-houseplant studies are shown in Figures 3 and 4. Although this research effort was not part of the NASA-ALCA two-year study, it is an essential component in the development of an indoor air pollution control system with plants to remove high concentrations of pollutants such as cigarette smoke and organic solvents. This biological system also utilizes plant roots and their associated microorganisms to purify indoor air; it differs from the potted plant study reported here in that a fan is used to rapidly move large volumes of air through an activated carbon filter. This filter adsorbs air pollutants and holds them until the plant roots and microorganisms can utilize them as a food source; therefore, bioregenerating the carbon.

To assure that no disease-causing microorganisms were released into the room from the carbon-plant filter, exhaust air from the filters was analyzed for microorganisms. To date, no pathogenic microorganisms have been found in the filter exhaust air.

It is common knowledge that plants give off trace levels of volatile organic chemicals under certain conditions, so metabolic off-gassing studies were conducted by screening several of the ALCA plants. These low-light-requiring plants were normally maintained at relatively low metabolic rates; therefore, one would not expect significant off-gassing of ethylene, terpenes, or any other metabolite. Gas chromatograph-mass selective detector studies using Tenax adsorption tubes to analyze the air inside the sealed experimental chamber indicated that the levels of plant metabolites were negligible.

As temperature and light levels are increased, it is expected that indoor pollution removal rates will increase along with some plant metabolite off-gassing. Increased oxygen production and carbon dioxide removal should also increase the rate of leaf participation in the removal rates of trace volatile organic chemicals.

Image courtesy Interior Landscape plants for Indoor Air pollution abatement report by B.C. Wolverton, Ph.D

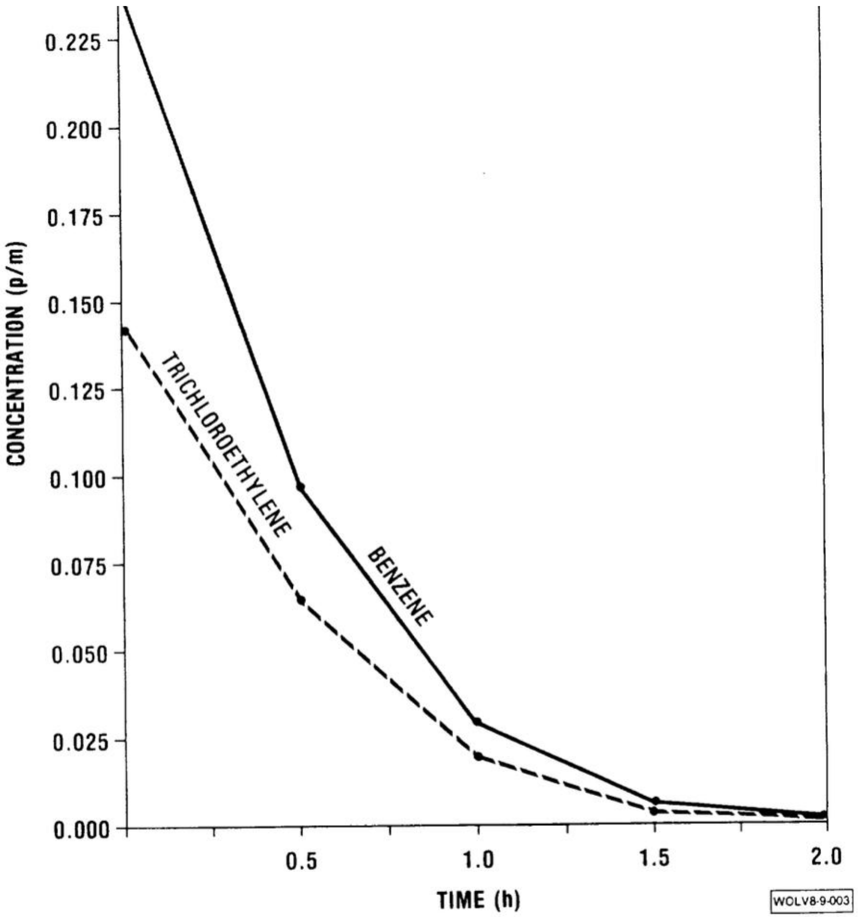


Figure 3. Removal of low concentrations of benzene and trichloroethylene from the air inside sealed experimental chambers using golden pothos in an 8-in. activated carbon filter system.

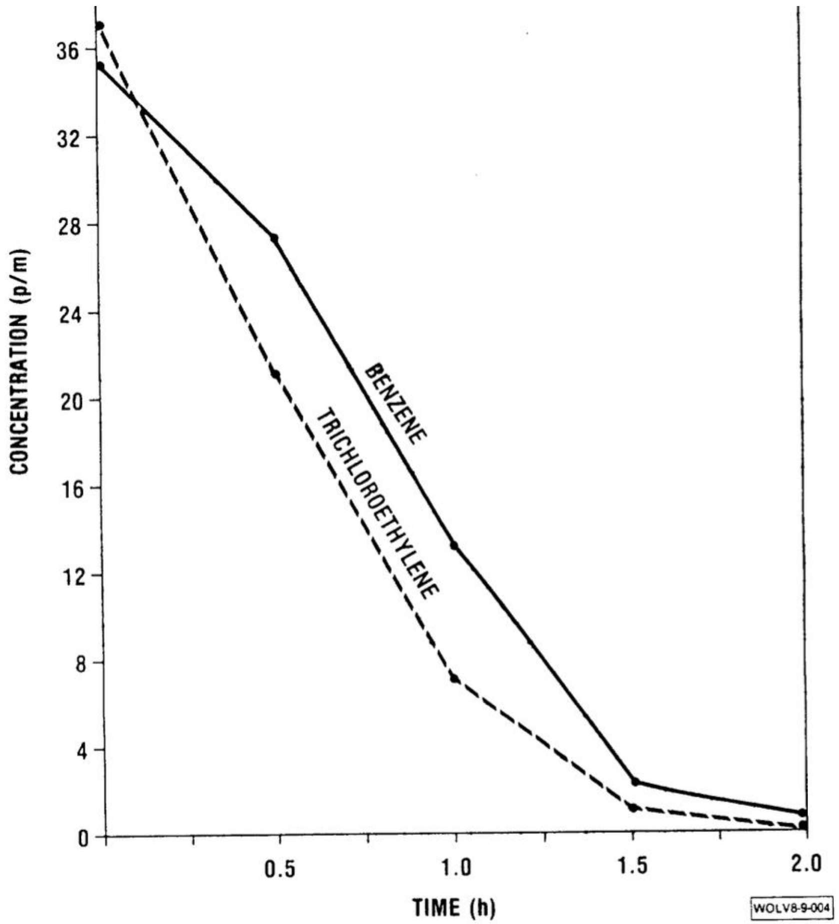
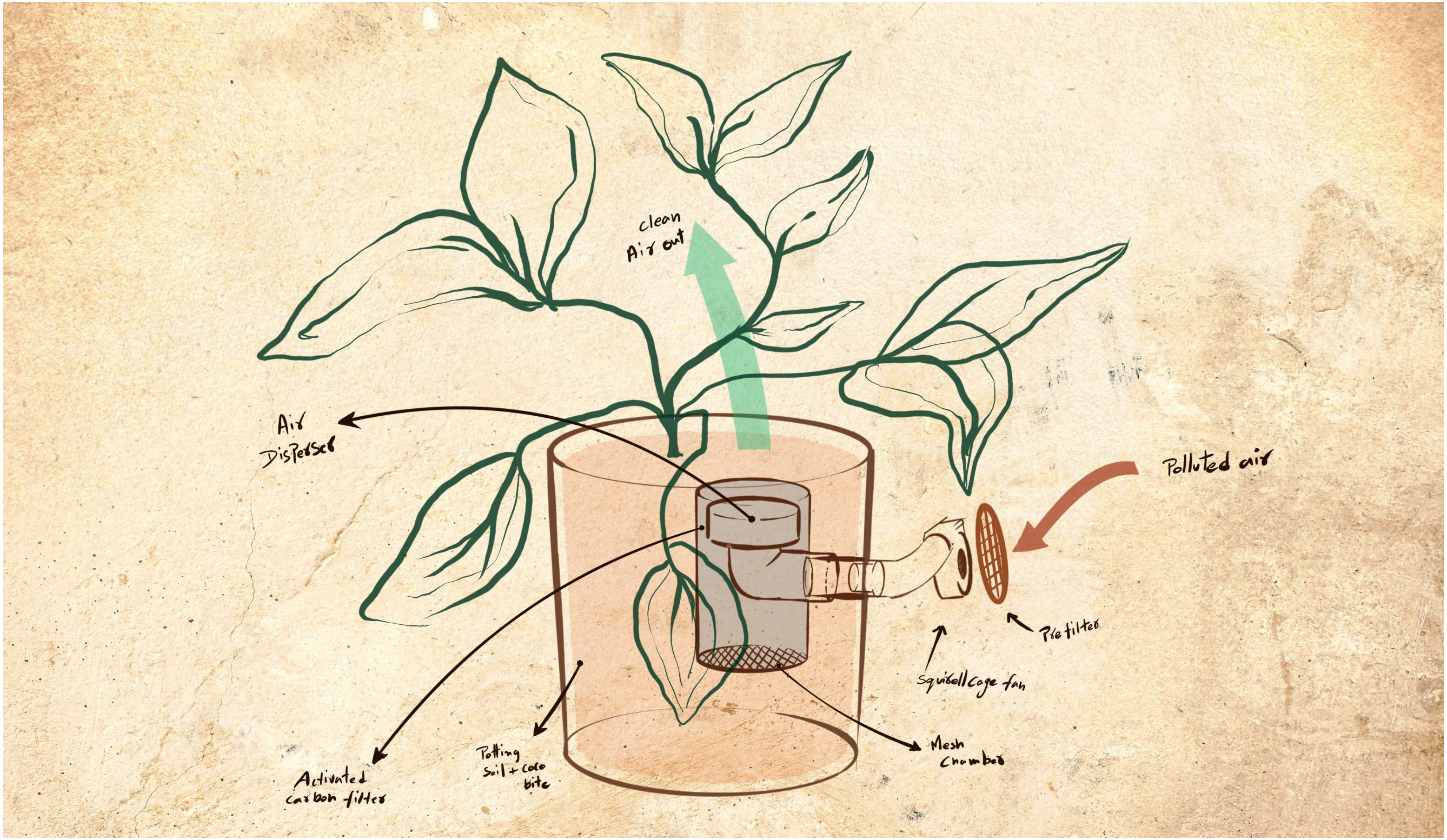
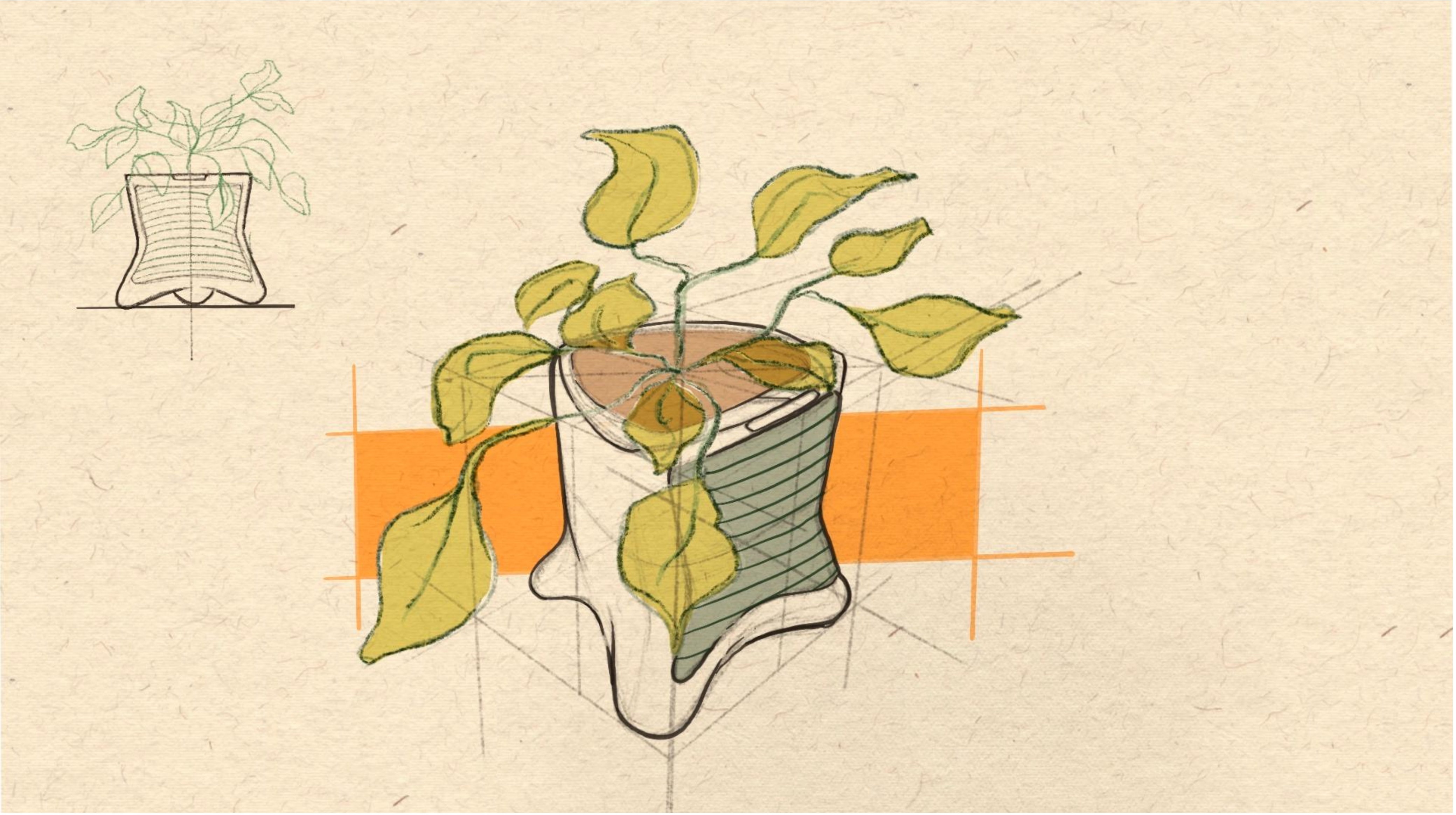
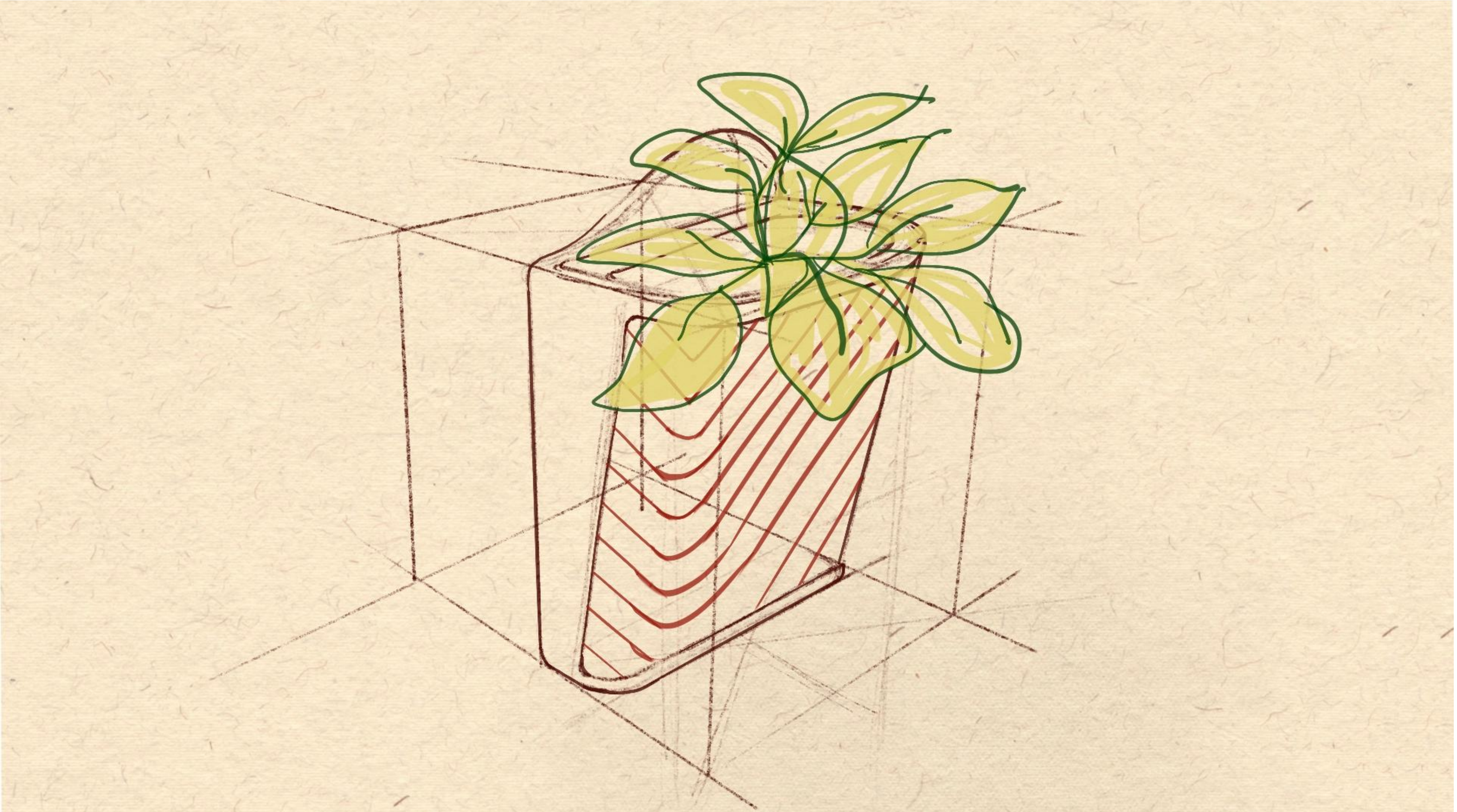


Figure 4. Removal of high concentrations of benzene and trichloroethylene from the air inside sealed experimental chambers using golden pothos in an 8-in. activated carbon filter system.

9. Ideation

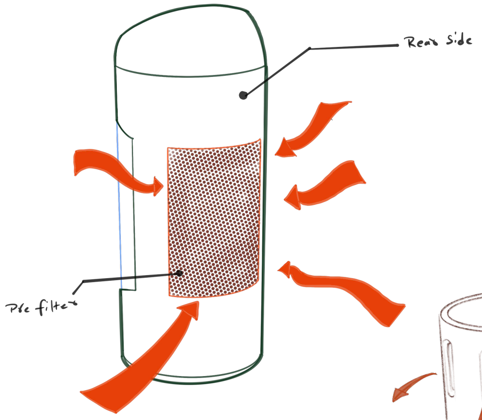

clean
Air out
Air
Disperser
Polluted air
Prefilter
Squirrell cage fan
Mesh
Chamber
Potting
Soil + coco
bite
Activated
carbon filter



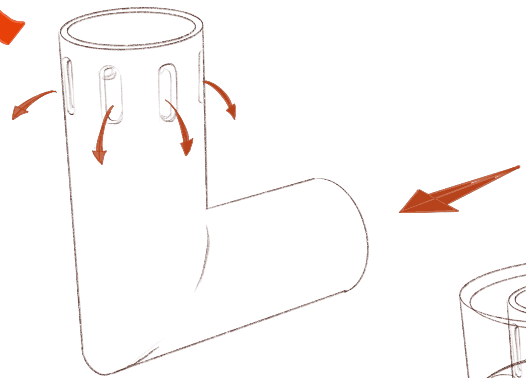


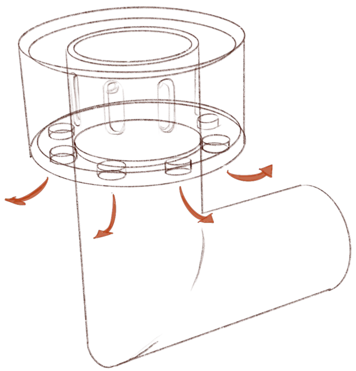
10. Final Design

10.1 HOW ?



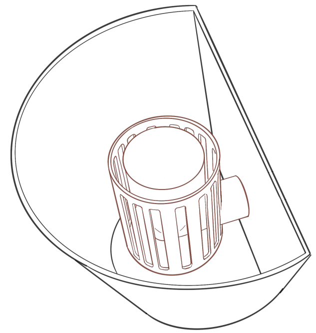
The air blown in via pre filter flows through the following guided provisions





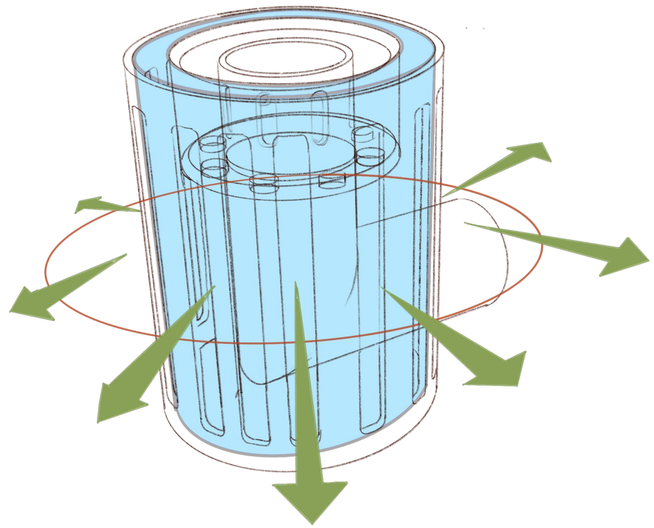
This guided provision ensures that the air flow and the expose to the inner soil and root spaces also doesn't allow flow of water in the reverse direction.

Active chamber then fixed in the plant pot

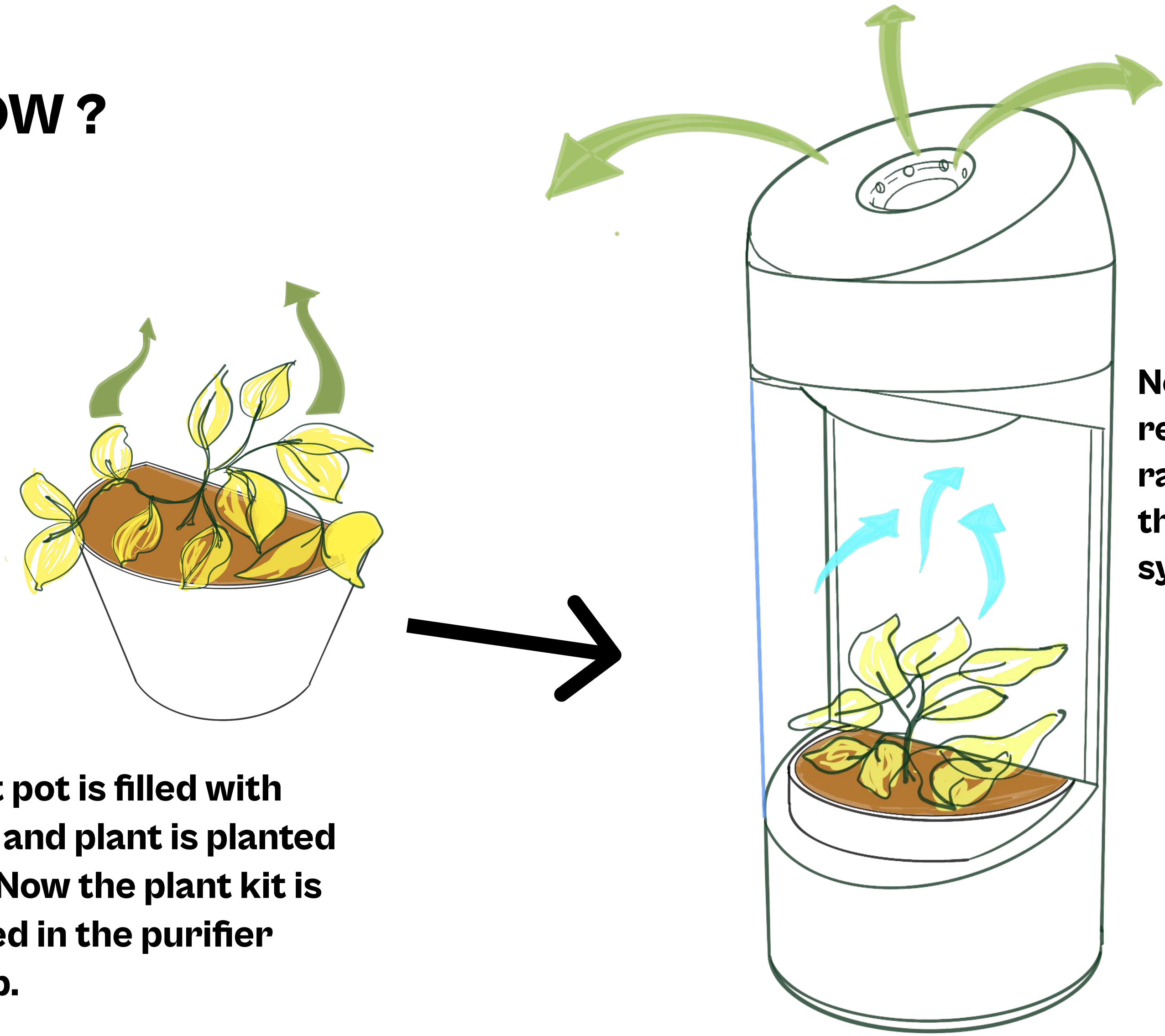


Active chamber

It contains the mixture of Activated Charcoal, Cocopeat and soil.

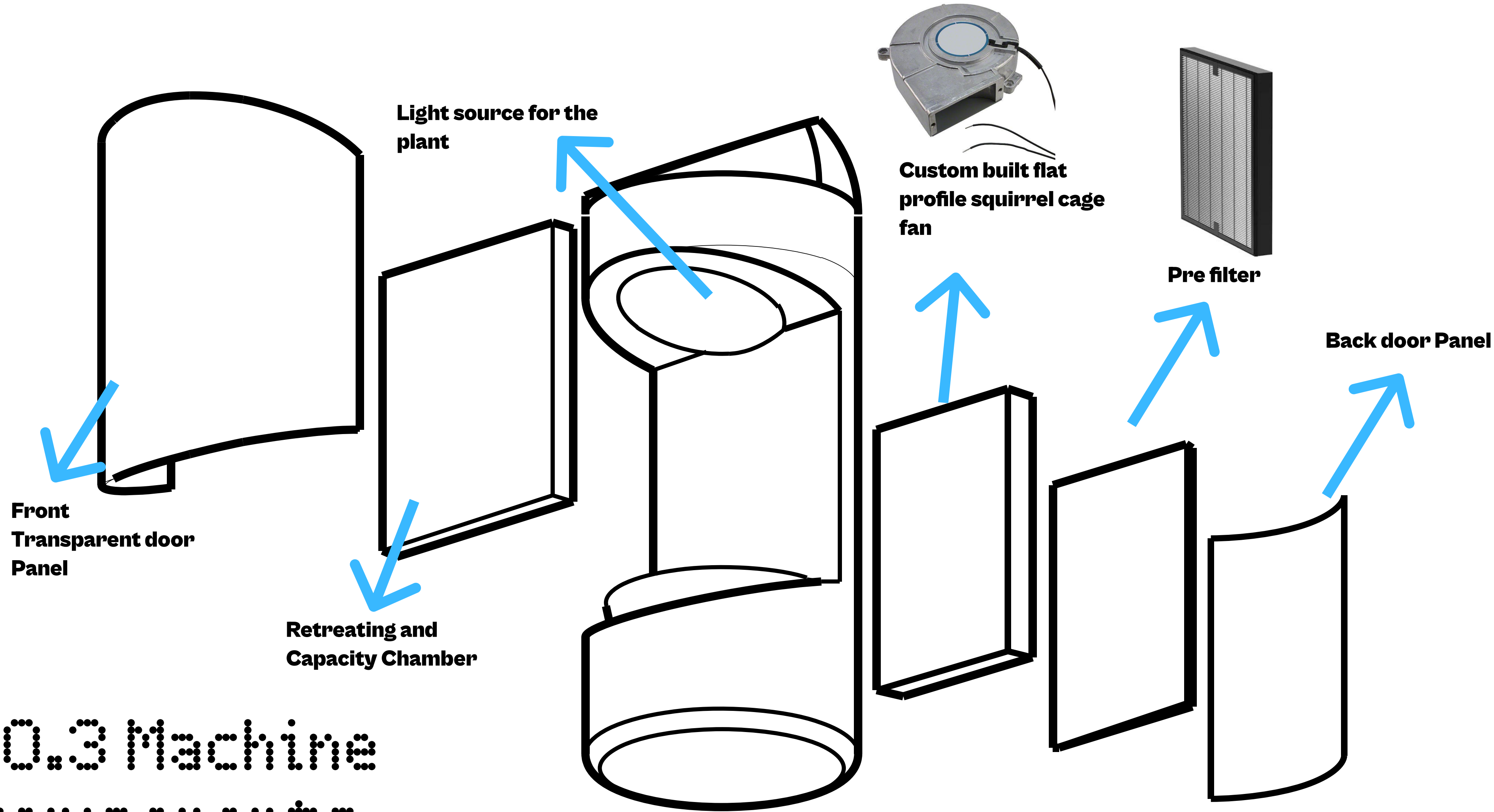


10.2 HOW ?



Plant pot is filled with sand and plant is planted in it, Now the plant kit is loaded in the purifier setup.

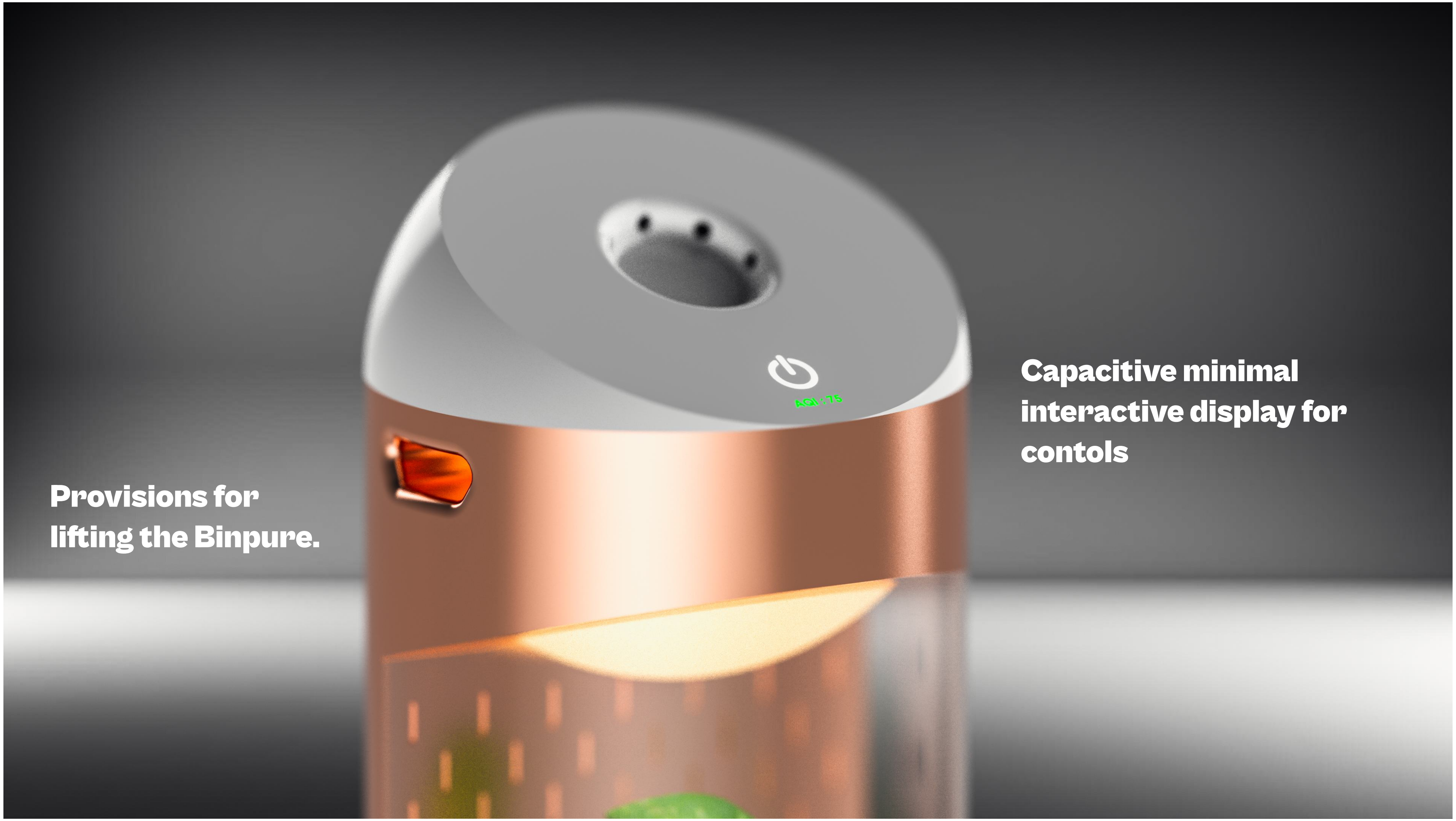
Now the purified air is stored and released with a reduced stable rate of flow in order to maintain the efficiency of this purifying system.



10.3 Machine components

10.4 Renders

10.5 Details


Capacitive minimal interactive display for contols
Provisions for lifting the Binpure.


Closer details of out
take patterned vents
in the in the panel

10.6 Product context

11. References

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