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SPACE BIO-TECHNOLOGY IN HOUSING

BY:

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During the early 1970's a highly sensitive gas chromatograph coupled with a mass spectrometer (GC/MS) was used to monitor the atmosphere inside the spacecraft during the Skylab missions. Results from these studies demonstrated the presence of over 300 volatile organic chemicals (VOC) in the Skylab atmosphere during the occupancy of the Skylab III crew (1). Of this number, 107 were identified. Twelve are listed in Table 1. The data demonstrated what levels of volatile organic chemicals can be expected when facilities containing man and modern synthetic materials such as in electronic equipment and furnishings are tightly sealed. These findings contributed to a more critical examination of conventional closures and opened up a new era in indoor air pollution and its potential health effects on man. Indoor air quality is not only a problem for future space stations but is a real and immediate problem on earth in some modern buildings.

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 oragnic 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, hair sprays and other health care and grooming aid 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, apartments, office

TABLE 1

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

Organic	Concentration, ppb 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

buildings, hospitals and condominiums were decreased to minimize the usage of expensive electricity and oil for heating and cooling these facilities. Shortly after the ventilation rates were reduced in homes and other buildings, a new ailment termed "sick building syndrome" began to appear (2, 3).

Recently EPA studies identified hundreds of different volatile organic chemicals in schools, office buildings, hospitals and nursing homes, Table 2 (4, 5). Other agencies and researchers have confirmed the presence of large numbers of trace organics inside modern buildings (6-26). Due to the mounting evidence of indoor air pollution problems, the need for simplified methods of purifying and revitalizing the atmosphere inside modern buildings and future space stations has become a necessity.

In the 1970's, NASA scientists at the National Space Technology Laboratories (NSTL) in south Mississippi started looking at natural biological processes for life support systems for future space stations. The NSTL research concentrated on using higher plants and the microorganisms associated with the plants' root systems and surrounding media for bioregenerating air and water while producing food products (27-33).

The Russians have a BIOS Research Facility in Siberia where they have been conducting research for many years on the development of bioregenerating life support systems. They are also using higher plants and have reached a state of development where researchers have been sealed inside their BIOS chamber for up to 5 months. In this totally artificial environment, various agricultural plants produced vegetables, oxygen and purified the air for the inhabitants (34-36).

The long range goal of the NSTL research is the development of a bioregenerating life support system for future space stations. The concept is artistically depicted in Figure 1. The immediate application of this technology is earthly. Most of the NSTL work has been funded through NASA's Technology

TABLE 2

CHEMICALS PRESENT IN ALL INDOOR MONITORING SITES AT HOME FOR THE ELDERLY IN WASHINGTON, D.C.: MARCH 1983†

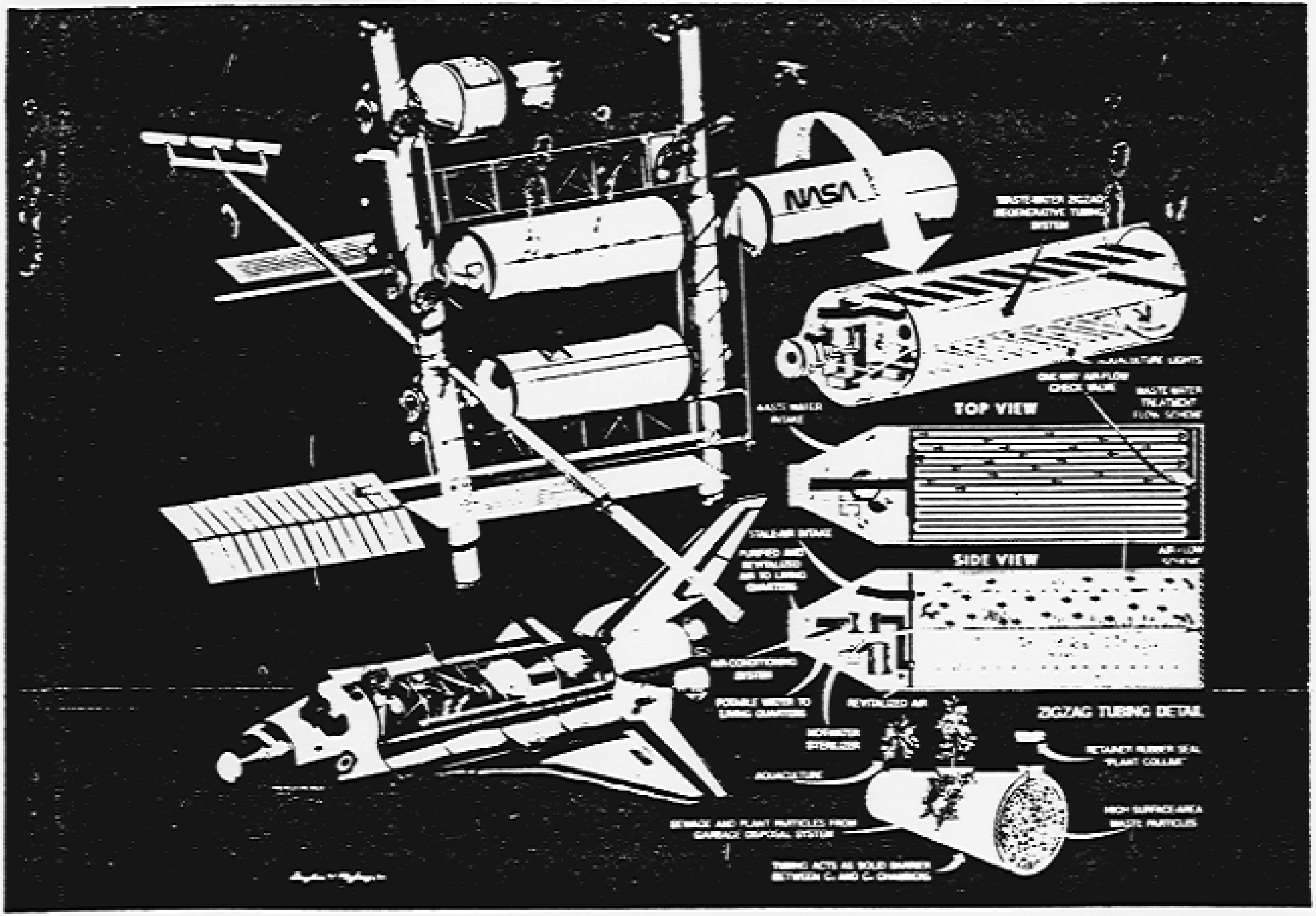
Acetone
*Benzene
*Carbon tetrachloride
*Chloroform
Cyclohexane
Decalin
Decanal
*Decane
*m,p-Dichlorobenzene
1,4-Diethylbenzene
Diethylcyclohexane
*1,4-Dioxane
*Dodecane
Ethyl acetate
Ethylbenzene
Heptane
Hexane
Hexanol
Methylcyclohexane
Methyl decalin
4-Methyldecane
5-Methyldecane
*Methylene chloride
2-Methylheptane
2-Methylhexane
3-Methylhexane
1-Methylnaphthalene
2-Methylnaphthalene
2-Methylnonane
2-Methyloctane
2-Methylundecane
Naphthalene
Nonanal
Nonane
*Octane
Pentane
Propylbenzene
i-Propylbenzene
Propylcyclohexane
*Styrene
*Tetrachloroethylene
Toluene
*1,1,1-Trichloroethane
*Trichloroethylene
Trichlorofluoromethane
1,3,5-Trimethylbenzene
1,2,4-Trimethylcyclohexane
1,3,5-Trimethylcyclohexane
2,2,4-Trimethylhexane
2,4,4-Trimethyl-1-pentene
*Undecane
m,p-Xylene
o-Xylene

* Mutagenic, carcinogenic, or co-carcinogenic properties.

† Wallace, L.A. ''Organics in indoor air: a review of human exposure studies and indoor air quality studies'' in Proc. of the 7th Life Sciences Symposium. p 361-77, published in 1984.

FIGURE 1

SPACE STATION BIOREGENERATIVE LIFE-SUPPORT MODULE



Utilization (TU) Office and has concentrated on adapting space-developed bio-technology to solving earthly environmental problems. This application is conceptualized in Figure 2.

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 (37, 38). NASA studies with plants have demonstrated the ability of common houseplants such as spider plant, Chinese evergreen, syngonium, peace lily, golden pothos, peperomia and banana plants to reduce the concentrations of indoor air pollutants such as formaldehyde and carbon monoxide in sealed experimental chambers, Figures 3 and 4.

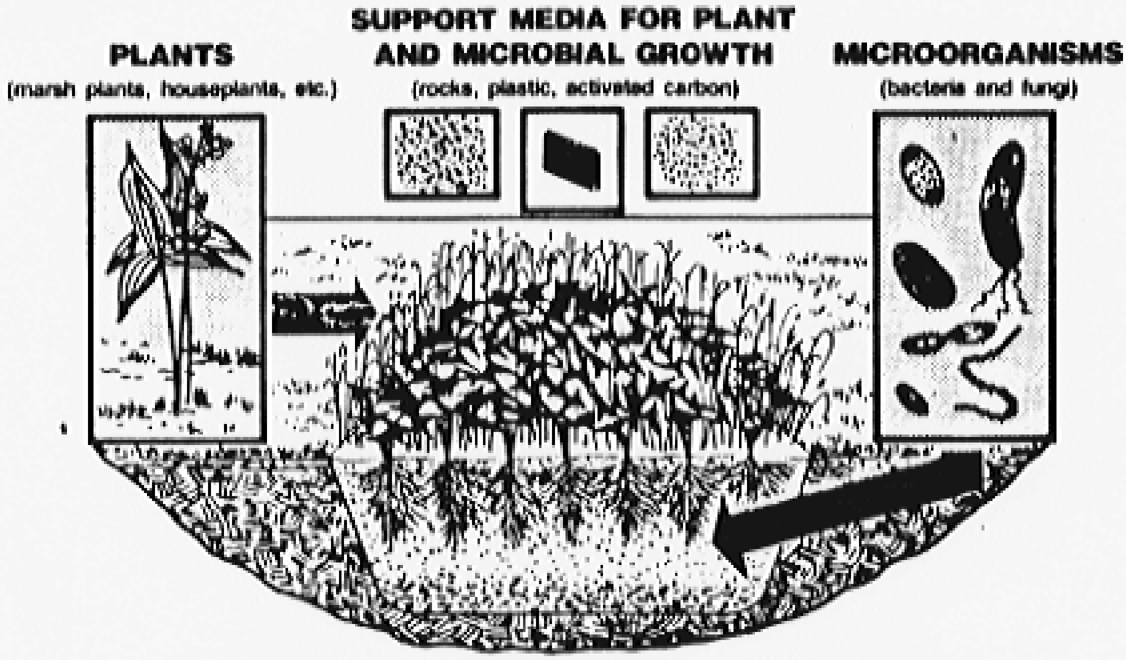
Another even more promising technique for using plants to remove indoor air pollutants is to combine the increased treatment capacity of the plant root-microbial-granular activated carbon process with the leaves as shown in Figures 5 and 6. This technique has been used very successfully in treating domestic sewage and removing toxic chemicals from wastewater (29-33). The process has the potential of rapidly removing relatively large quantities of chemicals and smoke from indoor air and biodegrading these substances, Figure 7.

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

FIGURE 2

BIO-TECHNOLOGY

A TECHNOLOGY OF THE FUTURE



SOME PROMISING APPLICATIONS OF BIO-TECHNOLOGY:

- CLOSED LIFE-SUPPORT SYSTEMS FOR FUTURE SPACE STATIONS
- TREATING DOMESTIC SEWAGE FROM SINGLE HOMES TO LARGE CITIES
- REMOVING INDOOR AIR POLLUTANTS FROM ENERGY-EFFICIENT HOMES, BUILDINGS, SUBMARINES, ETC.
- REMOVING HAZARDOUS CHEMICALS FROM DRINKING WATER, GROUND WATER, AND RIVER WATER
- RECYCLING DOMESTIC SEWAGE INTO POTABLE WATER AND OTHER USES
- REMOVING TOXIC CHEMICALS FROM INDUSTRIAL WASTEWATERS
- REMOVING RADIOACTIVE WASTE AND OTHER HAZARDOUS CHEMICALS FROM CONTAMINATED SOIL AND WATER
- CONVERTING SEAFOOD WASTE INTO USABLE PRODUCTS AND CLEAN WATER
- WATER RECYCLING AND PURIFYING IN INTENSIVE AQUACULTURAL OPERATIONS (FISH, SHRIMP, CRAWFISH, ETC.)
- FUTURE SOURCES OF FOOD, ENERGY, MEDICINE, AND INDUSTRIAL RAW MATERIALS.

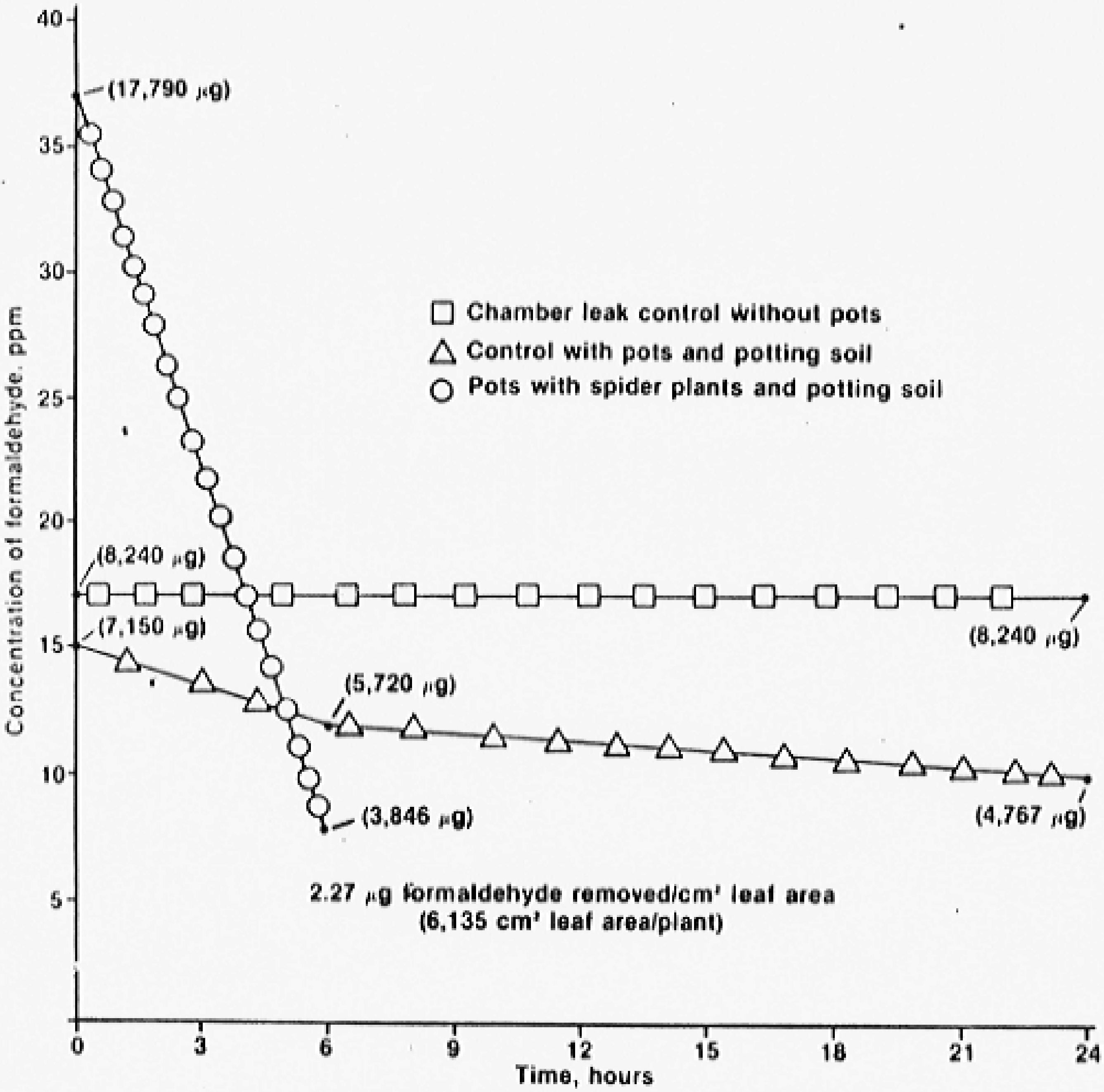


Figure 3. The use of spider plants *(Chlorophyfum sp.)* for removing formaldehyde from a closed chamber

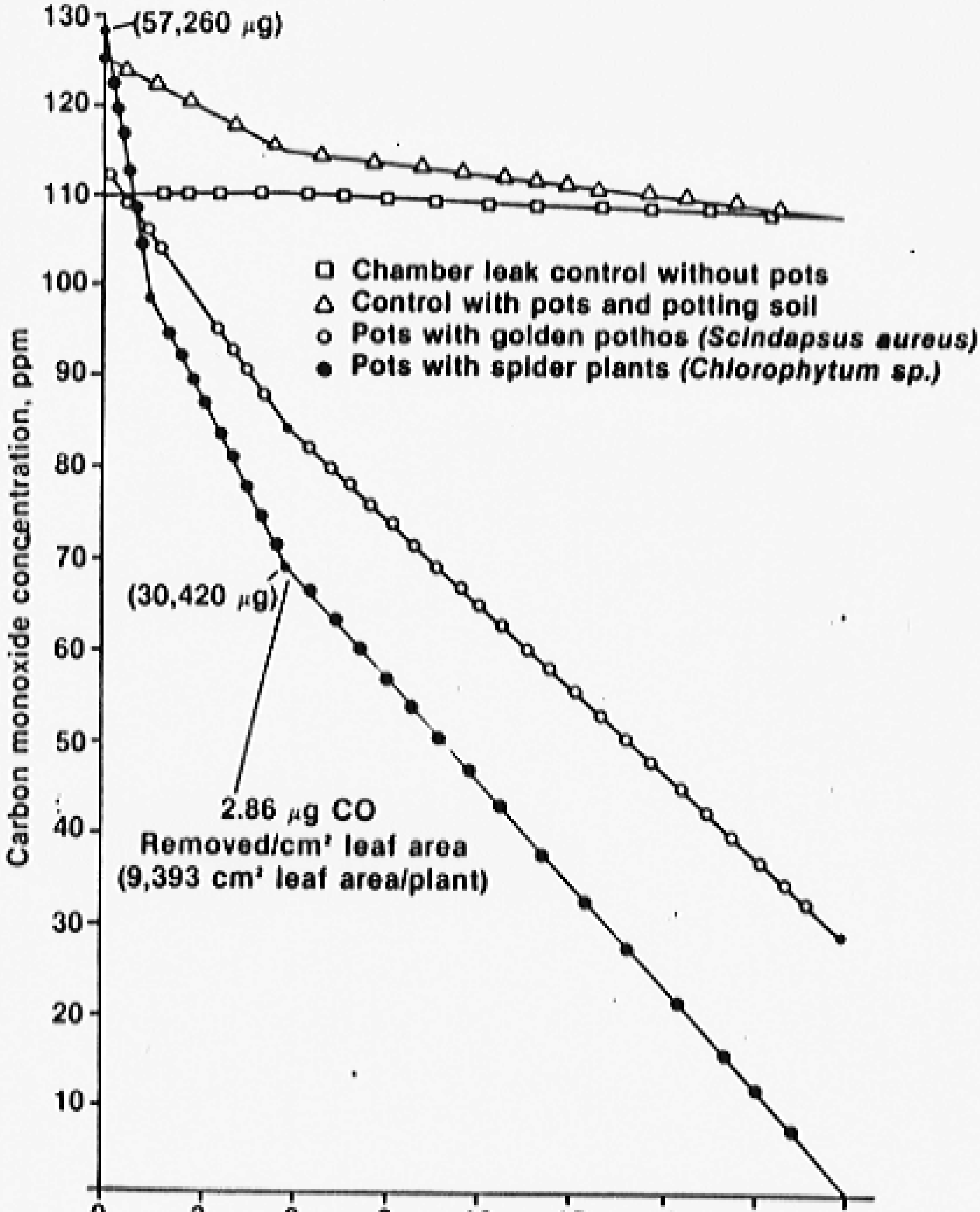


Figure 4. The use of spider plants and golden pothos for removing carbon monoxide from a closed chamber

FIGURE [illegible]

INDOOR AIR PURIFICATION SYSTEM COMBINING HOUSEPLANTS AND CHARCOAL FILTERS

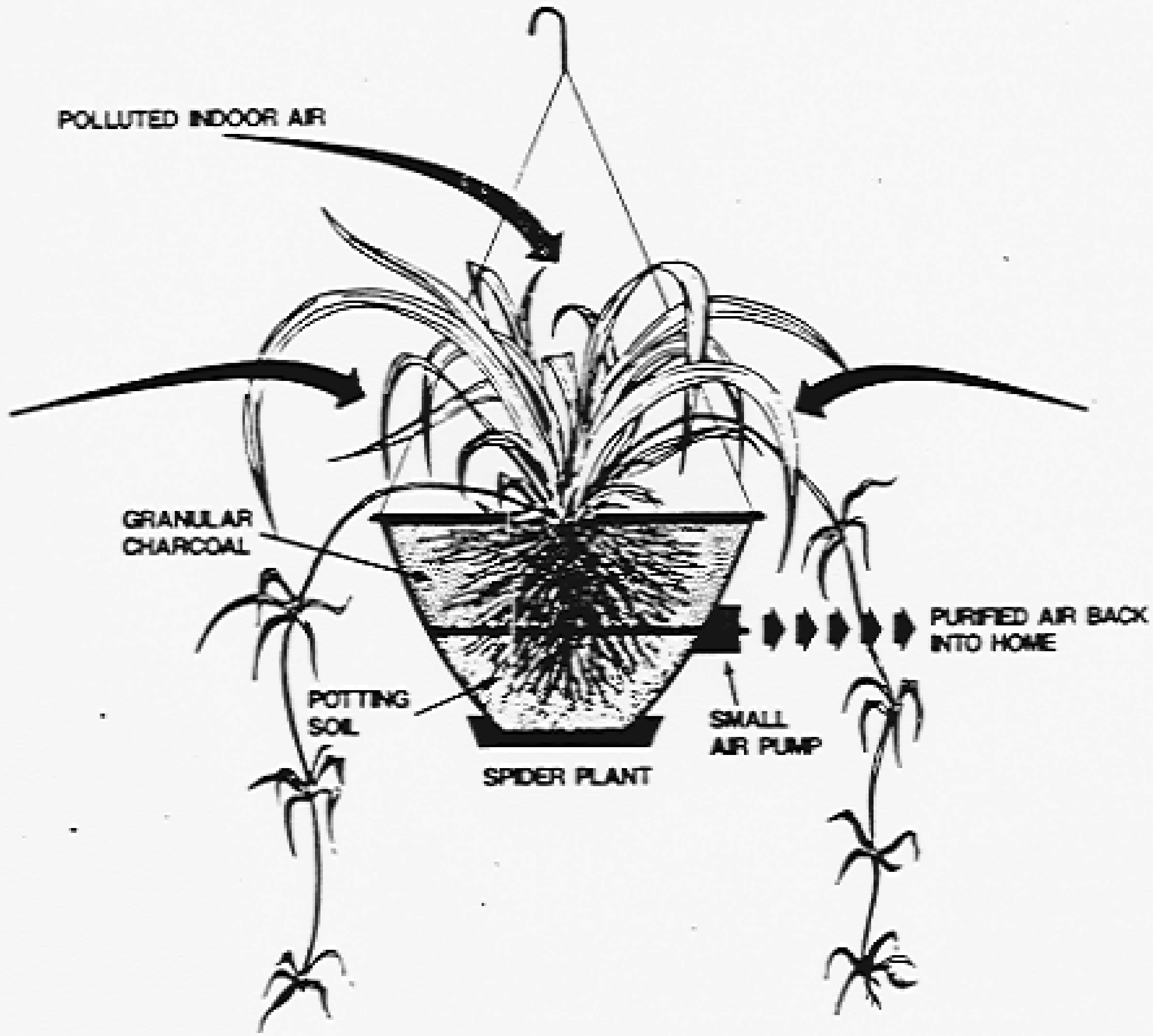
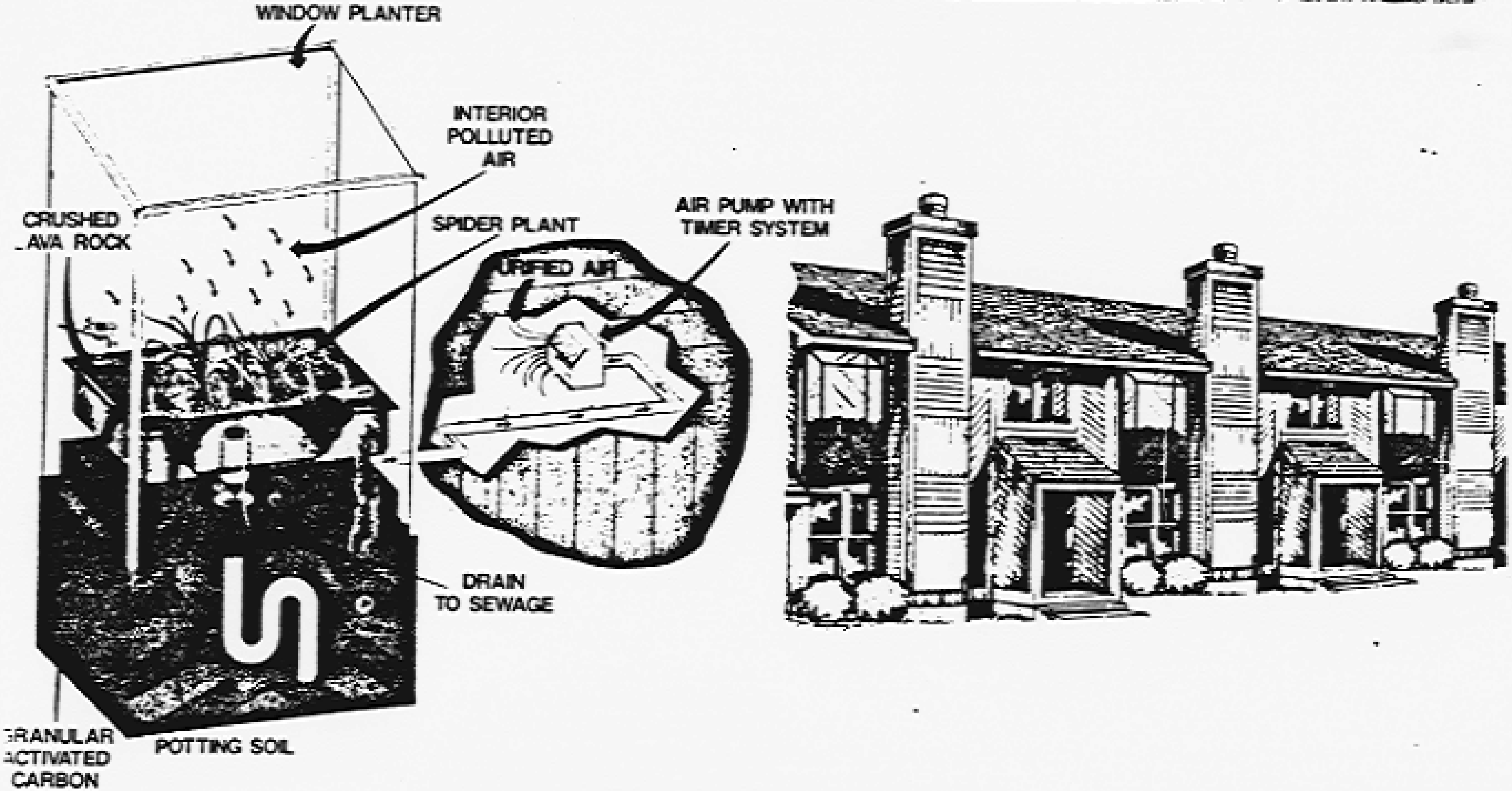


FIGURE 6

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



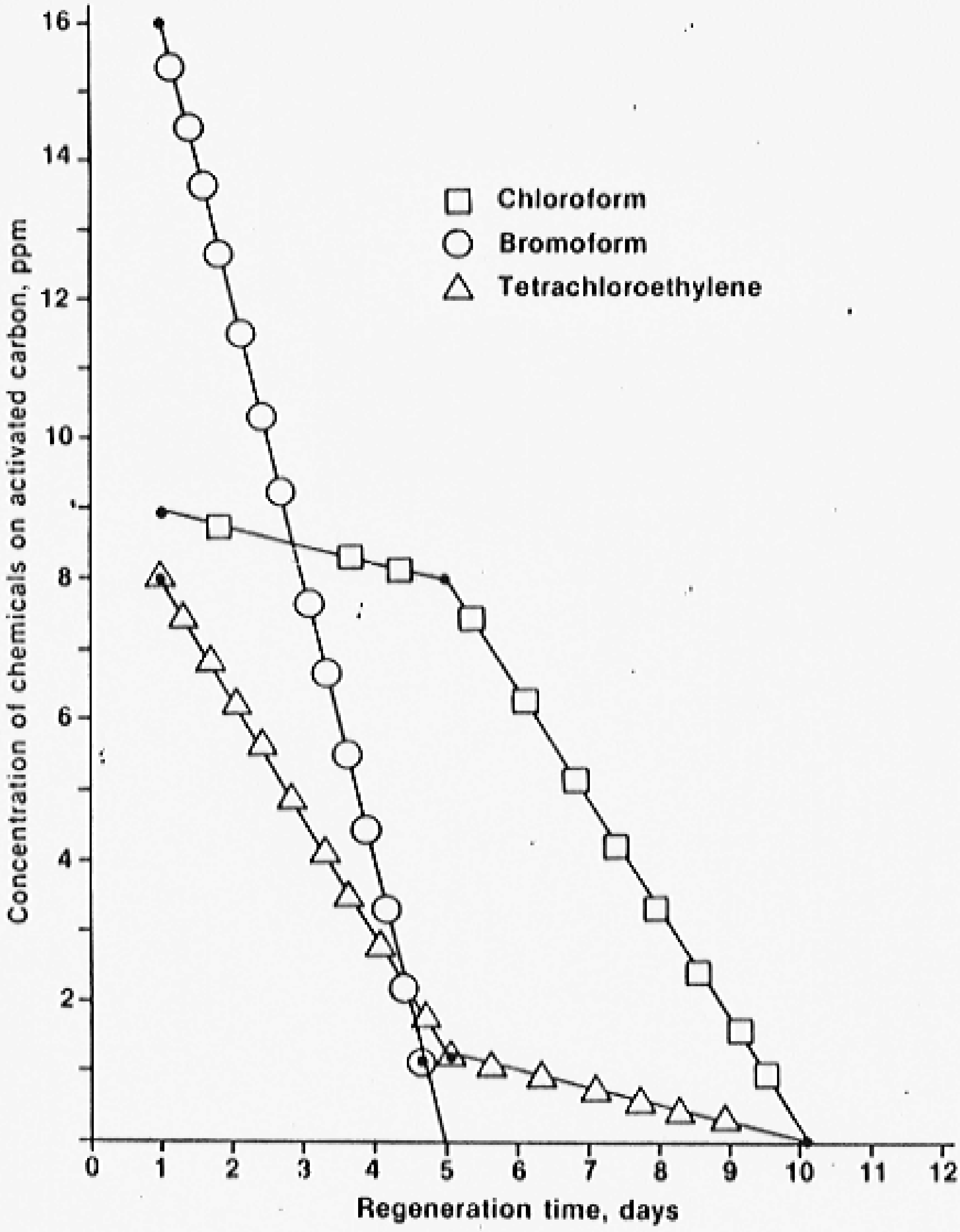


Figure 7. A bioregenerating activated carbon/plant system for removing toxic chemicals from indoor air and contaminated water. The detection limit is <1 ppm.

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, Figures 8 and 9. 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 facilities, especially in harsh, cold climates, that will be super energy-efficient and almost free of the 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 through waste recycling, air purification, and possibly even vegetable production using only natural processes as depicted in Figure 10.

FIGURE 8

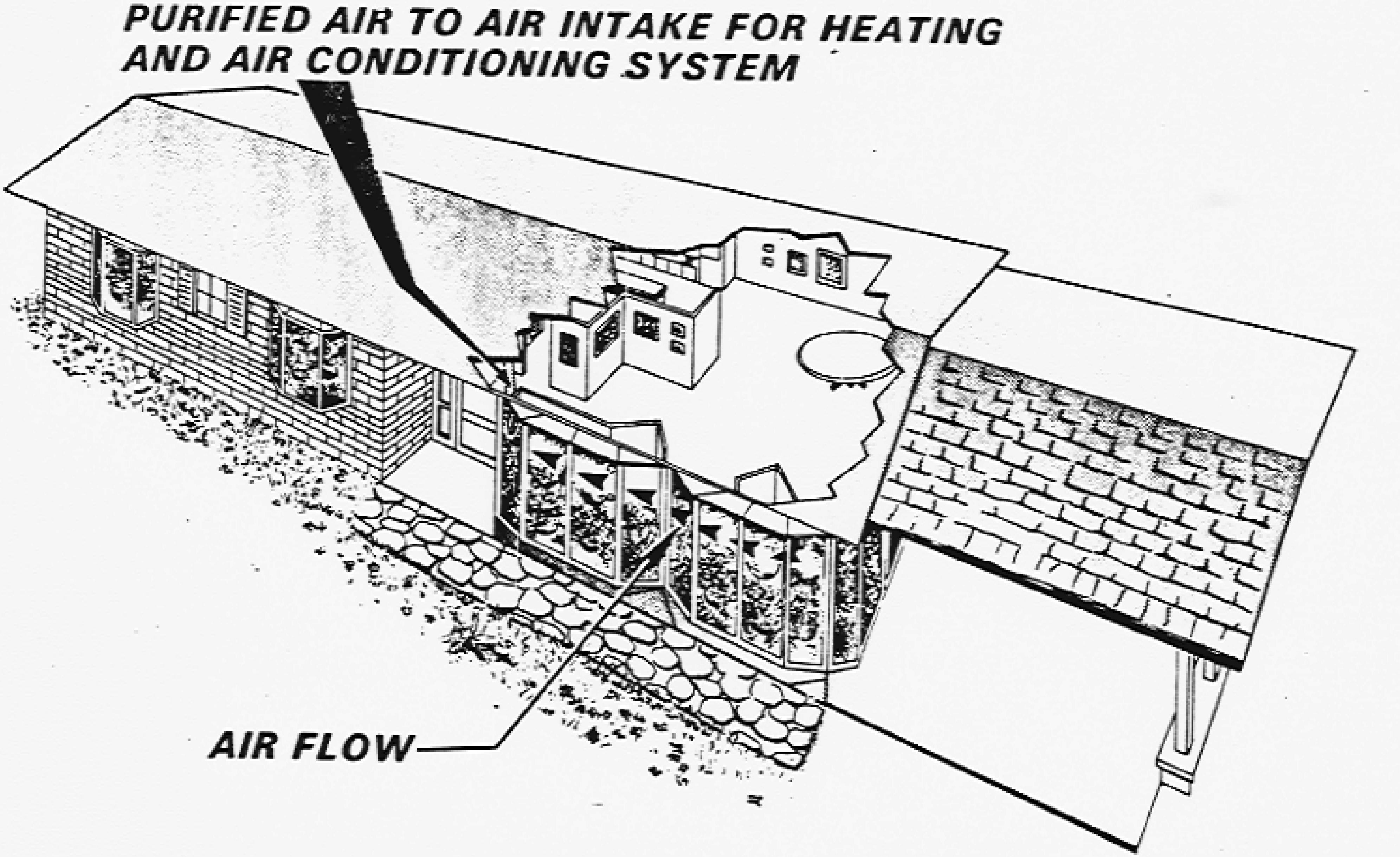

PURIFIED AIR TO AIR INTAKE FOR HEATING AND AIR CONDITIONING SYSTEM
AIR FLOW

FIGURE 9

PLANT SYSTEM FOR PURIFICATION AND REVITALIZATION OF ATMOSPHERE INSIDE ENERGY EFFICIENT BUILDINGS

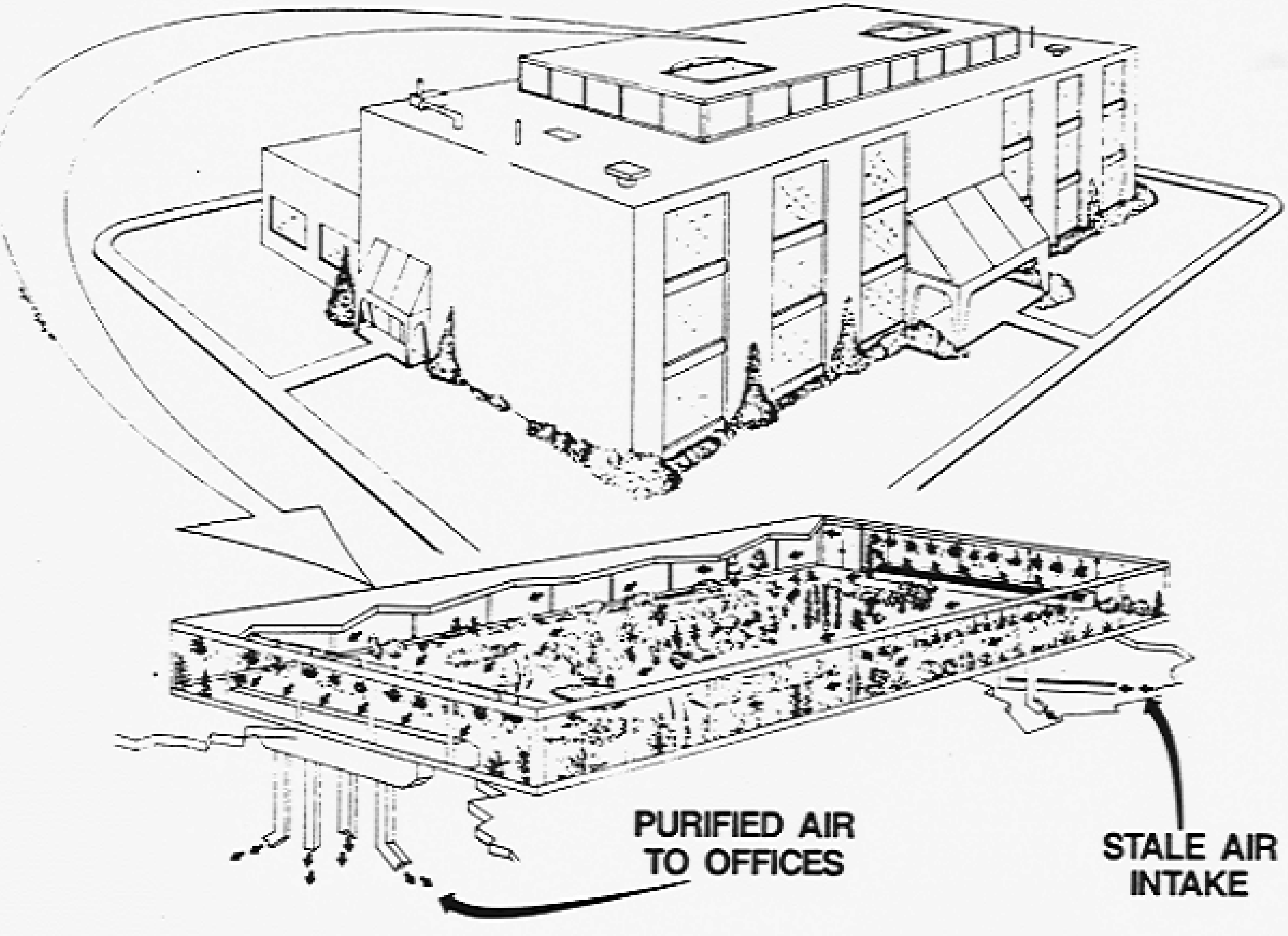
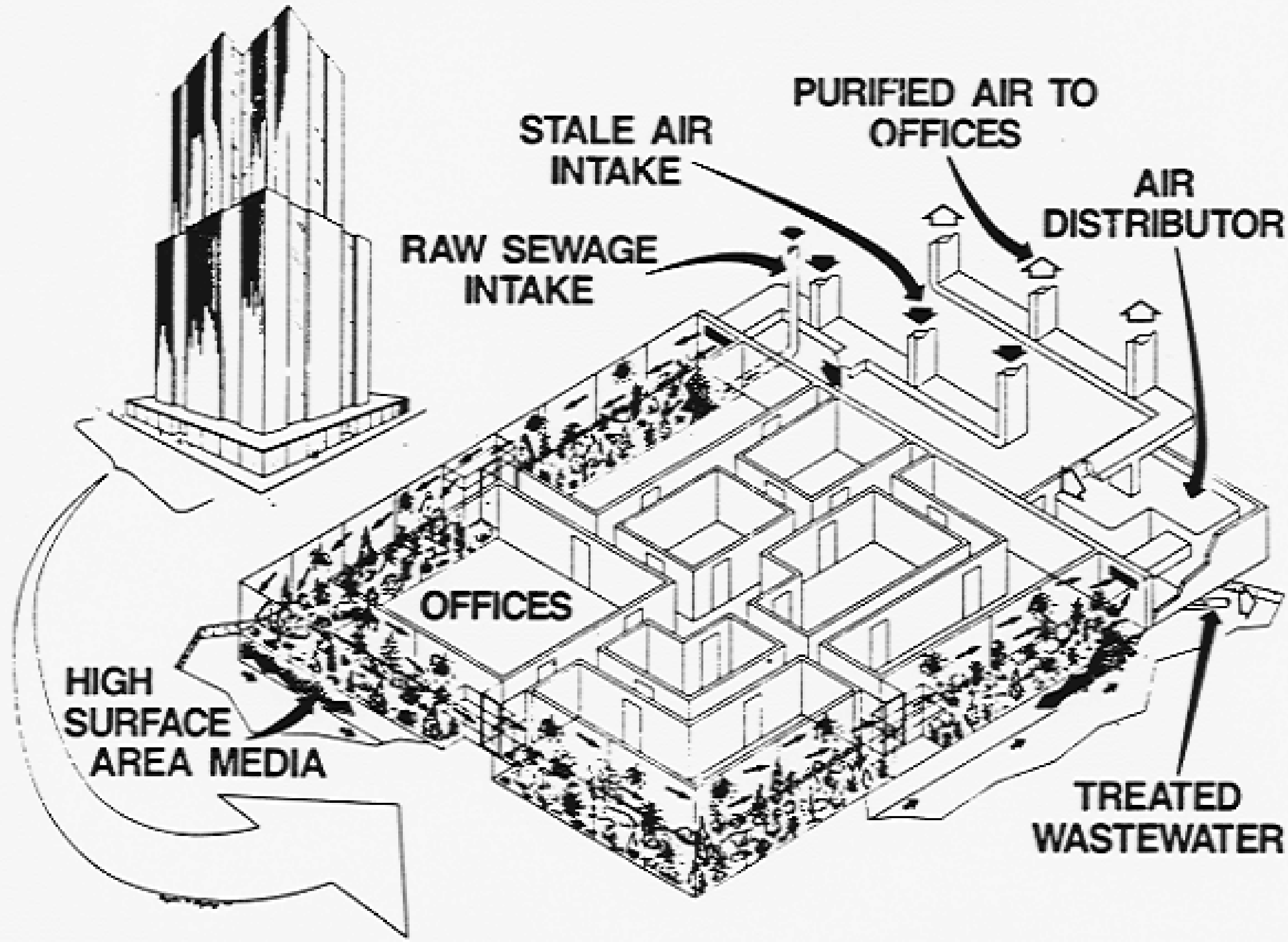


FIGURE 15

BIOLOGICAL AIR AND WASTEWATER TREATMENT SYSTEM FOR ENERGY EFFICIENT BUILDINGS



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