POTENTIAL APPLICATIONS OF WATER HYACINTH FOR WATER, AIR RECYCLING IN CLOSED SYSTEMS

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Abstract. Russian space scientists have done much work on closed ecological life support systems (CELSS) using higher plants and algae both for recycling water and air and regeneration of food. Research in this country has been directed mostly towards physiochemical methods for recycling water and air. Development of CELSS using biological components such as aquatic vascular plants (water hyacinth) has recently been recommended. Use of water hyacinth in open systems for municipal wastewater treatment has been studied extensively along with its many other terrestrial uses (animal feed, source of fresh water through evapotranspiration, methane source, fertilizer and compost). After reviewing the research work in CELSS, controlled environment agriculture, and water hyacinth and its uses, potential applications of water hyacinth in closed ecological systems for water, air recycling are outlined.

1. Introduction

Interest in self sustaining, regenerative life support systems is intensifying since habitats for missions involving large numbers of people working in space will have to be increasingly utilized with the advent of space industrialization. Life support systems for manned space missions provide for food, water, air/oxygen and waste management facilities. Development of closed (or partially closed) ecological life support systems using biological components such as aquatic vascular plants (water hyacinth) to recycle wastes and regenerate food has been suggested (Oswald, 1962; Phillips et al., 1978; Spurlock and Modell, 1979).

The purpose of this study is to explore the various possible applications of an aquatic plant such as water hyacinth as a potential biological component of closed ecological life support systems mainly for water, air recycling. The study is divided into 4 major parts: Review of biological processing in closed ecological life support systems; Review of controlled environment agriculture; Review of uses of water hyacinth in water/air recycling; and Recommendations on potential applications of water hyacinth in closed ecological life support systems for water, air recycling.

2. Closed Ecological Life Support Systems

2.1. RUSSIAN LITERATURE

Russian scientists have done much work on the use of higher plants as a possible link of a biological life support system. Their studies have been focused on bioenergetic systems; the higher plants can be a source of vegetable foodstuffs for human nutrition and a method of partial regeneration of water and O₂ (Milov and Balakireva, 1977). They
established that for complete support of 1 man per day, with 550 to 600 l of O\textsubscript{2} and 1200 kcal of vegetable food and water, a growing area (for higher plants) of 16 m\textsuperscript{2} was necessary. Crops such as peanut, onion, radish, potato, soybean, turnip and carrot were considered.

Volatile substances are given off by the plants. The leaves of radishes, tomatoes, carrots and potatoes give off propionaldehyde (Rusakova et al., 1977). In growing red beets by aeroponics, Rusakova et al. (1977) studied the gas exchange (CO\textsubscript{2} - O\textsubscript{2}) and found that an increase in CO\textsubscript{2} concentration, from 0.15 to 0.4%, does not affect the photosynthetic rate. The gas exchange and transpiration of certain higher plant crops proposed for human life support systems have also been studied and the most intensive gas exchange was observed for carrots (30 to 40 l), with most other crops varying from 2 to 10 l O\textsubscript{2} m\textsuperscript{-2} day\textsuperscript{-1}.

By far the maximum effort of Russian space scientists has been on the studies of single-celled algal cultures as regenerative links for life support systems (Gitel'son et al., 1976; Lavrov and Mel'nik, 1977). In their most publicized experiment called 'Bios-3' 3 human subjects lived in hermetically sealed room for 180 days during which time their O\textsubscript{2} was completely supplied by Chlorella grown in a special reactor. Urine and domestic water was also fed to the algae cultivator, while water vapor was condensed from the algae compartment, filtered with the activated carbon and recycled to the manned compartment (Gitel'son et al., 1976).

2.2. DEVELOPMENTS IN THE UNITED STATES OF AMERICA

Toxicity of the atmosphere to plants in 'Bios-3' led Spurlock et al. (1977) to recommend the use of physical and chemical methods to minimize the possibility of cross contamination. Shuler (1979) has discussed the key requirements for waste treatment options in closed systems. Wet oxidation processes (representing a physical chemical approach) have been shown to be more efficient in comparison with nonphotosynthetic aerobic microbial waste treatment (representing a biologically centered option). Krauss (1978) also mentioned that combinations of biological deterioration and pyrolysis of human waste and atmospheric contaminants are available.

Phillips et al. (1978) in their studies of potential biological components of closed life support systems, recommended the use of aquatic plants (water hyacinth) for water, air recycling, and for production of biomass which can be used as a foodstuff for livestock.

3. Controlled Environment Agriculture

Controlled environment agriculture (CEA) has been recommended to solve the world's agrofood problems because of the very high crop yields obtained through CEA (Fontes, 1973). CEA grown vegetable crop yields are usually 5 to 20 times higher than for the same crop in open field agriculture (Fontes, 1973; Phillips, 1977). Year round production of crops is accelerated and is very predictable. CEA systems, being capital, energy and labor intensive, motivate towards a highly efficient resource utilization. Phillips (1977) has listed several other beneficial characteristics of CEA and has extrapolated the knowledge