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MYCOREMEDIATION

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Time, it has been the most influencing factor entangled in the secret spool of the universe. Right from the expansion of the universe to this day we commemorate every milestone of our journey with time. Before the Jurassic era the planet was colonized by humongous achlorophyllous mushrooms. They utilized the matter that were available during that time converting to energy for growth and reproduction, thereby indirectly conditioning the earth for organisms to thrive.

Fig. 1: Bacons made of fungal mycelia

Courtesy: Ecovative Designs

Armillaria spp. fungi is known to be the largest organism living on earth surface, covering hectors of forest land. The fungi knew the concept and principles of internet even before we discovered. Those intricating networks exchanging vast amount of information between the higher organisms is still unknown to our humble intelligence. The one and only organism on earth that is purely selfish in nature whose satiety and hunger are never be quenched by any supernatural force even if existed are humans. Our actions took a huge toll on mother nature. Air, water, soil, everything around us is being contaminated and we are unaware of the fact that we our self is contaminated.

Hike in cancer cases around the world and the emergence of pandemics claiming the lives of many are indications that we have already crossed the limit. Just as fire was a great discovery for prehistoric men, plastic was a game changing discovery of modern man. From

the tip of your toes to the root of your hair we are dependent on various plastic products. The impact of chemicals, petroleum products, heavy metals and non-degradable materials are devastating to the environment. It was there where the concepts of Mycoremediation was born.

Mycoremediation is when fungi and its products are used to break down pollutants in environment. Myco is derived from the Greek word *mykes* meaning fungus and remediation from Latin word *remedium* meaning to restore balance. Fungi forms network of hyphae called mycelium in the soil to derive nutrients. They produce enzymes to degrade harmful contaminants in the soil. These contaminants get accumulated in the fungi and are easily degraded preventing further damage to the environment. Thus, fungi are gateway species that opens the world for other biological communities. New York based company called the Ecovative designs found substitute for Styrofoam, leather and many other plastic products. Modulating the mycelium of fungi to produce airy, soft and elastic material called aero mycelium is used as replacements for many goods. This aero mycelium can be sliced thin to make vegan bacon or can be compressed and dried to form leather revolutionizing fashion industry. Styrofoam used for packaging electronic and fragile products takes long time to decompose and they are hazardous to the environment.

Fig. 2: Air mycelium technology
Courtesy: Ecovative Designs

Similar packaging materials can be made using mushrooms and suitable substrate which is a perfect substitutefor Styrofoam. The mycelium of different mushrooms has different properties. Some are hardy and some others are soft and stretchy.

Mycelium as Building Material-Mycelium Brick

We have to consider the following steps for its formation. For this purpose, we need to:

1. Take a mushroom sample. Allow it to dry in the open until the tissues are visible.

2. Prepare the agar, which is a gelatinous substance made from seaweed. Put it in a pot of water and bring it to a boil. When finished, pour it into a container.

3. Put the tissue from the mushroom in the agar-filled container. One can observe how mushroom tissue collects on the surface and gradually grows into fibres that resemble hair. A semi-liquid mass of mushroom tissue should form after some time.

4. Prepare the substrate (item or food source) to encourage the growth of mushroom tissue. It might include sugars, pet food, agricultural waste, and even energy drinks. Put it in a container after filling it.

5. When the mushroom mass is prepared, put it in the container with the substrate mixture. Permit the mass to settle, increase in volume and occupy the substrate. Shake the container after closing it to evenly distribute the mass. This could take 3–7 days, depending on the quantity and kind of substrate.

6. Once the mushroom mass is prepared, take it out of the container, cut it into smaller pieces, and then put the pieces in a tray or mould to give the mass a particular shape. Allow it to stabilize and grow stronger under ideal circumstances.

7. Remove the completed brick block or form from the mould and store it for 7 days in ideal conditions. The block will become stronger and have dried out all of the moisture within 7 days.

8. The brick develops a white powdery coating on top as it dries. To eliminate any undesirable organisms that may have absorbed moisture, place the block in an oven. Once baked, the mycelium block is finished.

It is advantageous because it is completely biodegradable, less time consuming, temporary setups and depending on usage, installations can be quickly built and taken down. More heat can be trapped by mycelium tissue than fibreglass insulation and is also non-toxic and fireproof. It becomes lighter after drying despite developing porosity, it is still more powerful than a concrete pound for pound. It is a quick, low-cost, and simple to produce material. It has a lifespan of about 20 years.

The mycelium bricks' ability to hold water decreases over time, making them more vulnerable to mould and humidity. Mycelium bricks cannot be used for long-term structures due to their decreasing resistance to moisture, humidity, and mould growth. Mycelium bricks

expand, contract, and relax in response to the weather and when they are left untouched by the ground, so no coating is typically needed under normal environmental conditions.

Oil Degradation by Oyster Mushrooms

Some oyster mushroom strains have the ability to clean up oil-contaminated land. The most prominent study to prove this was led by Paul Stamens, and it is described in his book "Mycelium Running: How Mushrooms Can Help Save the World." Oyster mushrooms were utilized to solve diesel oil-contaminated soil. 95% of the oil was converted into non-toxic compounds by mushroom. *Pleurotus ostreatus* can also grow on and degrade oxo-biodegradable plastic bags; it can also aid in the degradation of green polyethylene.

The discovery of oil-eating mushrooms has numerous applications in industry, health, and environmental rehabilitation. Dispersants, which can increase oil toxicity, are now used in methods for cleaning land and shoreline oil spills. The lush and verdant pile of rehabilitated soil that was reduced from 20,000 ppm to 200 ppm of TAHs is

Fig. 3: Oil degradation by Oyster mushroom

Source: Fungi Imperfect i

An indication of the Oyster mushroom's efficiency and effectiveness. Even bacteria and enzymes used in Paul Stamets' experiment did not degrade the oil as well as the *P. ostreatus* culture. This discovery could have the same impact as fungi used in bread and beer; fungus is an important application in our everyday lives. It is clear that corporate and industry executives are ignorant of the possibilities for oyster oil-eating mushrooms. Oyster mushrooms have an advantage over the less hospitable settings of the bacterium and enzyme piles, as evidenced by the breakdown of oil and development of a functioning ecosystem on the infected dirt pile within a 6-week time frame. The potential efficiency and effectiveness of future GMO mushrooms are only made more hopeful by the discovery by researchers of the detoxifying characteristics of mushrooms (peroxidase). It won't take long for companies to start making money off of this finding. *Pleurotus ostreatus*, an oil-eating oyster mushroom strain, is the best candidate for removing land oil contamination. The mushroom absorbs the

oil and re-manufactures it to produce energy by breaking hydrogen-carbon bonds. The mushroom, in addition to catabolically dissipating the oil, creates a habitable environment for native species much faster than any other known method of oil dissipation. This discovery has not been fully utilized by industry and business sectors.

Mycofiltration

Mycofiltration is a technique that removes microorganisms and toxic waste from soil water using fungal mycelia. Decomposition is one of the primary roles of fungi in the ecosystem which is done by its mycelium. Extracellular enzymes and acids are secreted by the mycelium

Fig. 4: Mycofiltration of River water that breaks down lignin and cellulose, the two main building blocks of plant fibre.

Source: Tesla Nova

These are organic substances that resemble many organic pollutants structurally and have lengthy carbon and hydrogen chains. The key to Mycoremediation is identifying the best fungal species to target a particular pollutant.

Fungi have enzymes that break down woody materials such as ligninase and cellulase. This allows fungi to obtain the necessary carbon and energy for growth.These enzymes are non-specific, which means they can act on a variety of substrates, including environmental pollutants. Fungi can use hyphae to increase their surface area, making it easier to contact the pollutant. Extracellular enzymes can then be activated and they work on it.

Mycopackaging

Mycelium is the root network of a fungus which is found below ground. The branching network which are interconnected and can grow into any shape of delicate structure to tightly packed structures. The advantage of mycelium is that it can grow to very large area and is ecologically

Fig. 5: Mycopackaging of beauty products

Source: Ecovative Designs friendly.

The mycelium can be manipulated according to the human intention in order to form a definite shape as it can be used as a binder together with agricultural byproducts such as straw for the manufacture of protective packaging. Mycelium grows literally to fill the moulds; hence it can be molded into different shapes. A New York based company called Ecovative Design is the market leader of the mycelium packing technology and produces two packaging material solution- Myco Composite, which is the rigid composite material and Mycoflex, which is the mycelium flexible foam.

The advantages of mycelium are as follows – it is completely natural with no toxic effects plus, easy to grow and needs very less water to grow at an industrial level, making it almost perfect as a substitute to styro form in packaging material. The only drawback which can be seen is that, as a part of the fungus it actually utilizes oxygen and releases carbon dioxide which if produced in a large scale might trigger increased amount of carbon dioxide in the atmosphere.

Cellular Intelligence

A slime mold called *Physarum polycephalum* which is known to have baffled scientists by its ability to find food for itself when it is placed at one end and the food material is kept somewhere inside the maze. That, is called the nutrient maze. Now, the slime mold has special preference towards oat kernels as their food source so, what the scientists did was that they tried to mimic the map of Japan and took oats kernels and placed it all over an environment favourable for the slime mold similar to grow.

What we have to know is that each of the kernel represented a major city of Japan and Tokyo at the centre, was represented by the kernel with the slime mold inoculated on it. At

first the slime mold expanded in an exploratory manner, searching for more food i.e. oat kernels. But as the time passed, after 28 hours or so, the slime mold reorganized itself in the most efficient manner forming a network between those kernels which now represented each city in Japan connected to the source of slime mold i.e. Tokyo.

The question which arose was, how a unicellular organism was able to form a network that efficient? The engineers who worked around the clock for years, trying to find the most efficient way of connecting those cities were amazed by how a slime mold can do the exact same work in a matter of hours that too more efficiently than them. This was the demonstration of the cellular intelligence at its best, which teaches us how less we know about our own earthly organisms and us humans are searching for life beyond our earth.

Conclusion

Global warming along with water crisis is drawing attention of various scientists as well as the researchers. Acid rain is an another burning issue that is hampering the beautiful white marble structure of Taj Mahal since 1970s, even causing havoc in the Agricultural fields. For these consequences, sole reason that is to be blamed is the destructive use of plastics or polyethylene derived products mostly in packaging materials for various kind of commodities that results in variants of sources of pollution. There is a high need of finding an alternative to the use of plastics or it's derived products. For this, Mycoremediation can be considered the best remedy as well as can be utilized to replace at least 40% of the plastics. There is still a wide gap in mass production and commercialization of fungi-derived products and its awareness among the farmers as well as the common people. A pre-established stereotypic thought among people i.e., fungi are poisonous... still persist. Thereby, these drawbacks should be wiped off in order to promote Mycoremediation and save our planet earth from sinking deeper day by day.

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