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AN EXPERIMENTAL DESIGN FOR CULTURE OF MICRORGANISMS IN SPACE

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Abstract: All living things are made up of cells and share the same basic cellularity. This fact led to the biotechnology revolution. Understanding of complex cellular pathways and their impacts has always been a challenge for mankind. This problem is magnified when the 'living', is considered at microlevel. Microorganism are at present known to be the toughest survivors, not only on earth but also in space environment. They tend to thrive in space environment and show enhanced growth parameters demonstrating the ability to proliferate in the presence of normal inhibitory levels of antibiotics the mechanisms responsible for this observation however are not fully understood. This paper explores the methodologies and the efficacies of studying and understanding microbial growth phenomena without human intervention by a Nano-satellite in space and also the possibilities as well as scope in future.

I. INTRODUCTION

Life from cell to powerful intelligent humans has evolved along with the evolution of Earth. Out of the Earth, the interstellar space has always been fascinating to humans. While parallel galaxies are talked about, there is also search for life elsewhere in our own galaxy. Microorganisms were the first to originate as life, there are a few organisms which survive in toughest of environments and in space too, with a behaviour different from those on the Earth. While there are records of microorganisms found in space, there are also incidences of microorganisms taken and being tested in space. OREO/S, Genesat, Pharmasat etc, were the nanosatellite missions to carry out such tests.

Apart from these there are also experiments conducted in International Space Station (ISS). This paper focuses on the functional reach and ability of a nanosatellite in conducting the experiments on microbes and analysis as well as comparison of their growth and behaviour.

II. METHODOLOGY

The growth of bacteria reveals different patterns in different environments; the approach and hence the growth analysis has to be different. This research focuses on to such varied environments of limiting and sufficient nutrients for growth in the bacterial environment. The bacteria are subjected to the limiting growth medium first, the absorbance is recorded and then the growth is analysed, followed by same, analysis of growth in sufficient medium.

A. Selection Criteria of the Bacteria

1. The bacteria should be present in the human body and should perform specific function in any parts of the body organs. It could be either helpful or virulent in behavior with Human beings.

2. Growth conditions (Aerobicity and anaerobicity) of the microbe. The selection criteria would be in support an anaerobic bacteria as constant supply of Oxygen in Satellite would cause major difficulty.
3. A strain of disease causing bacteria that may or may not be present in the body. Study of growth and metabolism in of such bacteria would help know and mitigate reasons of the diseases caused by them.

B. Experiment

When the bacteria come in contact with the medium, it becomes active and the growth begins. The microbial growth has four phases - the lag phase, the exponential or log phase, the stagnation phase and declination phase. Initially the growth rate is not much enhanced and happens at a slow rate which is called as lag phase. When the condition becomes favourable, the growth rate increases exponentially and the bacteria multiply in an exponential order hence, the name exponential phase. After the exponential phase, the growth stagnates at the same level and gets saturated i.e., no further multiplication is possible and the growth becomes stagnant which is stagnation phase. After this the growth declines, and the declination phase begins.

The payload unit consists of a chamber having two cylindrical containers, integrated optical density measurement unit and a flushing chamber followed by operating pumps and pistons acting as regulatory valve.

One of the containers has lyophilised bacteria in it, while the other cylindrical container contains the medium for the bacteria. Top ends of both the cylinders have stepper-motor-driven pistons to push the required amount of medium and lyophilised bacteria into the test chamber below. There is one passage each beneath both the cylindrical chambers, for the bacteria sample and the medium to flow to the test chamber. The passages are curved from inside to reduce to stress concentration and for smooth flow of the bacteria and medium. Pistons move a required distance, by the rotations of the stepper-motor, where, the signals to rotate the motor are given through telecommand. The distance covered by the pistons is determined by changes in pressures of both the containers. The pressure change is determined by the pressure sensor, TE Connectivity's 1240 embedded in the top surface inside the containers. The contents of the containers flow through the passage, to transparent test chamber below which is made up of quartz.

Absorbance of the sample (bacteria in medium) readings are taken once in every four hours. The lyophilised bacteria and the medium are mixed as they enter the test chamber and thus the contact between the medium and bacteria is achieved. This mixing is pronounced in the test chamber. The light source is switched on and the optical density (OD) valves are recorded with plain medium acting as the reference. After spending sufficient time in the test chamber and after the readings are recorded, the bacteria and the medium are flushed into the chamber below by a reciprocating piston above which also acts as a valve by opening and closing one passages connecting the cylindrical containers and the test chamber.

The above process is repeated for both sufficient and deficient media concentration and absorbance values are recorded in each care for all phases of growth. From these values, growth curve is generated and the same is compared with that generated by experiments on Earth and analysed.

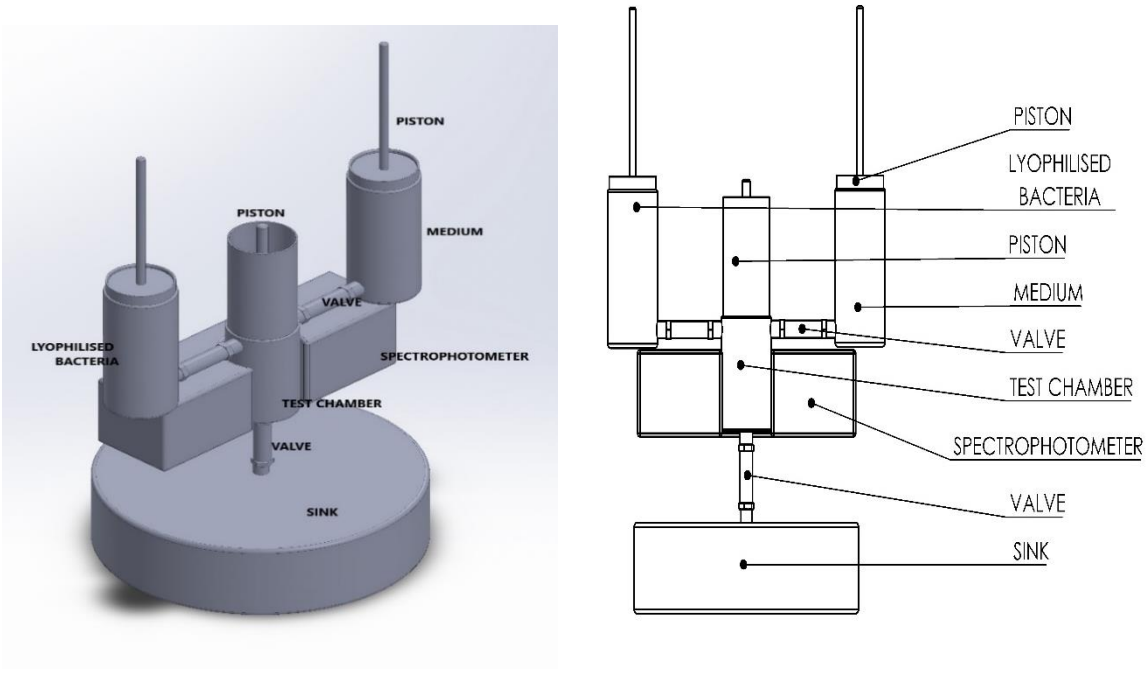
After the growth of bacteria, the grown culture has to be flushed out of the test chamber, that is achieved by the central piston, driven by another stepper-motor which is operated through

telecommand. The piston pushes the grown culture to the sink located below the test chamber. A unidirectional valve is used to connect the test chamber and the sink, so that there is no flow of used sample from the sink to test chamber. The sink is large enough to accommodate used samples and by-products, if any.

This complete setup is accommodated inside a chamber. Chamber is used to isolate the setup from magnetic interference, radiation and to maintain optimum temperature for bacterial growth. This chamber is cuboidal and is made of 2mm thick sheets of Al alloy. Temperature sensor LM35 is used to sense the temperature change and microheaters to maintain the temperature at optimum level.

Bacteria and medium being thrown into the sink, will the growth happen in the sink too? The answer is no. It is because the bacteria have reached the death phase and insufficiently less amount of nutrients.

C. Design



(a) (b)

Fig. 1(a) Isometric view. (b) Side view.

D. Simulation Results

Fig. 2 Fluid Sticking to walls of the container in micro gravity

The fluid simulation was done using a software named SE-FIT by NASA. Fig. 2 shows the fluid sticking to the walls of the cuvette due to surface tension in micro gravity conditions.

III. TECHNICAL DIFFICULTIES

There are high possibilities of cohesion and adhesion of both bacteria and medium in their respective containers. Also, it cannot be ensured that the contents especially the bacteria in the lyophilized state (powder), gets transferred to the test chamber. Added to this, in monitoring the pressure variation in the payload chamber.

This situation calls for a modified path for transfer and contact of lyophilized microbes and its medium with further studies for understanding the variation in pressure inside the chamber.

IV. CONCLUSION

This analysis, based on the future requirements of Indian Space Research explores the possibilities and proposes to use two-unit CubeSat platform, monitor the growth of microbes in human biological systems in the closed miniature experimental device to conduct space biological experiments. CubeSat platform and biological experiments micro-device can be applied to other in-orbit biological experiments mission, which has promotion value.

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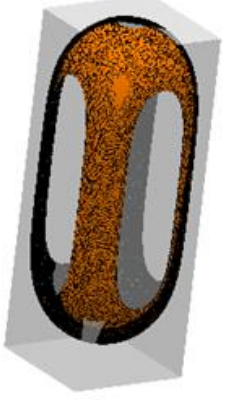

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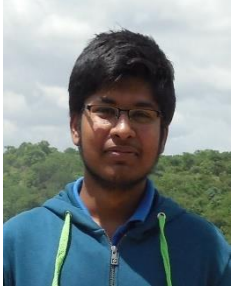

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