N91-13852

The BioHome: A Spinoff of Space Technology

Anne Johnson
Microbiologist, NASA Stennis Space Center
Picayune, Mississippi

I would like to preface the discussion of the BioHome with some information about the work we have been doing at our environmental laboratory over the past 15 years. The main focus of Stennis Space Center (SSC) is shuttle engine testing, however, we also have a very active laboratory addressing environmental issues related to biological life support.

Some of the earliest work at Stennis pioneered the utilization of water hyacinths for wastewater purification. This technology has been utilized throughout the world for treatment of both domestic and industrial waste.

The SSC environmental laboratory has also done a lot of research in the field of artificial marshes. These systems are essentially 18 inch deep pits in which 30 mil plastic liners have been installed. The rock substrate is then added to support various types of vascular plants such as canna lilies or bulrush. Artificial marshes are very effective in terms of reducing fecal counts in the effluent. Surprisingly, there is typically no odor associated with such a system. These factors, along with the system's low cost and esthetic quality have made it very appealing (Figure 1).

One of the primary goals of our laboratory is technology utilization. Simply this means that as we develop and refine technology, it is also our role to provide this information to the public as well as to aid in its implementation. Certainly the wastewater systems previously mentioned are such an example.

It should be noted that all of the wastewater at SSC is treated by these types of systems. We hope to be able to use this technology in conjunction with Space Biosphere Ventures to evaluate these systems in Biosphere 2.

Five or six years ago, we began looking at the problem of indoor air pollution. Many people are familiar with the problem of formaldehyde contamination. This chemical is known to leach from formaldehyde resins used inside buildings. However, there are a variety of other potential pollutants that you may encounter in an indoor environment including benzene and trichlorethylene, common constituents of paints and solvents.

We became interested in evaluating a biological system comprised of plants and microorganisms for the purpose of reducing organic contaminants. Initial studies involved placing various plants in plexiglass chambers and injecting known quantities of pollutants. The changes in concentration were measured by gas chromatography. We have since expanded the types of plants screened as well as the number of pollutants involved. We are also interested in the possible synergistic effects that may be occurring when organic substances interact. Also, we will be addressing the possible fluctuations that may occur with respect to pollutant concentration.

We have just completed a two year joint project with the Associated Landscape Contractors of America (ALCA), where we screened several foliage plants for their ability to reduce concentrations of benzene and trichloroethylene. Of the two, benzene is most easily reduced. However, plants such as the Chinese evergreen, peace lily and mother-in-law's tongue exhibited the capability to reduce concentrations of either pollutant. At this point, we are interested in figuring out what the mechanism behind the purification scheme is. We feel it is a symbiotic relationship between the plant roots and the associated microflora. A preliminary microbial profile indicates that the required microorganisms are common soil types. Future plans call for further microbiological analyses as well as exposure of the plants to radio-labeled pollutants. The latter will enable us to ascertain the regions of the system where the pollutant resides.

The plant filter has gone through several design changes. These are constructed on site with materials readily available off the shelf from stores like K-Mart. We started out using plants in a potting soil/lava rock/charcoal substrate, followed by soil and charcoal alone. The present filter incorporates a fan system which functions to pull room air across the soil/charcoal interface (Figure 2).

One of the main concerns that we have, especially with respect to a closed environment, is whether or not these systems are expelling microorganisms into the air. We are presently conducting analyses to determine the numbers and types of microbes that are emitted.

The BioHome is a 650 square foot habitat that will enable us to evaluate the efficiency of bio-regenerative technology in a closed system. The structure is 46 feet long and 16 feet wide with 12 inch thick fiberglass insulation. This facilitates maintenance of indoor temperatures over a narrow range. Although there is restricted air flow, the system is not closed at this time. However, the air conditioners are designed such that they do not introduce outside air, but rather recycle that from the interior (Figure 3).

The BioHome is divided into two areas: the living area and the waste treatment area. In the

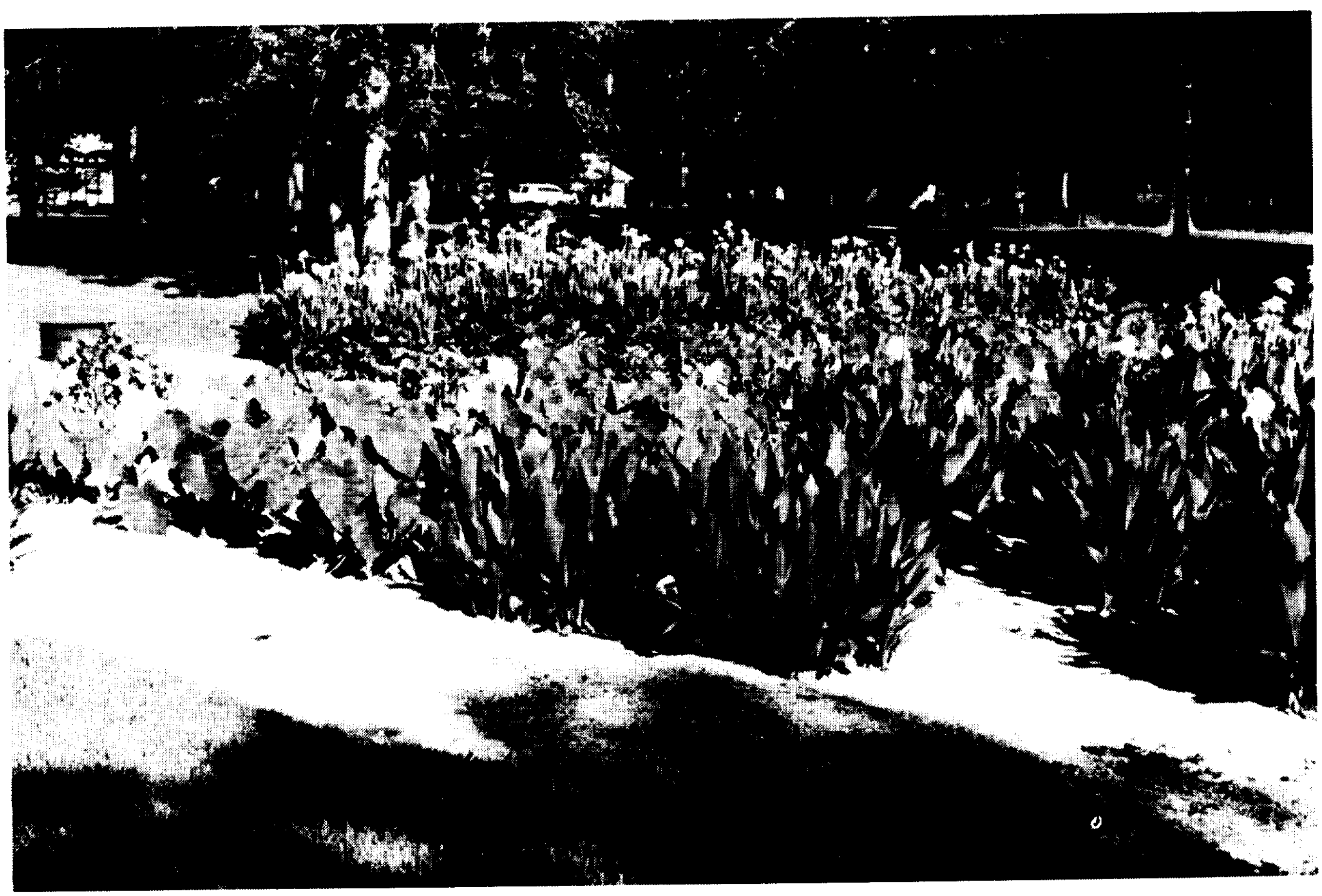

Figure 1. Artificial marsh for wastewater treatment.

former, plant filters have been included in an effort to dissipate off-gassing products. Either the plastic mats on the floor or the laminate from the wall tiles release a substance which tends to irritate the eyes and respiratory tract (Figures 4 and 5).

The wastewater facility is essentially a small artificial wetland system adapted for inclusion in the BioHome. Wastewater flows from the exterior septic tank into a series of 8 inch diameter PVC pipes and finally into a 100 gallon aquarium. Segment 1 of the pipe is empty in order to facilitate further settling of solids. Segments 2 and 3 are approximately 50% full of lava rock which functions to promote development of a biofilm. Plants such as canna lilies and water iris are also included. Segments 4 and 5 also have plants but the substrate inside is granular activated carbon, while segment 6 includes carbon in the first few feet of pipe, followed by a substance known as zeolite. The latter functions to remove ammonia from the system (Figures 6 and 7).

We are also in the process of growing numerous types of vegetables such as peas, tomatoes, and cabbage. As plants from the wastewater system die, they are removed and used as compost for the vegetable plants.

There is also a system utilizing plants to provide a source of drinking water. As water vapor is produced by the plants via evapotranspiration, a dehumidifier removes water from the air. From this point it is filtered by means of an activated carbon substrate, then treated with ultraviolet light prior to collection.

The living quarters of the BioHome comprises approximately one half of the total square footage. We have had an individual occupy the structure for a period of several months. Their primary function was to provide a source of waste for the system.

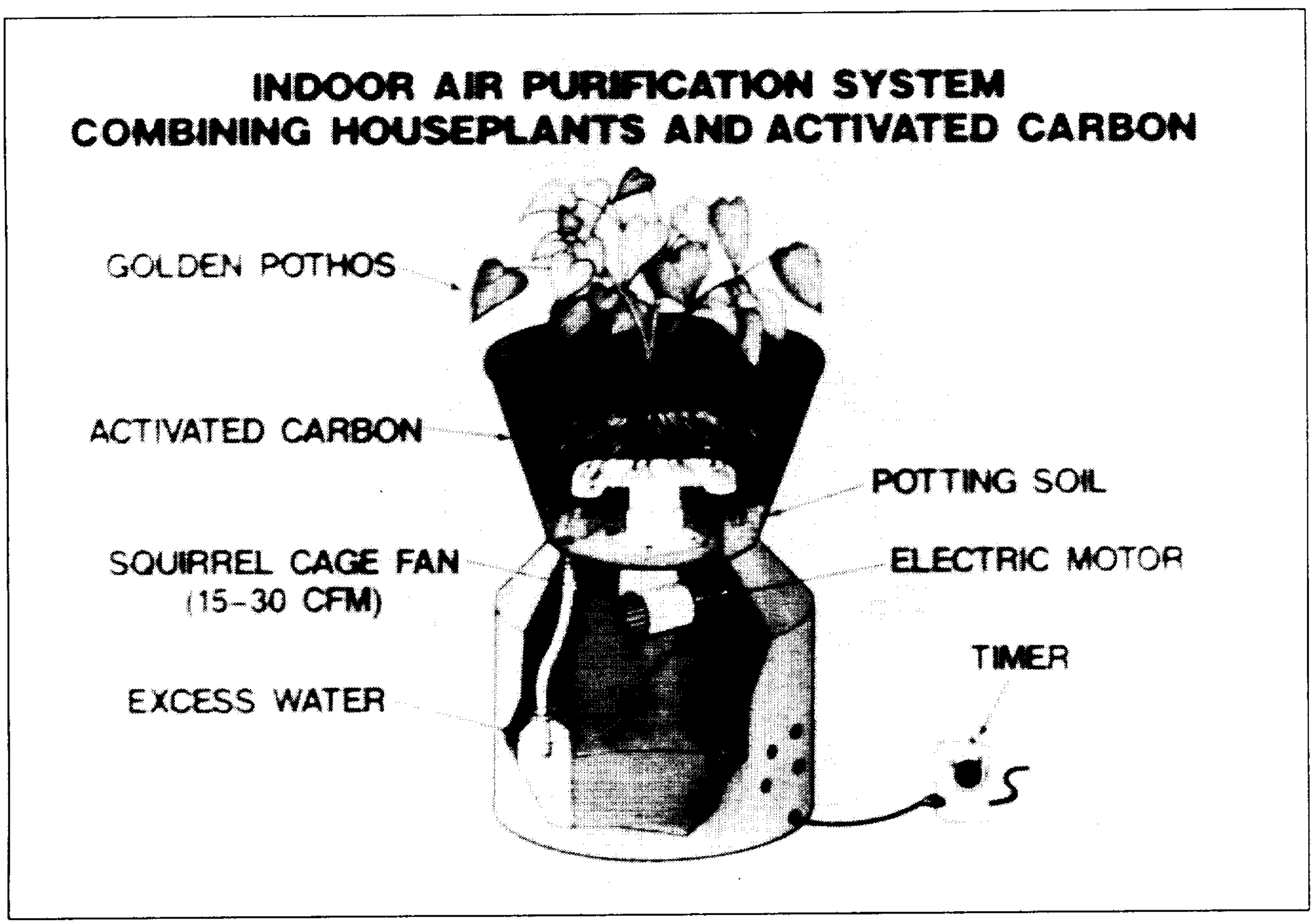

Figure 2. Indoor air purification system combining houseplants and activated carbon.

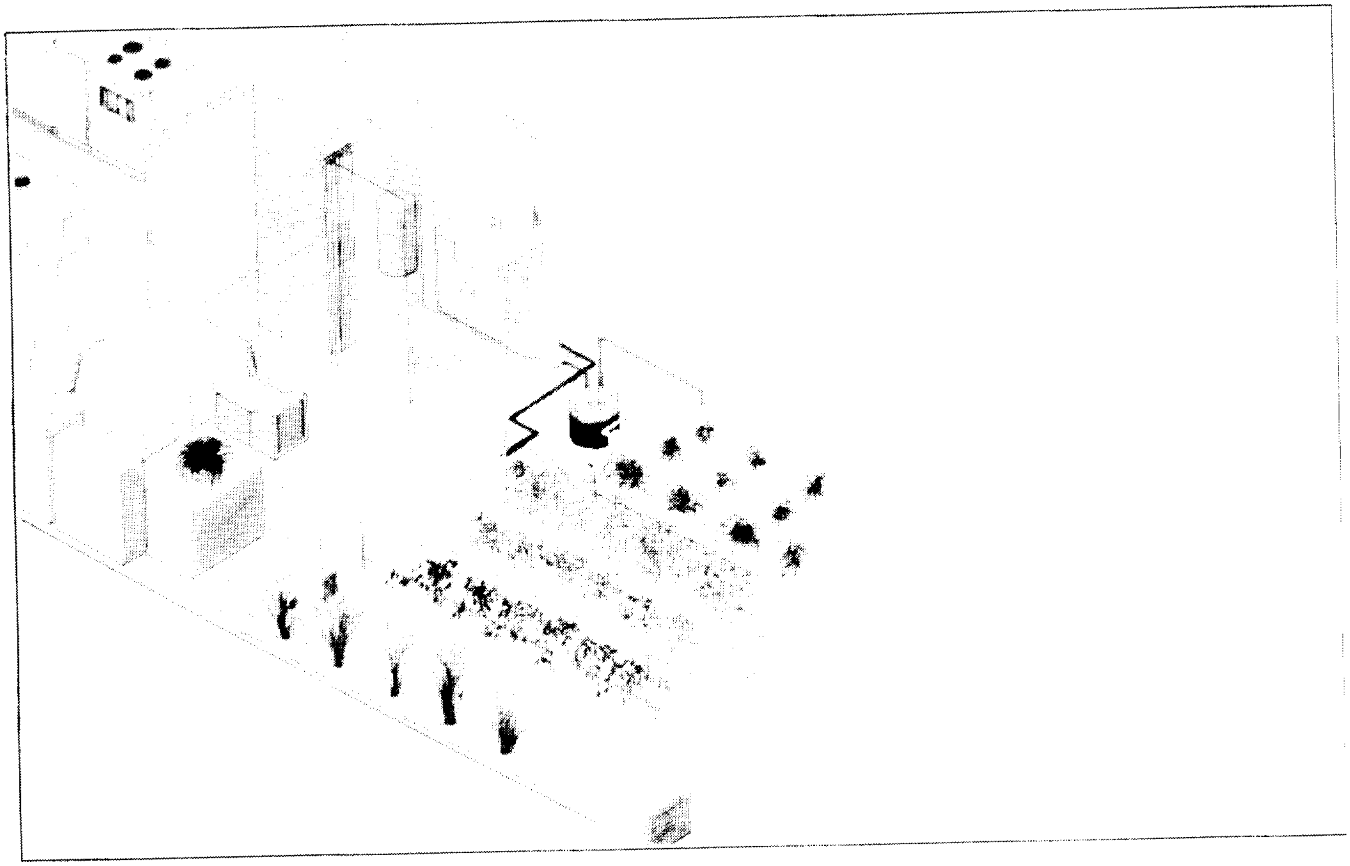

Figure 3. Cutaway section: the BioHome.

Figure 4. Interior of BioHome prototype: dining/study area.

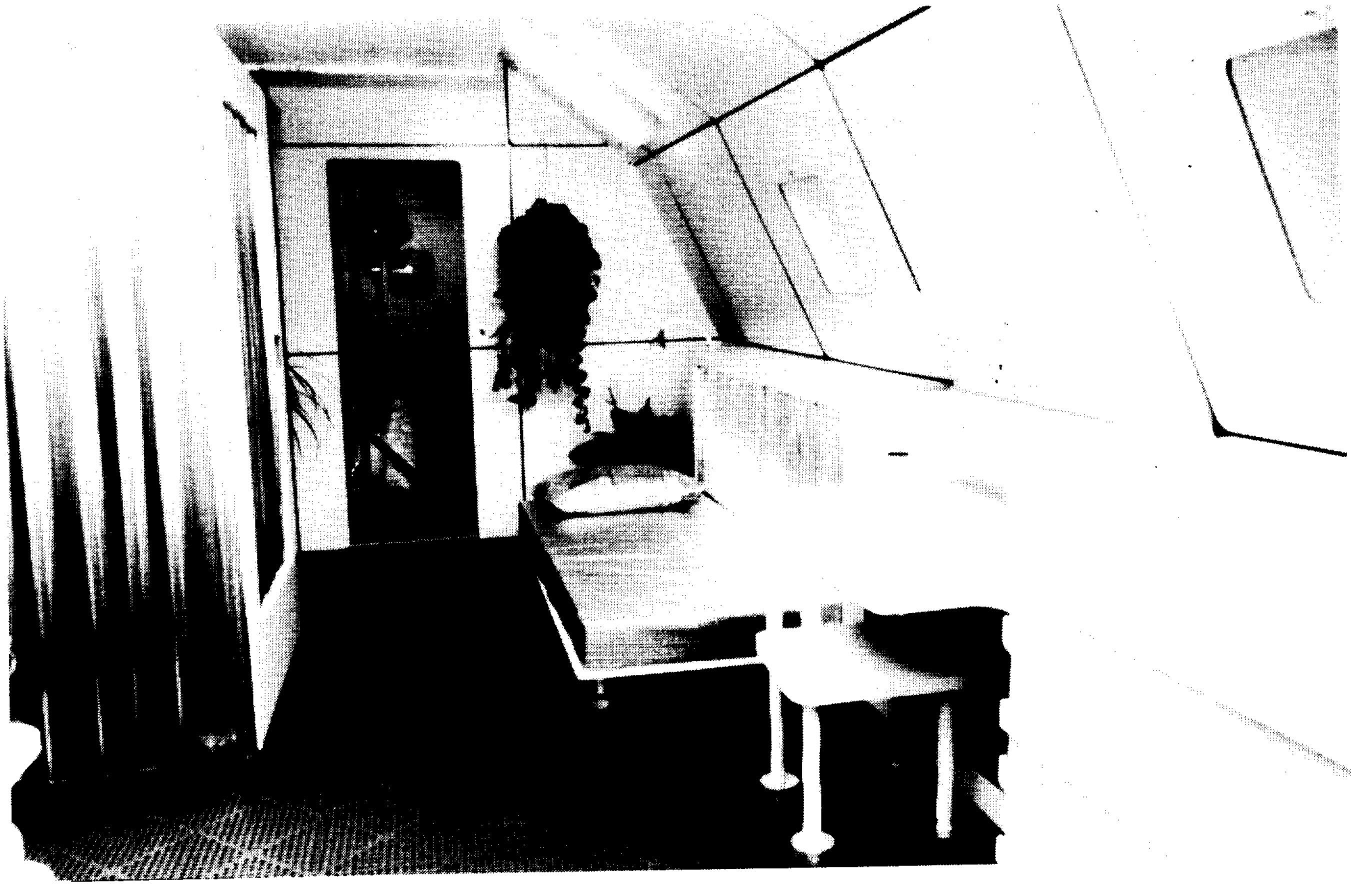

Figure 5. Interior of BioHome prototype: bedroom area.

Figure 6. Miniaturized artificial marsh wastewater treatment system for the BioHome prototype.

At this point, the only recycling of water that occurs is the pumping of treated water into the toilet. The majority of reclaimed water flows into a 100 gallon aquarium which serves as a buffer. In the event that the water level drops below a certain point in segment one, a sensor will function to turn on pumps in both the septic tank and aquarium to replenish the system.

We are screening several types of plants for inclusion in the wastewater facility including torpedo grass and canna lilies. It is important to keep in mind that different locations in the system have different organic concentrations. Therefore we are screening various plants to determine which will fare best in regions with a high organic content as opposed to those regions that do not.

We are also looking at inclusion of halophytic (salt-tolerant) plants into the system. This could be a useful addition since human waste is typically high in salt.

As I mentioned previously, the source of drinking water is water vapor obtained from plants. There are so many plants in the treatment facility at this point, it bears resemblance to a jungle. However, only about 11 liters of water are produced per day. This is not enough to accommodate one person's drinking water, bath and cooking requirements. Consequently our goal is to increase this volume of water production by adding additional plants.

We do an extensive array of tests on water from the BioHome. Typically, water quality results fall well within the necessary guidelines. We are also concerned with the possible presence of volatile organics in the air and consequently have instituted a sampling regimen.

The next few months will be devoted to extensive biological and chemical analysis in order to determine what types of microorganisms and chemicals may be found within such a system. With this information in hand, studies will expand to incorporate the presence of humans.

Figure 7. Detail of BioHome artificial marsh wastewater treatment system.