ALGAL RESEARCH IN SPACE

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Abstract: The aim of this article is to give a brief review of the history and current status of research experiments with cyanobacteria, algae, and lichens concerning their adaptation in space or their potentials use for the needs of astronauts. Drawing on archival and published sources, I detail the history of the bioregenerative life- support system, a system in which simple organisms- most commonly algae-would inhabit the spacecraft and, through a series of interspecies symbioses, maintain cabin conditions and sustain astronaut life. The future of apological space research is also being discussed with regard to creating self-sustainable stations .

Keywords: Cyanobacteria, algae and lichens.

1. INTRODUCTION

The idea to grow algae for human consumption is currently more than 70 years old after it was first suggested, in 1942, by Harder and Von Witsch (Research service special issue 1942, Report of the German Botanical Society 1942)that organisms such as diatoms could be source of lipid which could be used for food, with a detailed analysis published subsequently by Spoehr in 1951(Chlorella as a source of food. Proc Am Phil Soc 1951; 95:62). Algae have great potential to be used as part of a regenerative life support system and to facilitate in-situ resource utilization (ISRU) on long duration human space missions (New platform for studying photosynthesis and microalgae ; E D Fleming, M X Tan). Studies of bioregenerative life support systems for use in space indicated that they are scientifically feasible. Support of a crew in space, in an orbiter or on the surface of the planetary body requires that oxygen, potable water, food be supplied and that waste material be removed (NASA contractor NCC 2-501; M G Tadros ;Oct-1988). The concept of growing algae in space for the need of cosmonauts precedes even the launch of Earth's first cosmonaut. However although decades have passed since then, nowadays the algae are still being considered a novel example with tremendous potential for applications in space (Morrison N. Algae farming in low earth orbit; Past present and future- J Br Interplanet Soc 2014; 67:332-7), without actually being used as food or as a source of oxygen aboard the International Space Station. The prospect of terraforming the planets remains as distant as it was during the early space age.

2 A BRIEF HISTORY OF STUDYING CYANOBACTERIA AND ALGAL SURVIVABILITY IN SPACE

Algae flew in space as soon as the space race began and before the flight of Gagarin. On 19th august 1960, a Vostok rocket launched the spacecraft "Korabl-Sputnik 2". The most famous passengers aboard the spacecraft were the two dogs Belka and Strelka that later successfully returned to earth. However the dogs were accompanied by 40 white mice, two rats, numerous flies, seeds, fungi and cultures of the algae *Chlorella pyrenoidosa*

(Hall R, Shayler DJ. The Rocket Men: Vostok and Voskod.Springer Science Business Media 2001). The mission duration was very short. The results with *Chlorella*

From this particular flight are well documented. It was estimated that launch, landing and short duration stay in space flight conditions do not impact the main physiological processes such as growth, development and reproduction (Semeneko VE , Vladimirova MG. Effects of cosmic flight conditions in the Sputnik-ship on the viability of Chlorella. Physiology of plants 1961; 8:743-9).

By the mid-60s, it became clear that short duration spaceflight is survival by earth organisms (including algae).

0n February 1966, a Voskhod rocket launched the Soviet spacecraft Cosmos 110 with the dogs Veterok and Ugolyok and numerous other organisms, including *Chlorella*

Cultures (LARG-1, LARG-3) strains. The space craft stayed in orbit for 22 days before it safely landed, duration far longer than any of the previous missions. The occurrence frequency of the visible mutations has been surveyed, and no significance differences have been found between test cultures and control samples on earth. Statistically significant reduced survival of this algae cells have been noted only for the LARG-3 strain (Antipov VV, Delone NL, Nikitin MD, Parfyonov GP, Saxonov PP. radiobiological studies on cosmos 110- Life science space Res 1969;7 : 208-8).

3. FACTORS EFFECTS ON ALGAE IN SPACECRAFT

When we talk about studying plants in space, we must clarify which spaceflight conditions are being tested in experiments. In the cases cited above, we are talking about algae which have flown on the inside of spacecraft, i.e., pressurized containers, with strictly controlled conditions. Thus, only two factors could be studied – weightlessness and increased

radiation. Of these usually, the focus is on weightlessness. Studying radiation is more challenging because radiation conditions on the inside of spacecraft depend on orbital parameters and structure of the spacecraft. Experiments about survivability of algae on the inside of spacecraft are useful, but they say nothing about how algae react in harsh conditions of space with all factors – vacuum, direct solar illumination, and extreme temperatures. This is being reviewed in the following paragraph.

A Russian FOTON-M spacecraft laumched successfully from the Baykonur cosmodrome on May 31, 2005, via a Soyuz rocket. Aboard the spacecraft flew lichens *Rhizocarpon geographicum and Xanthoria elegans,* symbiotic organisms composed of algal and fungal cells. Lichens stayed space for 16 days before returning safely to earth after full exposure to space conditions including vacuum, UV illumination, extreme temperatures and weightlessness. It was confirmed that lichens were able to recover within 24 hours to their metabolic activity (Sancho LG et al. Lichens survive in space: Results from the 2005 lichens experiment , Astrobiology 2007; 7: 443-54)

4. ALGAL " AGRICULTURE "

The initial studies of space agriculture in 1950s and 1960s focused largely on algae, and in particular *chlorella* sp. For oxygen production and carbon dioxide removal (Sorokin and Myers, 1953; Krauss, 1962; Eley and Myers,1964; Gouleke and Oswald,1964; Miller and Ward,1966; Taub, 1974). Chlorella is hardy, productive and relatively easily to cultures in reactors where light sources could be embedded directly in, or surrounded by the cultivation vessels, thereby providing near total light absorption (Sorokin and Myers, 1953; Krall and Kok, 1960; Matthern and Koch, 1964; Miller and Ward, 1966; Taub,1974). These studies provided predictions of electrical power requirments ranging from 10 kW to 100 kW of of electrical power for lightning, and 5 to 50 square meters surface area to produce enough oxygen for one human (Miller and Ward;1966). Other algae and cyanobacteria were also studied. At the same time as these US studies were occurring, Russian researchers both in Krasnoyarsk, Siberia (Gitelson et al.,1975,1976) were conducting human life support studies using algal bioreactors and plants to provide oxygen in closed habitats, and I will expand on this below.

Much of the early work with algae focused on oxygen production for programs like Mercury and Gemini (F.Taub, personal communication). Unfortunately, the mass and power requirements for photosynthesis systems for oxygen generation did not "trade" well for short duration missions; however, the using of photosynthetic organisms to produce both oxygen and food did gain attention. But converting the algae to palatable foods proved challenging (Krauss, 1984; Karel et al., 1985). Many algae were to rich in protein and nucleic acids for balanced diet, and many contains large amounts of indigestible cell wall materials (Gouleke and Oswald, 1964; Karel et al., 1985). Other studies found that some algae and cyanobacteria produced phytotoxic volatiles, which compromised some closed life support studies in the early BIOS projects in Russia in the 1960s and 1970s (Gitelson et al., 1975; 1976).

5. REGENERATIVE LIFE SUPPORT SYSTEM

To keep the astronauts alive in space, life support systems must be utilized. So far, all space stations have been constructed in low earth orbit, and they have relied on continuously resupply of food, water, and oxygen delivered by spacecraft. Open loop life support systems have been successful on short duration missions. However when space missions get longer, the supply load gets heavier and resupply becomes prohibitive (Eckart P. Spaceflight Life Support and Biospherics . Vol 5. New York: Springer Science and Business Media; 2013). The author state that there is a logical intermediate step between physiochemical and bioregenerative life support system, and this is the hybrid life support system which uses integration of physiochemical and simple biological system components. Such biological components, according to the authors, could be algae which are grown in photobioreactors (Beltz et al., Aerospace Science Technology 2013;24(1):169-76). Despite the hardships, biological life support systems have been studied by several space agencies during the last decades including NASA, JAXA, ESA. The aim is to create a closed loop via the use of five main compartments (for waste liquefaction, carbon transformation, nitrification, for food ,water and oxygen production and crew compartment). An algal photobioreactor is being used as part of the compartment for food, water, and oxygen production, inhabited by a culture of cyanobacteria *Arthospira platensis* (ESA . Closed Loop Compartments;2015. Available from: http://www.esa.int/Our Activites/ human spaceflight/ Research). An assessment study has been conducted about the integration of an algal photobioreactor into an environmental control and life support system of space station. Researchers conclude that it is unfavourable to convert all the metabolically produced carbon dioxide within the photobioreactor, but it does contribute to the closure of the carbon cycle and in this way maintain the stable oxygen and carbon dioxide concentration. *Chlorella vulgaris* is a promising organism in such cases (According to Li et al., Advanced space Research 2013; 52(4):773-9).

6. CONCLUSION

We know that microgravity does not significantly affect the growth of algae. It has been proven that some strains are able to survive even after a long exposure to harsh conditions including vacuum and extreme temperatures. It has been widely accepted among the society that the most probable world for colonization and settlement in our foreseeable future is Mars. Unfortunately, Mars has a strong oxidative atmosphere, low temperature, extremely dry condition, and high UV radiation. The algae and cyanobacteria can tolerate this condition. It is common sentiment among people that the pace of

scientific development is very slow. This is especially true about space exploration. Although it has been suggested early in the space age that algae could be grown for the needs of astronauts, we can say that years, even decades will yet have to pass before this turns into reality. Still, important research has been conducted. This review article may help in future research. Work is being conducted to develop bioregenerative support systems, even though basic research still needs to be done. Terraforming Mars with the use of algae is still an idea worth to be considered.

REFERENCES

[1] Antipov VV, Delone NL, Nikitin MD, Parfyonov GP, Saxonov PP. Radiobiological studies performed on Cosmos 110 biosatellite. Life Sci Space Res 1969;7:207-8.

[2] Averner, M., M. Karel, and R. Radmer. 1984. Problems associated using algae in bioregenerative life support systems. NASA Contractor report 116615.

[3] Belz S, Ganzer B, Friedrich KA, Schmid-Staiger U. Hybrid life support systems with integrated fuel cells and photobioreactors for a lunar base. Aerosp Sci Tecnol 2013;24(1):169-76.

[4] Eckart P. Spaceflight Life Support and Biospherics. Vol 5. New York: Springer Science & Business Media; 2013.

[5] ESA An Ecosystem in A box;2015. http://www.esa.int/Our_Activites .

[6] Fong F and E.A. Funkhouser. 1982. Air pollutant production by algal cell cultures. NASA Cooperative Agreement NCC 2-102.

[7] Gitelson , I.I., B.G. Kovrov, G.M. Lisovsky , A. Terskov. 1975. Toxic gases emitted by chlorella. In: problems in space biology

[8] Gouleke, C.G. and W.J. Oswald. 1964. Role of plants in closed systems . Ann. Rev. Plant physiol.,15, 387-408.

[9] Harder R, von Witsch H. Report on attempting of photosynthesis by autotrophic microorganisms, Research Service Special Issue 1942;16-270-5.

[10] Harder R, von Witsch H. The mass cultivation of diatoms. Reports of the German Botanical Society 1942; 60:146-52.

[11] Krauss, R.1962. Mass culture of algae for food and other organic compounds. Amer. J. Botany ,49, 425-430.

[12] LI et al., Chlorella vulgaris culture as a regulator of CO2 in a bioregenerative life support system. Adv Space Res 2013;52(4):773-9.

[13] Miller, R.L. and C.H. Ward.1966. Algal bioregenerative system. Appleton Century Croft Pub., New York., pp 186-221.

[14] Myers,J.1954. Basic remarks on the use of plants as biological gas exchangers in a closed system. J. Aviation Med., 25 , 407-411.

[15] Sorokin, C. and J. Myers. 1953. A high temperature strain of Chlorella. Science , 117, 330-331.

[16] Taub RB et al., Annual reviews of Ecology and Systematics. Annual reviews Inc., Palo Alto, CA. pp. 139-160.