A Study of Interior Landscape Plants for Indoor Air Pollution Abatement

An Interim Report

B. C. Wolverton, Ph.D.
Principal Investigator

National Aeronautics and Space Administration
John C. Stennis Space Center
Stennis Space Center, MS 39529-6000

Willard L. Douglas, Ph.D.
Research Chemist

Keith Bounds, M.S.
Research Chemist

Sverdrup Technology, Inc.
John C. Stennis Space Center
Stennis Space Center, MS 39529

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BACKGROUND:

In the previous report, dated October 1989, preliminary data on the ability of a group of common indoor plants to remove organic chemicals from indoor air was presented. The group of plants chosen for this study was determined by joint agreement between the National Aeronautics and Space Administration (NASA) and The Associated Landscape Contractors of America (ALCA).

PLANTS CHOSEN FOR SCREENING:

Common Name:	Scientific Name:
Bamboo palm	Chamaedorea seifritzii
Chinese evergreen	Aglaonema modestum
English Ivy	Hedera helix
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
Pot mum	Chrysanthemum morifolium
Peace lily	Spathyphyllum "Mauna Loa"
Warneckei	Dracaena deremensis "Warneckei"
Ficus	Ficus benjamina

In addition to this group of plants, several others have been used during the study. These include several plants in the philodendron family such as the heart leaf philodendron (Philodendron oxycardium), the elephant ear philodentron (Philodendron domesticum), the golden pothos (Scindapsus aureus) and the green spider plant (Chlorophytum elatum). These plants are being included in some tests because they represent the group of plants which were used in some of the original work done in this laboratory and therefore serve as a point of comparison between current and previous work.

The chemicals chosen for study were benzene, trichloroethylene and formaldehyde. Although many other chemicals are commonly found in indoor atmospheres, these have been indicated as possible carcinogens or teratogens and are some of the more commonly found. The characteristics and sources of these chemicals in indoor air were described in the previous report.

SUMMARY OF PREVIOUS RESULTS:

The previous report shows the results of preliminary screening tests that were performed using Sensidyne-Gastec air sampling equipment. This equipment consists of detector tubes that are specific for different chemicals and a hand held pump to draw air through the tubes. When air containing the chemical is drawn

through the tube, a reaction takes place and a color change occurs which is proportional to the concentration of chemical in the air sample. Table 1 lists the plants and chemicals not included in the October, 1988 report. This completes the initial screening of all plants on the ALCA list.

CURRENT TESTING METHODS:

For experiments previously reported, the concentrations of chemical were in the 15 to 20 part per million (PPM) range. Although this gave a good indication of which plants might be particularly suited to the removal of one or more of the chosen chemicals, it is far above the levels commonly found in indoor atmospheres. Therefore, shortly after issuing the previous report, we began to investigate removal of much lower concentrations (less than 1 PPM) of chemical from the air. As the Sensidyne-Gastec equipment is not sensitive enough for testing these lower concentrations, a gas chromatographic (GC) method has been developed for analysis of both benzene and trichloroethylene (TCE) in the same sample. Formaldehyde cannot be determined by a GC method and an ultra sensitive chemical method is currently being evaluated for analysis of low levels of this chemical. As with all previous studies, plants were maintained in a healthy condition using Stern's Miracle-Grow fertilizer.

All studies are being performed using the plexiglass chambers from

previous experiments. For the benzene/TCE study currently underway, two chambers of similar size are being used, having volumes of 0.868 cubic meters and 0.694 cubic meters. Sampling is performed by withdrawing 200 mil of air through a glass tube containing Tenax adsorbent with a Sensidyne hand pump. The samples are analyzed promptly using a Supelco air desorption unit interfaced to a Hewlett-Packard Model 5890 gas chromatography, equipped with a Hewlett-Packard Ultra 2 capillary column and flame ionization detector.

During past studies, the only controls used were chambers free of plants to test for loss of chemicals from leakage, and pots with potting soil without plants. It was then assumed that the removal of chemicals from the sealed chambers after making corrections for the potting soil could be attributed to the plant leaves.

Another major change made for this study in an effort to determine the exact mechanism involved in chemical removal was the defoliation of plants during the experiments and the coverage of potting soil with pea gravel using full plant foliage.

To our surprise, we found with benzene that significant chemical removal appeared to be from the soil containing the plant roots. Thus, we began incorporating a test for this hypothesis into all experiments. Mature plants with full foliage were tested for one or more 24 hour period followed by testing of the same plants from

which all of the foliage had been cut away, leaving only short stalks 1 to 2 inches in length protruding above the level of the potting soil. To determine if water vapor was important, some of the potting soil containers were saturated with water before conducting the tests. Water did not appear to be a major actor in chemical removal.

Another major change made for this study was the analysis of plants that have been defoliated. Due to recent work, we began to suspect that the plant leaves were not solely responsible for removal of organics from the air. Thus, we began incorporating a test for this hypothesis into all experiments. Mature plants with full foliage were tested for one or more 24 hour period (identical to methods previously used), followed by testing of the same plants from which all of the foliage had been cut away, leaving only short stalks 1 to 2 inches in length protruding above the level of the potting soil. Plants were also tested with the potting soil covered with pea gravel.

The general protocol followed for these tests is summarized as follows:

1. For each test, two healthy individuals of the plant species to be tested were used. One individual was placed into each of two chambers.

2. The chambers were sealed and a mixture of benzene/TCE injected into each.

3. After a short equilibration period to allow for complete volatilization and circulation of the chemicals inside the chamber, two replicate samples were withdrawn from each chamber. These samples were analyzed without delay on the GC. If the two samples drawn from a single chamber did not replicate within approximately 10%, two more replicates were drawn and analyzed.

4. The plants were left overnight in the sealed chambers. In some cases a sample was drawn 4 to 6 hours after injection of chemical. However, in most cases, only a final sample, drawn approximately 21 to 22 hours following injection, was collected. As with the initial sample, replicates were withdrawn from each chamber and analyzed as described above.

5. At the end of the 24 hour testing period, the chambers were opened and the plants removed. All of the foliage was cut away from the plant 1 to 2 inches above the surface of the potting soil.

6. The chambers remained open for approximately one hour, during which time a good circulation of air was

maintained in them to remove any remaining organics prior to resealing.

7. The defoliated plants were placed back into the chambers and the chambers were resealed.

8. Initial and final sampling was performed as described above.

Although the above outline indicates the general protocol followed, variations occurred in most actual trials. In all tests, however, two individuals of the same species were tested and the foliage was completely removed from at least one of these two plants. In several trials, the two plants were tested for two or three days with full foliage, following testing for a similar period with the potting soil covered with pea gravel. Tests were then conducted with uncovered potting soil after removal of foliage.

During the course of these experiments, leak tests on sealed, empty chambers were periodically conducted to affirm that the chambers did not leak during the course of the experiments.

RESULTS:

It can be seen from Table 1 and earlier reports that for virtually all plants tested, the reductions in benzene and formaldehyde are

significant. The most interesting observation from data shown in Table 2 is that the mean removal of benzene by the defoliated marginata is greater than the removal by plants with full foliage. This suggests that the plant roots and their associated microorganisms are the major pathway for chemical removal, at least in this study. This phenomenon cannot be fully explained at this writing. We are continuing to study this from various aspects to try to determine why it occurs. Microbial studies have been implemented in an effort to better understand this phenomenon.

Figures 1 and 2 also demonstrates the efficiency of plant/activated carbon filters for removing benzene and trichloroethylene from contaminated air inside sealed chambers. The cfm rate of the fan used is a major controlling factor in the speed in which a room can be cleaned of smoke and toxic chemicals. The small 8" pot system used in Figure 1 had a motor fan rating of 15 cfm free air flow.

DISCUSSION:

As in previously reported studies, these results indicate that plants can play a major role in removal of organic chemicals from indoor air. The work reported herein confirms that plant systems, and not the potting soil itself, are responsible for removing most of these chemicals. However, it now appears that the part microorganisms and plant roots play may be more important in the removal of chemicals than was previously believed. This opens a

broad new avenue that will be investigated and discussed in depth in the final report.

It is also interesting to note in our studies, that for the soil to be highly effective in removing indoor air pollutants, plants must be growing in this soil. Therefore, the plant is very important in removing indoor air pollution either directly through its leaves or indirectly through the root/soil pathway. For removal of high concentrations of chemicals and/or smoke from inside buildings it is desirable to have an integrated system using potting plants and one or more activated carbon/plant filtration systems.

TABLE 1
CHEMICALS REMOVED BY HOUSEPLANTS FROM A SEALED EXPERIMENTAL CHAMBER DURING A 24-HR EXPOSURE PERIOD.

	Formaldehyde (ppm)			Benzene (ppm)			Trichloroethylene (ppm)		
	Initial	Final	Percent Removed	Initial	Final	Percent Removed	Initial	Final	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. Twenty-four hours test were conducted in sealed chambers with temperatures and light intensity readings of 30°C ±1 and 125F-T ±5 respectively.

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TABLE 2
BENZENE REMOVED BY MARGINATA FROM A SEALED EXPERIMENTAL CHAMBER DURING A 24-HR EXPOSURE PERIOD. (Concentration in ppm)

	Initial	Final	Percent Removed
Full Foliage	0.152	0.051	66
Full Foliage with Potting Soil Covered with Pea Gravel	0.171	0.085	50
Uncovered Potting Soil with Foliage Removed	0.278	0.194	70
Potting Soil Control	0.206	0.164	20

FIGURE 1. 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.

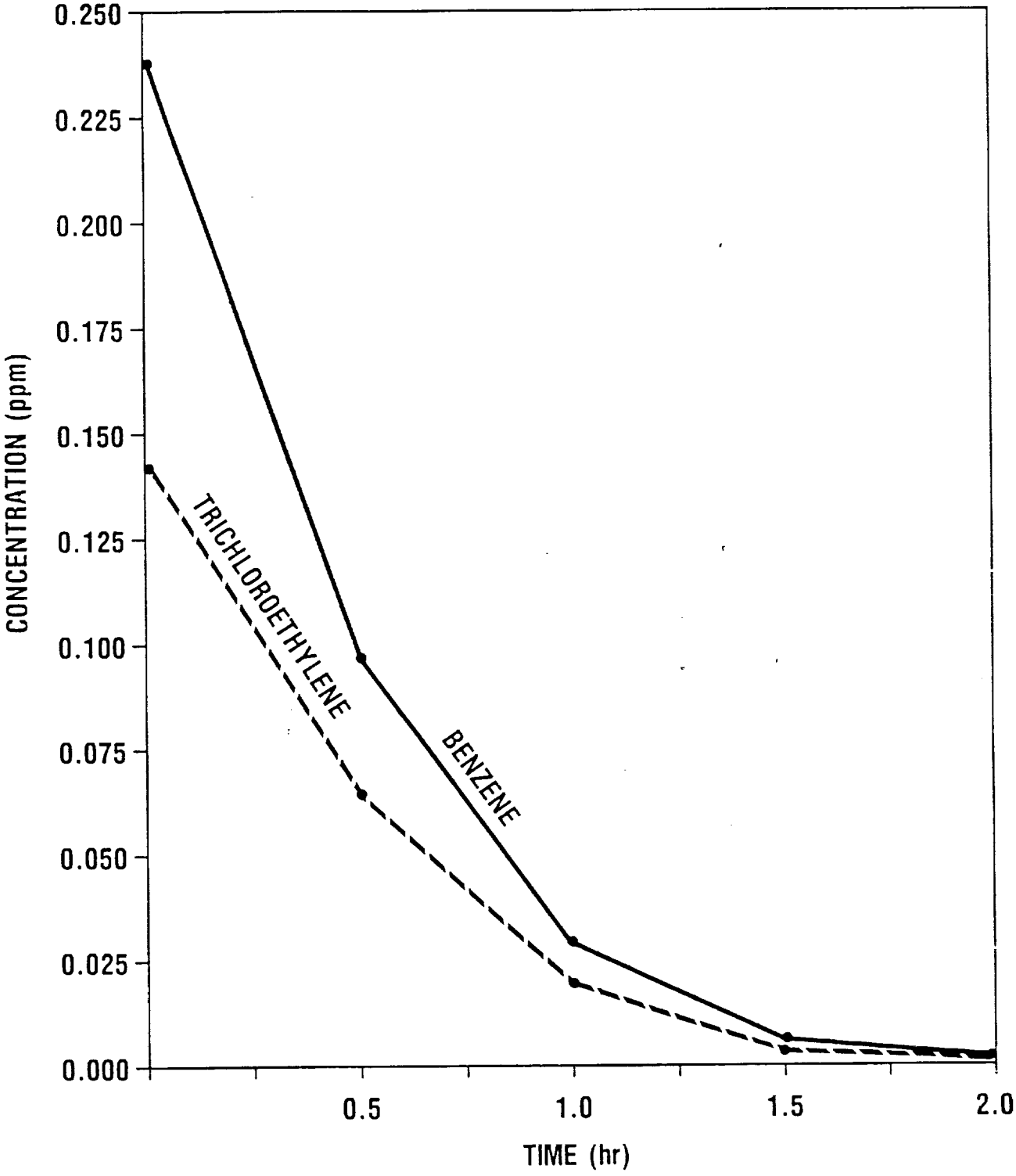

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FIGURE 2. REMOVAL OF HIGH CONCENTRATIONS OF BENZENE AND TRICHLOROETHYLENE FROM THE AIR INSIDE SEALED EXPERIMENTAL CHAMBERS USING GOLDEN POTHOS IN AN 8-IN. ACTIVATED CARBON FILTER SYSTEM.