NASA-TM-108057

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HOUSEPLANTS, INDOOR AIR POLLUTANTS, AND ALLERGIC REACTIONS

NASA
7N-45-TM
130481
P.22

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NSTL, MS 39529

TO BE PRESENTED AT:

OTOLARYNGOLOGY, ORTHODONTICS AND SLEEP DISORDERS CONFERENCE

PASS CHRISTIAN, MS

DECEMBER 13 - 14, 1986

(NASA-TM-108057) HOUSEPLANTS, INDOOR AIR POLLUTANTS, AND ALLERGIC REACTIONS (NASA) 22 p

N93-70419

Unclas

Z9/45 0130481

Dr. Theron G. Randolph, was one of the first medical doctors to associate indoor air pollution with allergies and other chronic illnesses during the early 1950's (1). Since this time, the extent of the problem of indoor air pollution has continued to grow larger.

During the past 25 years, the nature of building materials and household furnishings has dramatically changed. Pressed wood products and fiberboard which emit trace levels of organic chemicals have been used to replace natural wood in building construction. Household furnishings also have changed with increased use of pressed board, plastic and artificial fibers which add additional organics inside homes. Household products such as cleaners, insecticides, glues, air fresheners, hair sprays, shoe polish, magic markers and numerous health care and personal grooming air products add even more synthetic chemicals to the atmosphere inside homes.

The 1973-74 energy crisis aggravated an already increasing indoor air pollution problem. The ventilation rates of new homes, mobile homes, apartments, office buildings, hospitals, nursing homes and condominiums have been decreased to minimize the use of expensive energy in cooling and heating these facilities.

The sealing of these buildings has brought about an increase in allergic reactions and other chronic illnesses resulting from exposure to increased concentrations of hundreds of toxic chemicals.

During this same time period, NASA used a highly sensitive gas chromatograph coupled with a mass spectrometer (GC/MS) to monitor the atmosphere inside the spacecraft during the Skylab missions. Results from these studies demonstrated the presence of over 300 volatile organic compounds (VOC) in the Skylab atmosphere during the occupancy

of the Skylab III crew. Of this number, 107 were identified. Twelve are listed in Table 1 (2).

Ten years later, in 1983, EPA studies identified more than 350 volatile organics in five different locations in a Washington, DC home for the elderly (5,6). Twelve of these organics are listed in Table 2. Other agencies and researchers have also confirmed the presence of large numbers of trace organics inside modern buildings (7 - 27). The numbers and types of these organics demonstrate the serious potential health hazards associated with indoor air pollution in modern, energy-efficient buildings and future space stations. A large number of these chemicals not only have the potential for producing allergic reactions but also cancer and other forms of illness.

Recent research by the Environmental Protection Agency (EPA) suggests a rare throat cancer is associated with long-time occupancy of mobile homes. The chief suspect in the causes of the cancer is formaldehyde which is found in higher concentrations inside mobile homes than most other buildings (28 - 30).

As the evidence of health problems from indoor air pollution mounts, the need for simplified practical means of reducing indoor air pollutants becomes urgent.

Research at NASA's National Space Technology Laboratories (NSTL) in south Mississippi during the past 15 years has looked at the use of natural biological processes using microorganisms and higher plants for both wastewater treatment and indoor air pollution abatement. Although, the long range goal of the NSTL research is the development of a bioregenerating life support system for future space stations, Figure 1, the immediate applications of this technology is earthly.

Most of the NSTL work has been supported by NASA's Technology Utilization (TU) Office and has concentrated on adapting space-developed biotechnology to solving earthly problems in waste treatment and indoor air pollution (31 - 39).

One exciting area of this research is directed toward the use of houseplants for improving the quality of air inside modern buildings. The photosynthetic process that allows plants to live and grow requires a continuous exchange of gaseous substances between plant leaves and the surrounding atmosphere. The most common gaseous substances exchanged are carbon dioxide, oxygen and water vapor. The plant leaves normally give off water vapors and oxygen and take in carbon dioxide. However, it appears that plant leaves can also take in other gaseous substances from the surrounding atmosphere through the tiny openings (stomates) on the leaves. NASA studies with plants have demonstrated the ability of common houseplants such as spider plant, philodendron and golden pothos to reduce the concentrations of indoor air pollutants such as formaldehyde, benzene, and carbon monoxide in sealed experimental chambers, Figures 2, 3 and 4. A clear, cubical chamber measuring 73.7 cm on each side and constructed of 12.7 mm thick Plexiglas, was used in the plant screening process (38).

Because formaldehyde is probably one of the toxic chemicals with the greatest human exposure in the U.S., NASA's initial indoor air pollution studies concentrated on this chemical, Table 3. There are numerous sources of formaldehyde emissions indoors. Formaldehyde is used in urea-formaldehyde foam insulation, plywood, particle board, decorative panels, grocery bags, waxed papers, facial tissues, and paper towels. Many common household cleaning agents contain

formaldehyde in addition to floor coverings, carpet backing, adhesive binders, fire retardants, and permanent-press clothing. Other sources are combustion devices using fuels such as natural gas and kerosene for heating and cooking in addition to smoke from tobacco. A promising concept for designing homes using plants for reducing indoor air pollution is shown in Figure 5.

Another, even more promising technique for using plants to remove indoor air pollutants, is to combine the increased treatment capacity of the plant root-microbial-granular activated carbon process with the leaves as shown in Figure 6. This technique has been used very successfully in treating domestic sewage and removing toxic chemicals including radioactive elements from soil and wastewater (35,36,40,41). The process has the potential of rapidly removing relatively large quantities of chemicals and smoke from indoor air and biodegrading these substances, Figure 7. The activated carbon-plant root filter may also be capable of removing radon gas from inside homes. Although studies have not been conducted to date using this process with radon, other radioactive elements have been removed from water and soil using plant roots (41).

Interior landscaping design with live plants is an already rapidly expanding practice for offices, lobbies, reception rooms, hotels, hospitals, restaurants, and many institutions. Since more and more people are spending a greater percentage of their time indoors, it is desirable for psychological as well as physiological reasons to bring some of the natural outdoor environment inside. As more data become available on the ability of foliage plants to improve the quality of

air inside buildings, interior landscaping with plants will probably experience an even greater increase in use.

Technology is rapidly becoming available from space research which will allow architects and builders to design and construct environmentally safe facilities, especially in harsh, cold climates where super energy-efficient buildings are a must because of the hostile outside environment. Special lighting for growing plants is available from several prominent vendors to alleviate the necessity of natural sunlight. With proper design and special lighting where necessary, new buildings can provide excellent environments where waste treatment and air purification can be combined inside buildings using only natural processes as depicted in Figure 8.

SUMMARY

1. The technology of using houseplant leaves for reducing volatile organics inside closed facilities has been demonstrated with formaldehyde and benzene.
2. Philodendrons are among the most effective plants tested to date. Philodendron domesticum had demonstrated the ability to remove formaldehyde from small experimental chambers at a rate of 4.31 $\mu g/cm^2$ leaf surface area with initial starting concentrations of 22 ppm. At initial starting concentrations of 2.3 ppm a formaldehyde removal rate of 0.57 $\mu g/cm^2$ was achieved during a 24 hour test.
3. Aleo vera demonstrated a much higher formaldehyde efficiency removal rate than Philodendron domesticum at low formaldehyde concentrations. During a 24 hour exposure period 5 ppm of

formaldehyde were reduced to 0.5 ppm demonstrating a removal efficiency rate of 3.27 $\mu g/cm^2$.

Removal efficiency rates can be expected to decrease with concentration levels because fewer molecules of chemicals come in contact with the leaf surface area.

4. Several centimeters of small washed gravel should be used to cover the surface of pot plants when large numbers of plants are kept in the home. The reason for this is to reduce the exposed are of damp potting soil which encourages the growth of molds (fungi).

5. The leaves of Philodendron domesticum and golden pothos (Scindapsus aureus) have also demonstrated their ability to remove benzene and carbon monoxide from closed chambers.

6. A combination of activated carbon and plant roots have demonstrated the greatest potential for removing large volumes of volatile organics along with smoke and possible radon from closed systems. Although fewer plants are required for this concept a mechanical blower motor must be used to pull or push the air through the carbon-root filter. NASA studies on motor sizes and bioregeneration rates should be completed by 1988.

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TABLE 1

Twelve of the 107 Volatile Organics Identified in the Atmosphere of Skylab 3.

	Concentration, ppb		
Organic	11th Day	46th Day	77th Day
Acetone	7895.0	7098.0	2760.0
Freon–112 & 113	5907.0	8553.0	8446.0
Toluene	1647.0	1040.0	1717.0
2-Butanone	1505.0	1222.0	665.0
Xylene (total)	515.0	384.6	406.5
Ethylacetate	454.0	390.0	221.0
Dichloroethane	454.0	224.0	213.0
Benzene	116.0	70.1	38.6
Benzaldehyde	114.0	62.4	102.0
Heptene	88.0	52.0	116.0
Dichlorobenzene	25.6	13.0	24.8
Naphthalene	90.9	59.8	113.0

TABLE 2

Twelve of the More Than 350 Volatile Organics Identified in a Washington, D.C., Home for the Elderly: March 1983

Acetone	Methylene Chloride
Benzene	Tetrachloroethylene
Carbon Tetra Chloride	Toluene
Chloroform	1,1,1-Trichloroethane
Dichlorobenzene	Trichloroethylene
Ethylacetate	Xylene

TABLE 3

FORMALDEHYDE REMOVAL DURING A 24 HOUR EXPOSURE PERIOD

Plants*	Total Formaldehyde in Chamber (µg)			Ave. Leaf Surface (cm^2)	µg Formaldehyde Removal Per cm^2 of Leaf Area	
	Initial	After 6 hr	After 24 hr		6 hr	24 hr
Philodendron oxycardium (heart leaf philodendron)	11,921	5,256	3,455	1,696	3.93	4.99
Philodendron domesticum (elephant ear)	11,575	4,665	1,555	2,323	2.97	4.31
low concentrations	1,209	570	432	1,361	.47	.57
Philodendron selloum (lacy tree philodendron)	11,403	4,665	2,747	2,373	2.84	3.65
Chlorophytum elatum (green spider plant)	12,975	7,319	2,709	2,471	2.29	4.15
Scindapsus aureus (golden pothos)	10,741	4,325	1,854	2,723	2.35	3.26
Aglonema modestum (Chinese evergreen)	11,248	8,238	6,866	1,894	1.59	2.31
Aloe vera	2,592	1,037	259	713	2.18	3.27
Brassaia arboricola (mini-schefflera)	8,333	----	4,904	1,743	----	1.96
Spathiphyllum 'clevelandii' (peace lily)	10,298	6,655	5,387	3,476	1.05	1.41
Peperomia obtusifolia (peperomia)	10,140	6,971	5,387	3,264	0.96	1.46
Dracaena fragrans 'massangeana' (corn plant)	10,003	7,878	5,974	2,934	0.72	1.37
Sansevieria trifasciata (mother-in-law tongue)	9,330	5,636	2,954	4,881	0.76	1.31
Tradescantia sillamontana (oyster plant)	10,298	7,341	5,704	6,843	0.43	0.67

*Average of three or more different experiments

FIGURE 1

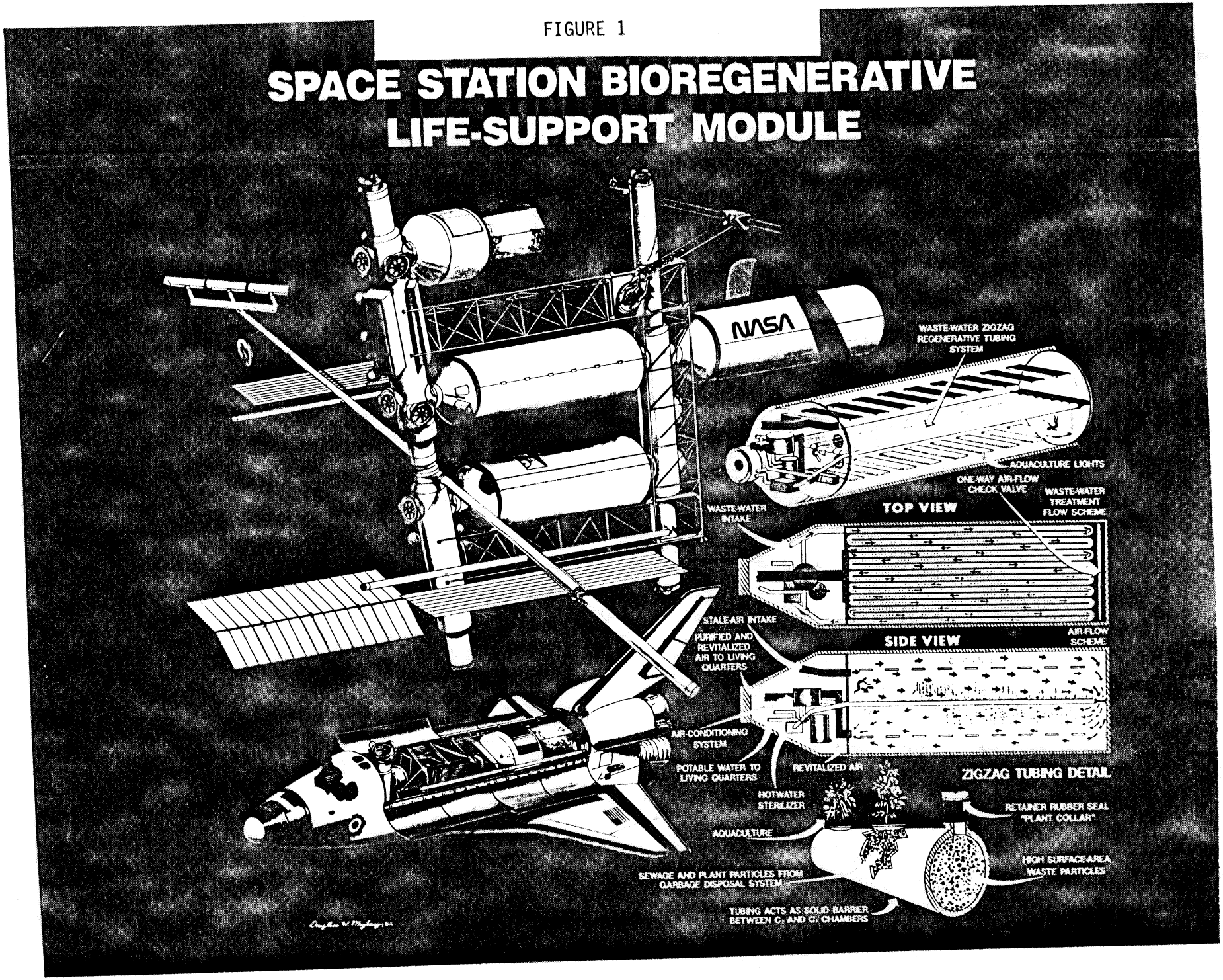

SPACE STATION BIOREGENERATIVE
LIFE-SUPPORT MODULE
NASA
WASTE-WATER ZIGZAG
REGENERATIVE TUBING
SYSTEM
AQUACULTURE LIGHTS
ONE-WAY AIR-FLOW
CHECK VALVE
WASTE-WATER
TREATMENT
FLOW SCHEME
TOP VIEW
WASTE-WATER
INTAKE
STALE-AIR INTAKE
PURIFIED AND
REVITALIZED
AIR TO LIVING
QUARTERS
SIDE VIEW
AIR-FLOW
SCHEME
AIR-CONDITIONING
SYSTEM
POTABLE WATER TO
LIVING QUARTERS
REVITALIZED AIR
ZIGZAG TUBING DETAIL
HOTWATER
STERILIZER
RETAINER RUBBER SEAL
"PLANT COLLAR"
AQUACULTURE
HIGH SURFACE-AREA
WASTE PARTICLES
SEWAGE AND PLANT PARTICLES FROM
GARBAGE DISPOSAL SYSTEM
TUBING ACTS AS SOLID BARRIER
BETWEEN C_1 AND C_2 CHAMBERS

FIGURE 2

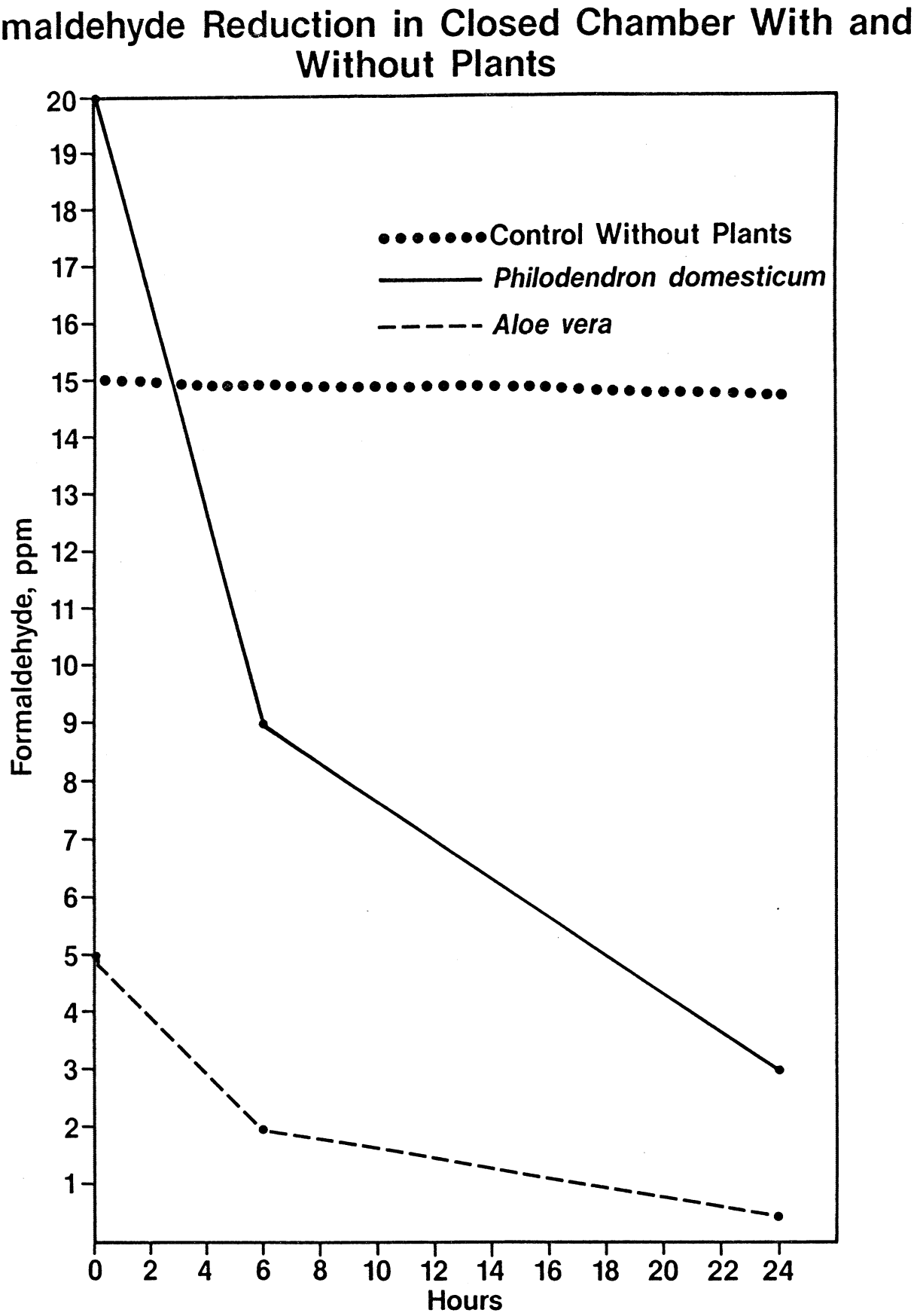
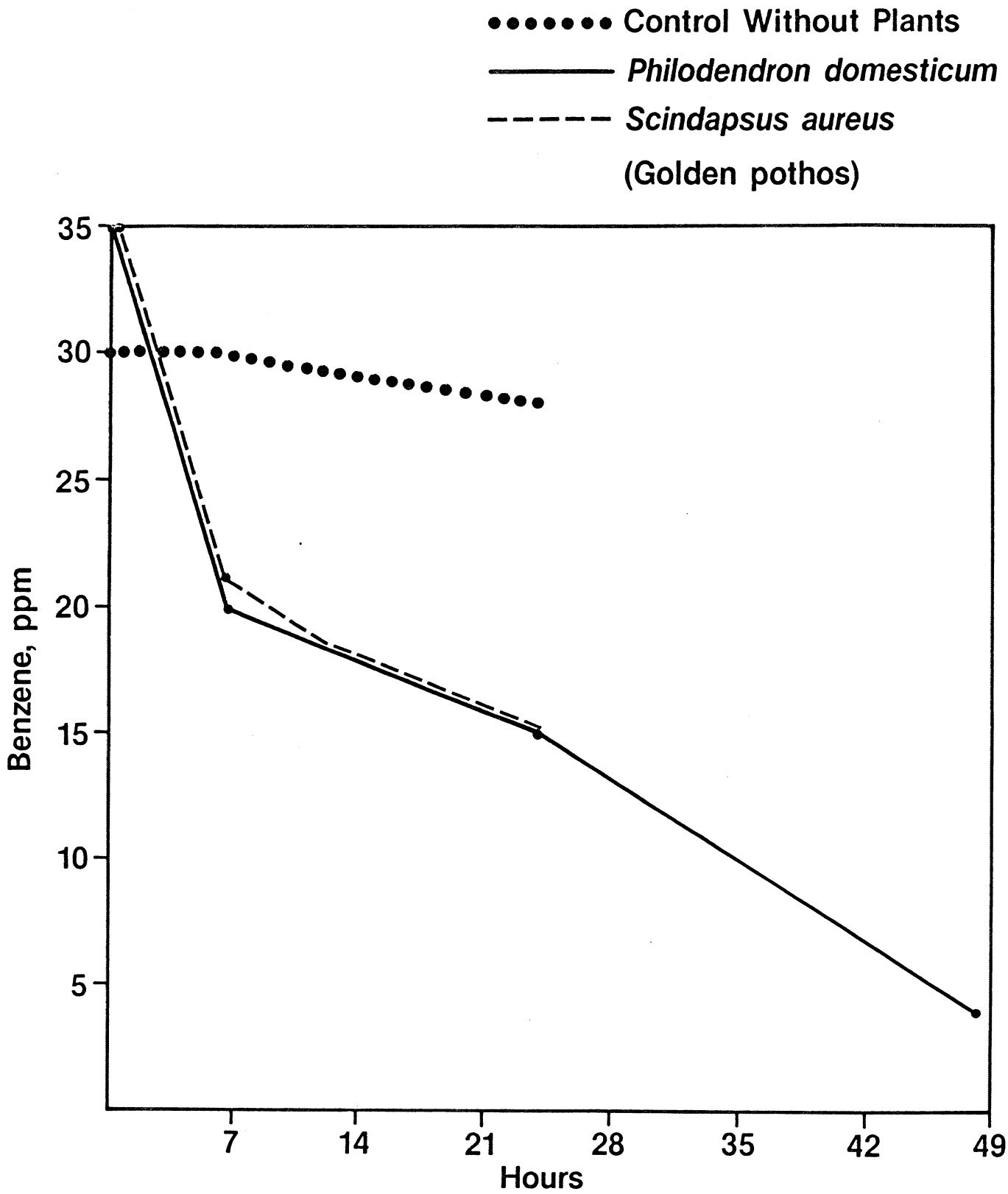

Formaldehyde Reduction in Closed Chamber With and Without Plants
Control Without Plants
Philodendron domesticum
Aloe vera
Formaldehyde, ppm
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
22
24
Hours

FIGURE 3

Benzene Reduction in Closed Chamber With and Without Plants



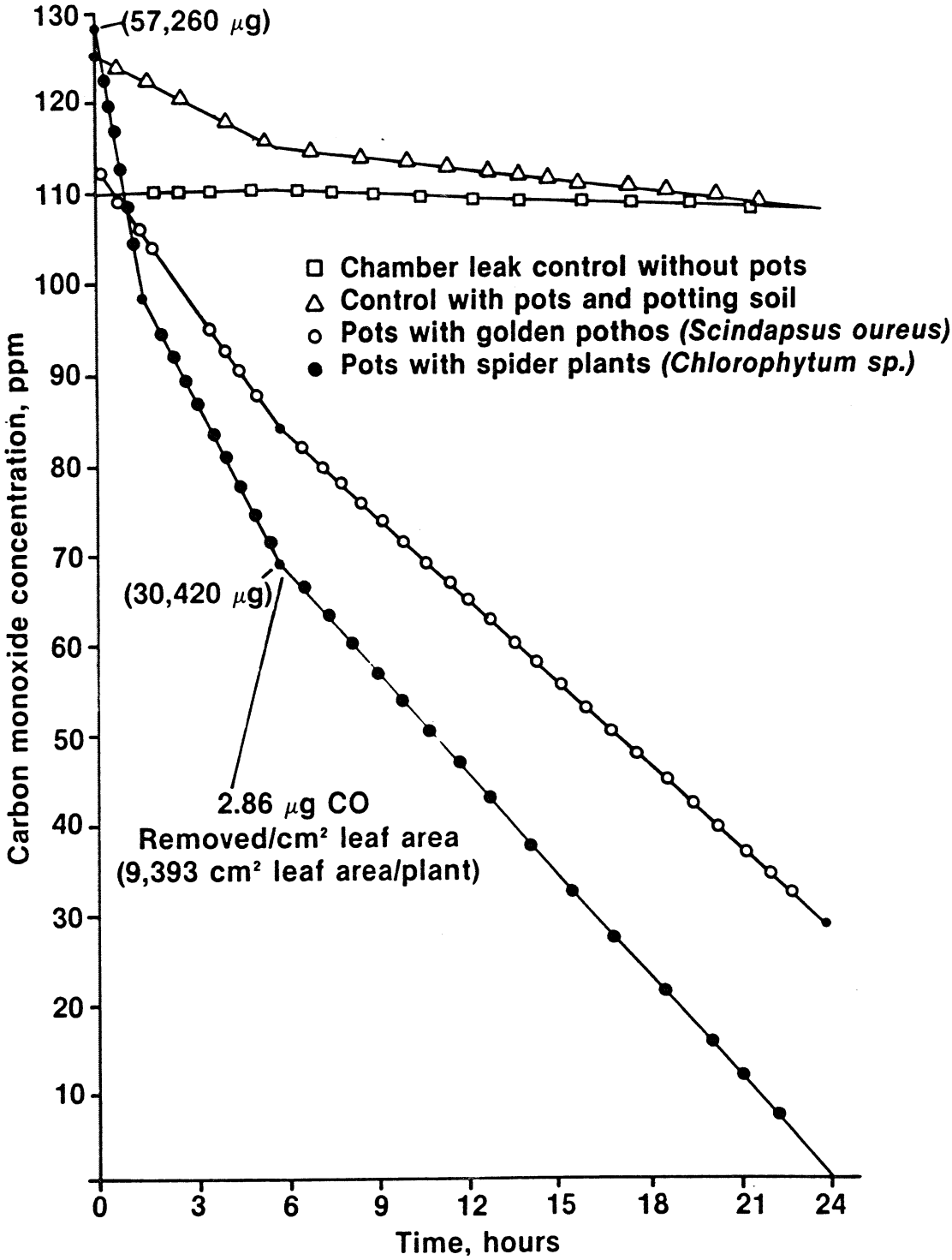


Figure 4. The use of spider plants and golden pothos for removing carbon monoxide from a closed chamber

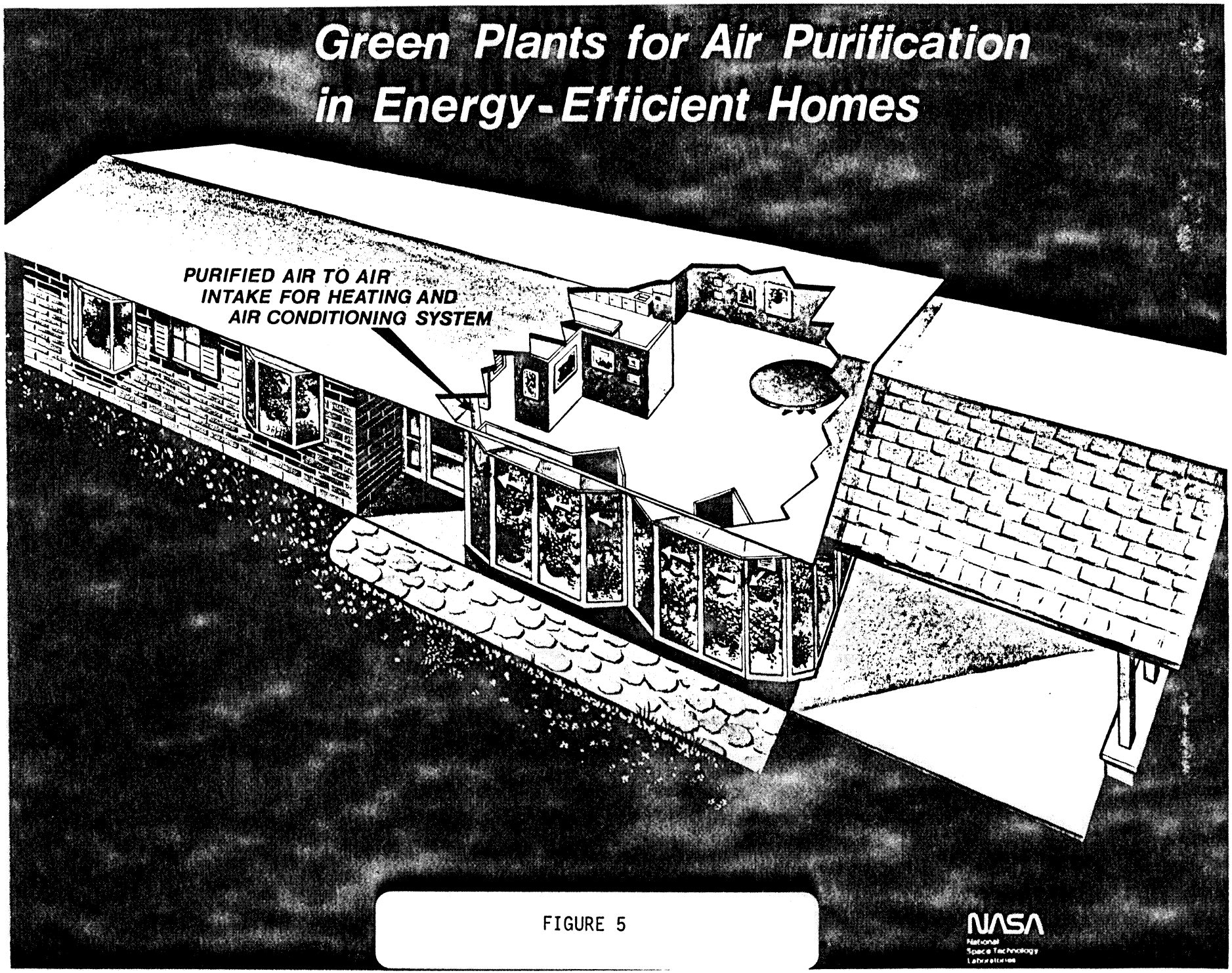

Green Plants for Air Purification
in Energy-Efficient Homes
PURIFIED AIR TO AIR
INTAKE FOR HEATING AND
AIR CONDITIONING SYSTEM
NASA
National
Space Technology
Laboratories

FIGURE 5

INDOOR AIR PURIFICATION SYSTEM COMBINING HOUSEPLANTS AND CHARCOAL FILTERS

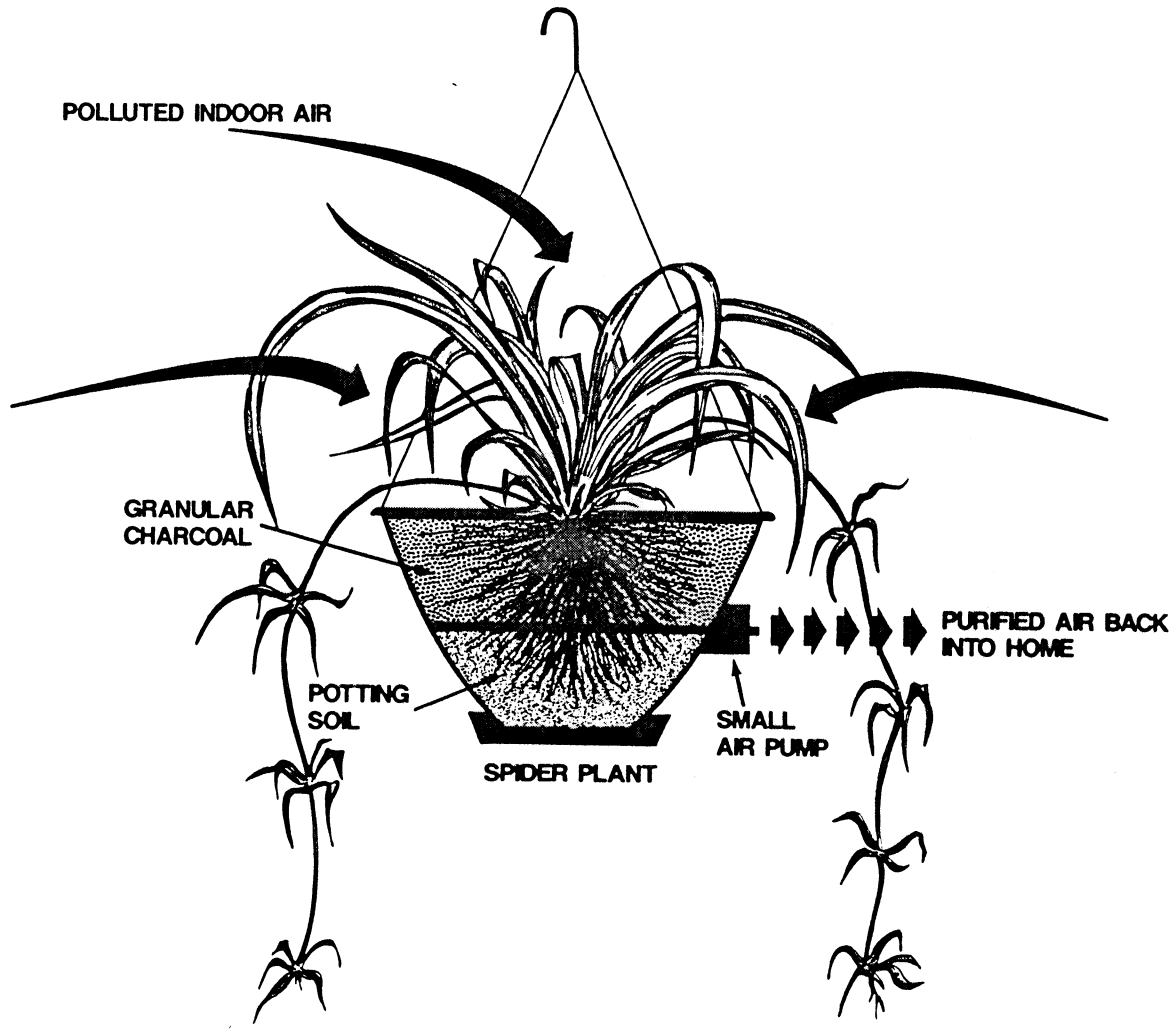


FIGURE 6

FIGURE 7

WINDOW PLANTER COMBINED CARBON AND SPIDER PLANT FILTER SYSTEM FOR REMOVING INDOOR AIR POLLUTANTS FROM ENERGY EFFICIENT CONDOMINIUMS.

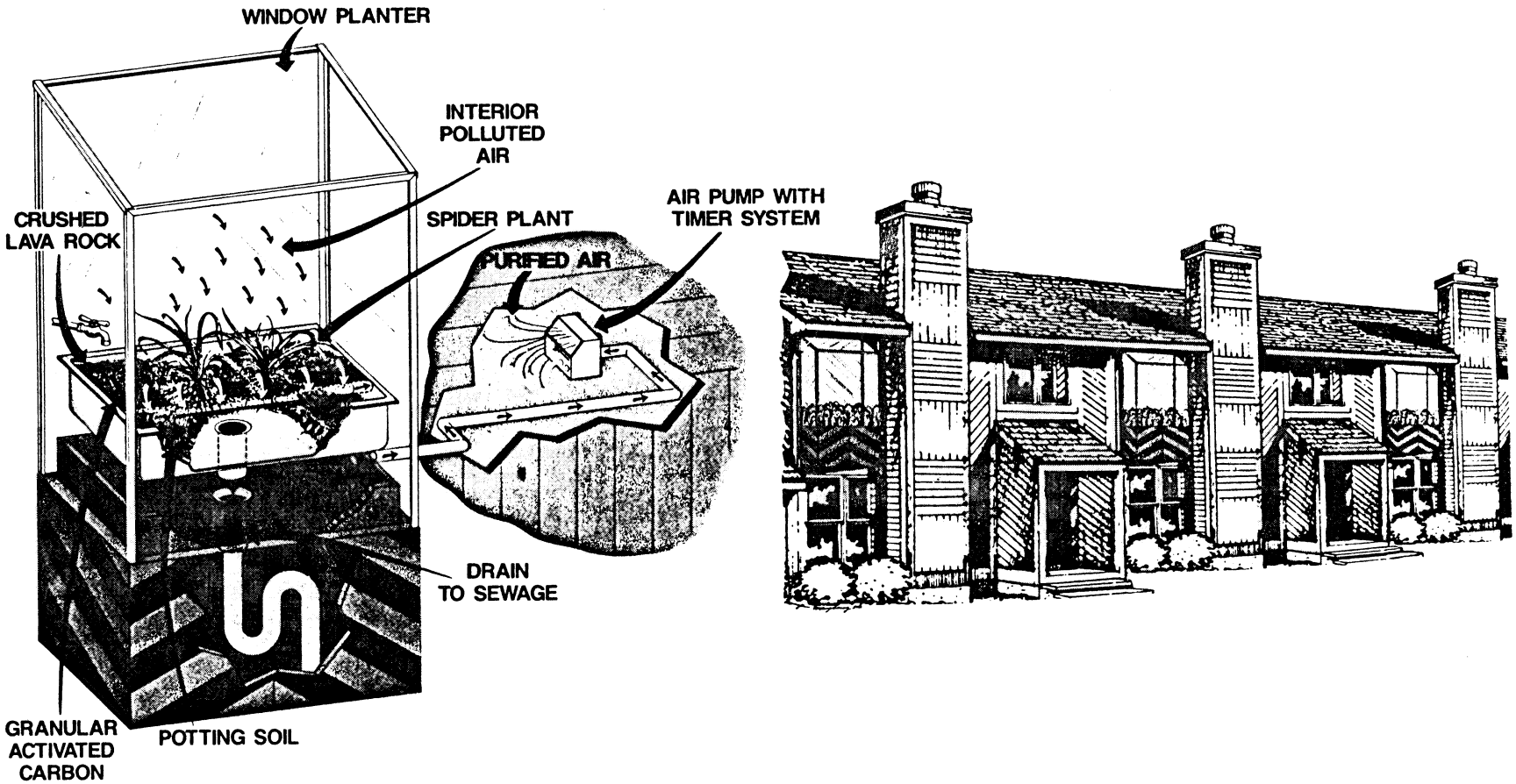
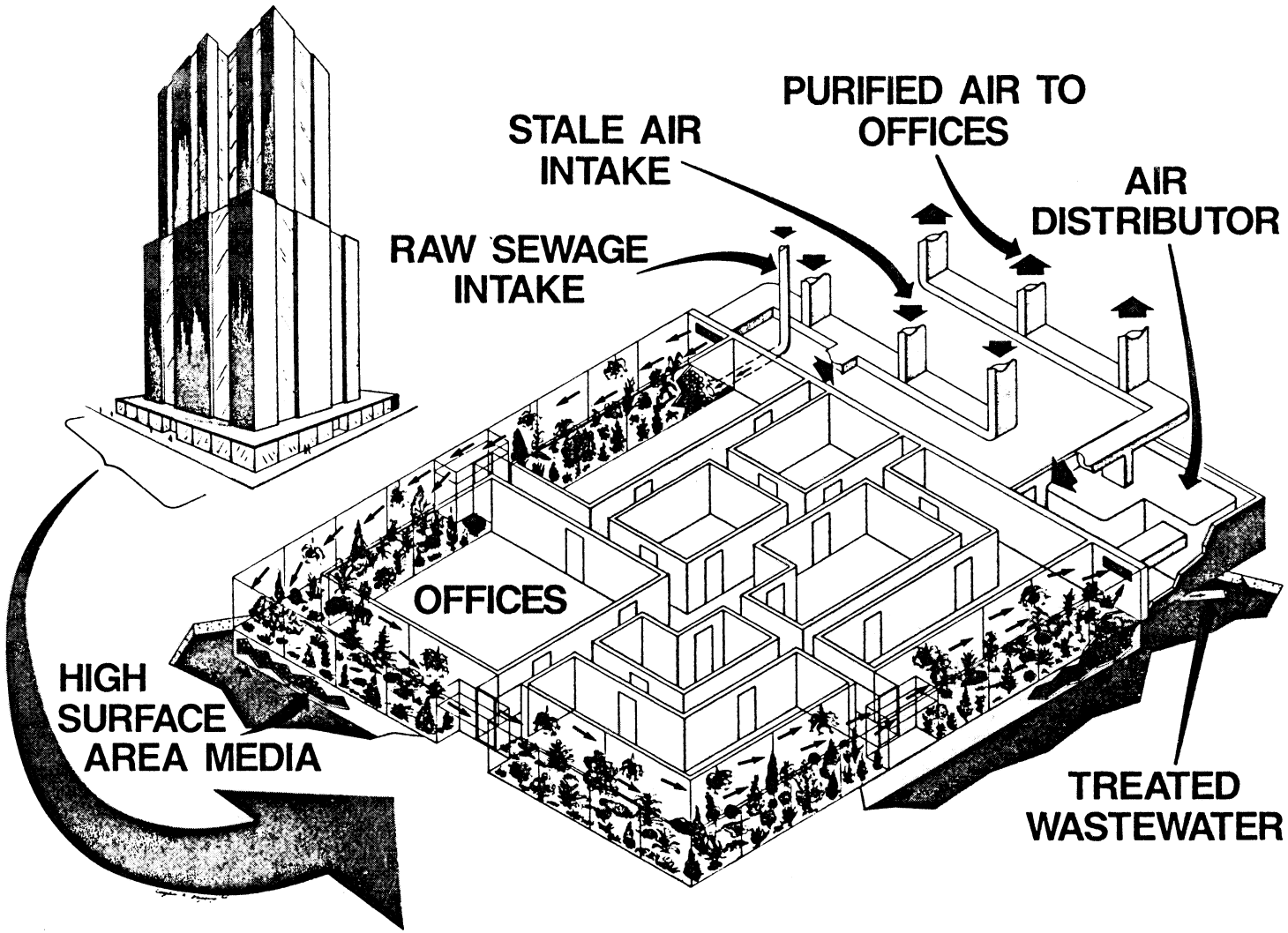


FIGURE 8

BIOLOGICAL AIR AND WASTEWATER TREATMENT SYSTEM FOR ENERGY EFFICIENT BUILDINGS