Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2015, 2(8): 49-53

Research Article ISSN: 2394 - 658X

Capsula Mundi: An Organic Burial Pod

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ABSTRACT

In ever growing populated world there is no enough space to accommodate the remains of the deceased, so the concept of capsula mundi has been developed by Italian designers Anna Cielli and Raoul Bretzel. Capsula mundi is an organic burial pod made of natural starch plastic in which body of deceased is placed in foetal position that nurture tree seeds as the body break downs. The natural decomposition process feeds the tree above, and over time, burial spaces can be transformed from bleak graveyards into inhabited memorial forests. As the burial space grows and more trees are added, the area transforms into sacred woodland, bodies are returned to the natural world from which they came, and barren land can be reforested. This is just a conceptual design right now as burial legislation is being revisited around the world, but hopefully in the near future it can turn to reality. Biodegradable burial pods could save our planet, as they are the ultimate eco-friendly statement. The release of various nutrients and its uptake by the plant for its growth and metabolism is discussed with some information on biodegradable materials that can be used for the designing of the capsula.

Key words: Biodegradable, Decomposition, Liquefaction, Putrefaction, Skeletanization

INTRODUCTION

With over 7 billion people on the earth, all of whom have an expiration date; outdated modes of burial really have to be revisited. There is no enough space to accommodate the remains of an ever-growing population on a planet with a limited surface area, and even incinerating bodies uses up a remarkable amount of energy [1]. Most of the major cities are experiencing the repercussion of having a finite amount of space available for cemeteries, and in turn, cemetery plots. This prompted inflation in burial costs all over the world and also making the funeral home business a very lucrative one. In the attempt to make cemeteries, funerals, and burials many different ideas have been put forth over the last couple of decades, one of which includes turning deceased body into compost, but this concept of capsula mundi (organic burial pod) goes a step further and envisions planting 'sacred forests' with the bodies of the deceased serving as fertilizer [2].

This is the first Italian project created to promote the realization of green cemeteries. The idea of full circle rotation and returning where we came from is one that appeals to most of us, regardless of our faith (or lack thereof), and this is an idea caught perfectly by Capsula Mundi designers Anna Cielli and Raoul Bretzel[3]. They developed an organic burial pod (capsule) that turns the deceased body into nutrients for a tree that will grow out of their remains. The deceased body will be encapsulated in the foetal position and is then buried, and either a tree or a seed will be planted above the capsule. The tree is chosen when the person is alive, relatives and friends look after it when death occurs. A graveyard will no longer be full of gravestone and will become a holy forest.

Unfortunately, these burial pods are only a conceptual idea as of now, as it is against Italian Law to bury someone in this manner. So if or when, the project is allowed to be implemented, the overall goal is to create cemeteries full of trees instead of gravestones. Instead of a graveyard, these parks will be referred to as 'memory forests' [4].

OBJECTIVES AND METHODOLOGY

We have come across the concept of Capsula mundi through many sources. Nevertheless, most of the sources have given information about general concept of Capsula mundi, and none of these dealt simply and solely with the nutritional and biological value of the concept (capsula mundi). For that reason, we decided to collect and document a detailed data on nutritional value available to plant or seed present on the top of the organic capsule by the process of natural decomposition of the body present in the pod. The literature search was done by using the following search terms: ‘capsula mundi’, ‘decomposition of dead’ and ‘plant nutritional requirement’. We have related the biological and physiochemical aspects underlying the concept of Capsula mundi.

Organic Pod (capsule)

Capsula Mundi is an organic burial pod shaped just like an egg, made with 100% biodegradable material-starch plastic. The starch is taken from cyclical plants such as corn and potatoes. Biodegradable burial pods are the ultimate eco-friendly, and could help save our planet. The body (which hasn’t been befouled with formaldehyde or other toxins) is first encapsulated into a foetal position to be fit inside of the burial pod. The pod looks like an earthy piece of art, but really it’s a biodegradable ‘casket.’ A tree (or tree seed) is then planted over the top of the casket, which is then buried in the soil, will utilize the nutrients from the decomposing body as fertilizer for its growth [5].

Literature survey shows that several biodegradable polymers have already been tested in soil. Soil environment is used as first (and frequently unique) test to screen various biodegradable materials produced from laboratory scale reactions by polymer scientists. Most of the literature produced in the past has originated from studies aimed at showing the biodegradability in soil of polyethylene (PE) and other traditional plastics, solely or in combination with other polymers and additives. Polyesters such as polyhydroxybutrate (PHB) and its co-polymers, polycaprolactone(PCL), polybutlene succinate adipate, show degrees of mineralization which on one hand suggest a substantial biodegradability in soil and, on the other hand, indicate a rather high variability. Some of the other materials are cellulose, ecolene combined with starch, ethylene acrylic acid, gelatine, coated jute, nlon 6,6, polylactic acid, polyvinyl alcohol, etc[6].

Human Body Decomposition

In-soil human decomposition is unconditionally described in terms of the physicochemical, bacterial and environmental conditions. The soil, being a complex assemblage of minerals, organic matter, salt and organic solutions and various macroscopic and microscopic organisms will also wield varying influences in various locations and burial situations. Decomposition commences almost immediately after death, Soft tissue that has not been naturally or artificially preserved is subject to the processes of autolysis and putrefaction. After the process of putrefaction, the decomposition process follows liquefaction and disintegration, leaving skeletonised remains enunciated by ligaments. Skeletonization proceeds until eventually only the harder resistant tissues of bone, teeth and cartilage remain. These remains are then subjected to inorganic chemical weathering [7].

Putrefaction is characterized by the bacterially induced breakdown of soft tissue and subsequent alteration of their carbohydrate, protein and fat constituents. Van Haaren (1951) indicated that the body composition is approximately 64% water, 20% protein, 10% fat, 1% carbohydrate and 5% minerals. Normally, putrefaction is initiated by autolysis processes or self-digestion. As cells of the body are deprived of oxygen, carbon dioxide in the blood increases, pH decreases and wastes accumulation in the cells poison them. Concomitantly, unchecked cellular enzymes (proteases, lipases, amylases, etc.) begin to dissolve the cells from the inside out, resulting in the rupture of cells, and releasing nutrient-rich fluids. This process begins and progresses more rapidly in tissues that have high enzyme content (such as the liver) and high water content such as the brain, but eventually affects all the cells in the body. After enough cells have ruptured, nutrient-rich fluids become available and the process of putrefaction [8].

Decomposition Products of Protein

After death, proteins are broken down by the action of enzymes through a process known as proteolysis. The proteins of the epithelial and neuronal tissues are usually the first to be destroyed, including the lining membrane of the gastro-intestinal tract while that are more resistant to decomposition, include epidermis, reticulum, collagen and muscle protein. Keratin, which is an insoluble fibrous protein found in hair and skin is resistant to attack by most proteolytic enzymes. The integrity of this substance is the reason that hair remains among skeletonized remains for a long time due to the disulfide bridges between its component cystine structures. Its destruction is typically aided by physical or microbial damage; Streptomyces spp. bacteria facilitate this decomposition, the rate at which proteolysis proceeds depends largely on temperature, moisture and bacterial action. In general terms, the proteins break down into proteoses, peptones, polypeptides and amino acids. Proteolysis continues leading to the production of the phenolic substances skatole and indole, and the evolution of gases such as methane, hydrogen sulfide, carbon dioxide and ammonia. The common proteolytic bacteria genera are: Pseudomonas, Bacillus and Micrococcus. The sulfur containing amino acids of the proteins, for example cysteine, cystine, and the essential methionine undergo desulfhydralation and decomposition by the action of bacteria to yield sulphides, thiols, hydrogen sulfide gas, ammonia and pyruvic acid. The decomposition processes result in the production of wide range of organic acids and other substances that are generally of low or moderate molecular weight, ionic or non-ionic, and are susceptible to rapid breakdown by bacteria. However, under aerobic conditions it soon disappears as it is oxidized to elementary sulfur and then rapidly to sulfate through a series of steps producing sulfurous acids. This process is in common with standard chemical weathering of sediments. Various specific bacteria, mainly belonging to the Thiobacillus group, are also capable of bringing about these processes in the soil.

The nitrogen of proteins is present as a constituent of amino acids. The amino acids are readily used by most of the soil microbes as a source of energy when the proteins undergo deamination. The nitrogen, however, is liberated by chemical reactions as ammonia. The ammonia produced may in turn be used by higher plants or various microbes, may be converted to nitrate, may accumulate in the soil, and has suggested that plant growth may be enhanced. In the presence of low soil pH, ammonia (NH_3) is converted to ammonium ions ($NH_3^+H^+$ fi NH_4^+), which are readily utilized by plants. Under alkaline conditions, a fraction of the ammonium ions entering the soil may revert to ammonia and undergo volatilization (NH_4^+ fi NH_3). Alternatively, ammonium ions not subjected through one of the above mechanisms can undergo denitrification and nitrification. Nitrification can occur directly by light or during the metabolism of some heterotrophs, but is more usually accomplished by various species of soil organisms that convert ammonia to nitrate. Two autotrophic bacteria are the most important: the first oxidizes ammonia to nitrite (Nitrosomonas spp.), and the second transforms nitrite to nitrate (Nitrobacter spp.). The nitrifying organisms, however, unlike the denitrifiers are very sensitive to environmental pH. Nitrobacter spp., prefer a pH between 5 and 8, while Nitrosomas species have optimum conditions at pH 7 to 9. In the right medium, transformation of ammonia gives rise to nitrite, and once a large part of the ammonia has disappeared, nitrate is then formed. Nitrification normally occurs above the water table in the soil zone where oxygen and organic matter are abundant; the reactions are inhibited by added lime or high pH, and stop altogether at pH less than 5. Phosphorus is another important element that should also be considered. In the body the phosphorus store is found in a number of components: in proteins comprising nucleic acids and coenzymes; in sugar phosphate; and in phospholipids (fats) of the brain and spinal cord. As phosphorus is liberated during decomposition it does not follow simple pathways nor does it remain in elemental form. The mobility of phosphorus is far from simple. Phosphorus leaching in its oxidized forms-orthophosphates, appears to be tightly controlled by slight soil acidity within the range pH 6–7, yet these forms are the most thermodynamically stable and hence most mobile. Above pH 7 and certainly below pH 5 the phosphorus is locked up into insoluble components. In most soils, the phosphorus is likely to exist as insoluble inorganic complexes, probably associated with calcium, iron, aluminium and magnesium. The situation may be complicated by addition of lawn and garden fertilizers containing phosphates. Soil microorganisms also play an important role in phosphorus transformations from insoluble organic complexes to soluble ones and its release from mineral forms as well as its incorporation in new protoplasm. ‘A great many microbes(Mycobacterium, Pseudomonas, Micrococcus, Flavobacterium, Penicillium, Aspergillus and others) have the ability to solubilize inorganic phosphorus compounds’.

Decomposition Products of Fat

The body’s adipose tissue typically constitutes, 5–30% water, 2–3% proteins and 60–85% lipids (fats), of which 90–99% are triglycerides by weight. Triglycerides are composed of one glycerol molecule attached to three fatty acid molecules. Of the numerous fatty acids that are present, monounsaturated oleic acid is the most widespread in adipose tissue followed by palmitoleic, linolenic (both unsaturated) and palmitic (saturated) acids. If the neutral fat has been hydrolyzed to produce a large concentration of unsaturated fatty acids, oxidation of these fatty acids can thus result in the production of aldehydes and ketones. Both hydrolytic and oxidative processes generated by various fungi and bacteria will continue to decompose the adipose tissue in the soil. The fatty acids and glycerol breakdown giving shorter-chain saturated fatty acids and eventually carbon dioxide and water. The bacterium Clostridium perfringens has been widely implicated as a major agent for anaerobic decomposition of corpse because it is a resident of the human intestine and has strong proteolytic, saccharolytic, and lipolytic capabilities as well as being able to grow at a relatively high redox potential. The Clostridium genus is a ubiquitous inhabitant of soils.

Decomposition Products of Carbohydrate

The carbohydrates present in the soft tissues also break down during the decomposition process. For example glycogen, a complex polysaccharide will break down into sugars (glucose monomers) by the action of microorganisms. This destruction process occurs in the early stages of decomposition and is manifested largely in the liver. Some of the sugars are completely oxidized to carbon dioxide and water while some are incompletely decomposed for example by Clostridia spp. to form a number of organic acids and alcohols.

Liquefaction is a process in which the body’s tissues and organs soften during decomposition and degenerate to a mass of indistinguishable tissue that under continued decomposition becomes liquefied. This liquefaction is aided by the breakdown of proteins to simpler units thus allowing a greater range of microorganisms to grow on the substrate and to subsequently be dispersed throughout the tissues. Discoloured natural liquids and liquefying tissues are made frothy by the gases forming within the decomposing remains. Some of these liquefaction products may exude from the natural orifices, forced out by the increasing pressure of the gases. Skeletanization is decomposition products of bone. Bone is a composite tissue and is composed of three main fractions: a protein fraction consisting mainly of collagen which acts as a supportive scaffold; a mineral component consisting of hydroxyapatite to stiffen the protein structure; and a ground substance of other organic compounds such as mucopolysaccharides and glycoproteins. The collagen and hydroxyapatite are strongly held together by a protein-mineral bond that gives bone its strength and contributes to its preservation. The organic collagen phase of bone is eliminated predominantly by the action of bacterial collagenases by reducing the proteins to peptides, which in turn break down to their constituent amino acids. Collagen degradation is also thought to be affected by the activity of Clostridium spp. that operate in a pH range of 7-8. Following elimination of the collagen phase, the loss of mineral hydroxyapatite proceeds by inorganic mineral weathering. The calcium ions in the apatite crystal migrate into the soil solution when they are replaced by protons at low pH. Not only is there removal of proteins and minerals but also substitution, infiltration and adsorption of ions, which serve to undermine the protein-mineral bond leaving the bone susceptible to internal and external elements.Acidic soils are the most destructive as they work by dissolving the inorganic matrix of hydroxyapatite which produces an organic material susceptible to leaching by water. In general, bone preservation is best in soils with a neutral or slightly alkaline pH, and is worse in acid conditions. Dry sand assists preservation because of reduced bacterial action yet elsewhere sandy and permeable soils assist decomposition because of the free exchange of water and gases. During life, the body’s bones accumulate trace amounts of non-primary elements—notably strontium and fluorine and various metals, so that these are available to be released during the later chemical weathering of decomposition.

Plant Nutritional Requirements

Plants whether grown in the field or in a container, use inorganic minerals for their nutrition. Complex interactions involving decaying organic matter, animals, microbes and weathering of rock minerals, take place to form inorganic minerals in soil. Absorption of mineral nutrients such as ions in soil water is carried out by roots of the plant. Many other factors influence nutrient uptake for plants. Ions can be readily available to roots or could be ‘tied up’ by other elements or the soil itself. Soil with too low pH (acid) or high in pH (alkaline) makes minerals unavailable to plants. The term ‘fertility’ refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts and in suitable proportions. Most fertilizers are formulated to account the deficiencies of mineral elements in the soil. Plant nutrition is a term that takes into account the interrelationships of mineral elements in the soil or soilless solution as well as their role in plant growth. This interrelationship involves a complex balance of mineral elements essential and beneficial for optimum plant growth. The term essential mineral element (or mineral nutrient) was proposed by Arnon and Stout (1939). They concluded three criteria must be met for an element to be considered essential. These criteria are: 1. A plant must be unable to complete its life cycle in the absence of the mineral element. 2. The function of the element must not be replaceable by another mineral element. 3. The element must be directly involved in plant metabolism. These criteria are important guidelines for plant nutrition but exclude beneficial mineral elements. Beneficial elements are those that can compensate for toxic effects of other elements or may replace mineral nutrients in some other less specific function such as the maintenance of osmotic pressure. The omission of beneficial nutrients in commercial production could mean that plants are not being grown to their optimum genetic potential but are merely produced at a subsistence level. This discussion of plant nutrition includes both the essential and beneficial mineral elements.

There are actually 20 mineral elements beneficial or necessary for plant growth. Hydrogen (H), carbon (C) and oxygen (O) are supplied by water and air. The six macronutrients, Calcium (Ca), magnesium (Mg), nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) are required by plants in large amounts. The rest of the elements are required in trace amounts (micronutrients). Essential trace elements include chlorine (Cl), boron (B), copper (Cu), manganese (Mn), iron (Fe), zinc (Zn), molybdenum (Mo), nickel (Ni), and sodium (Na). Beneficial mineral elements include cobalt (Co) and silicon (Si). The beneficial elements have not been deemed essential for all plants but may be essential for some. The distinction between beneficial and essential is often difficult in the case of some trace elements. Cobalt for instance is essential for nitrogen fixation in legumes.

Nitrogen is present in the soil in many different forms, including as a gas (N_2); as various oxides of nitrogen, such as nitrate (NO_3) and nitrite (NO_2); and as ammonia (NH_3), amines (formed from ammonia), or ammonium (NH_4). Organic matter is a major storage area for nitrogen. In fact, in most soils, more than 95% of the nitrogen is present in the organic matter Plants can only use two of the many forms of nitrogen, namely, nitrate and ammonium. Therefore, other forms of nitrogen need to be converted to either nitrate or ammonium before the plant can use them. The conversion process is carried out by various soil micro organisms, such as fungi and bacteria, and by chemical reactions in the soil. Phosphorus **(P)** helps run the 'power station' inside every plant cell and has a key role in energy storage and transfer. Phosphorus is necessary for all growth processes and for the nodulation of rhizobia bacteria and nitrogen fixation. Phosphorus is a mobile nutrient within the plant and is moved to the actively growing tissue, such as root tips and growing points in the tops of plants. Therefore, deficiency symptoms occur first in the older leaves. It is important that plants have an adequate supply of phosphorus to ensure recovery and re-growth after grazing. Likewise, newly sown pastures benefit from a supply of readily available phosphorus close to the germinating seed to help quickly develop a large root system. Potassium (K) is needed for a wide range of important processes within the plant, including cell wall development, flowering and seed set. Potassium has a key role in regulating water uptake and the flow of nutrients in the sap stream of the plant. It helps legumes fix nitrogen and also helps the plant to resist stress from weather, insects and diseases. **Sulphur (S)** is required for the formation of several amino acids, proteins, and vitamins and for chlorophyll production. It also helps the plant to resist stress from weather, insects and diseases. **Calcium (Ca)** is usually in adequate supply for plant growth. It is involved in the proper functioning of growing points (especially root tips), maintaining strong cell walls, and seed set in clovers. Magnesium (Mg), like calcium, is usually present in sufficient quantities in the soil for plant growth; and pasture deficiencies are rare. It is an essential component of chlorophyll and is required for the transport of phosphorus around the plant [9].

Manganese (Mn) has several plant-growth functions. It is closely associated with iron, copper and zinc as a catalyst in plant-growth processes; is essential for rapid germination; and plays a role in enzyme systems in seed and new tissues. Iron (Fe) is associated with the production of chlorophyll and helps to carry oxygen around the plant cells. Iron is also involved in reactions that convert nitrates to ammonia in the plant. Boron (B) is mainly involved in the movement of sugars throughout the plant and in seed production in legumes. It is also an important nutrient in the metabolism of nitrogen, carbohydrates, and hormones and is involved in the uptake and efficient use of calcium in the plant. Chlorine (Cl) is thought to stimulate carbohydrate metabolism, some plant enzymes, chlorophyll production, and the water-holding capacity of plant tissues. Chlorine seems to be more important for animals than for plants. Chlorine deficiencies seldom occur as the chloride ion is continually replenished via rain water, the amount increasing with rainfall quantity and closeness to the sea.

The term pH refers to the alkalinity or acidity of a growing media water solution. This solution consists of mineral elements dissolved in ionic form in water. The reaction of this solution whether it is acid, neutral or alkaline will have a marked effect on the availability of mineral elements to plant roots. When there is a greater amount of hydrogen H^+ ions the solution will be acid (<7.0). If there is more hydroxyl OH^- ions the solution will be alkaline (>7.0). A balance of hydrogen to hydroxyl ions yields a pH neutral soil (=7.0). The range for most crops is 5.5 to 6.2 or slightly acidic. This creates the greatest average level for availability for all essential plant nutrients. Extreme fluctuations of higher or lower pH can cause deficiency or toxicity of nutrients.

CONCLUSION

Capsula Mundi is an eco-friendly alternative to being buried in a coffin. To make a coffin nowadays you cut down an old tree, of valuable wood. A coffin has a short life span and is a product of our society. The growth of a tree needs from 10 to 40 years and a coffin is used for three days. In the concept of capsule mundi, an organic biodegradable burial capsule turns the deceased’s body into nutrients for a tree that will grow out of their remains. The deceased is encapsulated in the foetal position and is then buried, and either a tree or a seed will be planted above the capsule. The essential macro and micro nutrients required by the plant or seed, such as nitrogen, phosphorous sulphur, potassium, magnesium, calcium, manganese, iron etc., are obtained by continuous process of decomposition from death such as autolysis, putrefaction, liquefaction and disintegration, skeletonization and chemical weathering of the human body. Capsule Mundi saves the life of a tree and proposes to plant one more. By planting different kinds of trees next to each other it creates a forest. The capsule compounds solely or in combination with other additives can be invented which show eco-friendly degradation in soil. We should also work on standardization of protocols for complete utilization of nutrients that are released by the dead bodies by the plant for its growth and metabolism. Hence, there is a necessity for polymer scientists along with biologists and other group of scientists to work in coherence to invent efficient compounds and advanced techniques for a clean and green environment.

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