Technical Discussion
Bioremediation of Eutrophic Lakes and Ponds

Eutrophication can be defined as "The process by which a body of water acquires a high concentration of plant nutrients, especially nitrates or phosphates. This nutrification promotes algae growth that, when it dies, can lead to the depletion of dissolved oxygen, killing fish and other aquatic organisms. While eutrophication is a natural, slow-aging process for a body of water, human activities greatly accelerate the process".

To restore a eutrophic lake to the more desirable mesotrophic state, the dead organic material must be decomposed in such a manner as not to rapidly deplete the oxygen level of the water and, very importantly, the excess nutrients then must be reduced to acceptable limits. EmTec believes the best way to solve this problem is with bioremediation: the application and growth of selected specialized bacteria. The product EmTec-FM contains specialized bacteria and has been specifically designed to treat eutrophic lakes and to restore them to a mesotrophic state where fish and wildlife may flourish.

Background

Bacteria are procaryotic organisms that reproduce primarily asexually by a process known as binary fission. One organism splits into two organisms and each one is capable of reproducing further. The principle of bioremediation of eutrophic lakes is based on the tremendous growth potential of bacteria with the binary fission process and, in most cases of bioremediation, growth of the bacteria is absolutely essential.

Bacterial Growth requirements

Bacteria, as all living organisms, have certain chemical and physical growth requirements. The basic knowledge of these requirements is especially important in considering, understanding, and utilizing bioremediation.

I Chemical requirements

1. An energy source. This is needed primarily for biosynthetic reactions to make polymers such as proteins from amino acids and RNA and DNA from nucleotides. Some Bacteria can utilize light energy, however the ones that we are concerned with oxidize chemical compounds to obtain their energy.

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A. Chemoorganotrophs

The bacteria that are involved in decomposing dead biomass are chemoorganotrophs, as they utilize organic compounds for their energy source. Chemoorganotrophic bacteria obtain energy by removing hydrogen from an organic compound and reacting it with oxygen in a stepwise fashion.

Using glucose as an example of an energy source:

glucose + 6 oxygen → 6 carbon dioxide + 6 water

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

Hydrogen is removed from the glucose molecule and tranferred to oxygen providing biologically useful energy to the organism through the electron transport system with some of the energy being lost as heat. A solid compound is oxidized to a gas and a liquid.

B. Chemolithotrophs

Some bacteria, including nitrifiers, involved in the removal of nitrogen compounds, such as, ammonia, nitrite, and nitrate are chemolithotrophs as they utilize inorganic compounds as an energy source.

Using ammonia as an example:

$NH_3 \rightarrow NO_2$ (Nitrosomonas)

$NO_2 \rightarrow NO_3$ (Nitrobacter)

2. A carbon source. Carbon is required for the biosynthesis of all of the polymeric units in the cell such as DNA, RNA, and proteins.

A. Heterotrophs

Bacteria which require an organic source of carbon for growth are considered heterotrophic. These are the ones EmTec utilizes for the decomposition of the organic material in the bioremediation process.

Using glucose as example once more:

glucose → new cell mass

$C_6H_{12}O_6$ → new bacterial protein, new bacterial DNA, new bacterial RNA

In this example the carbon from glucose is transformed into carbon in Protein, DNA, and RNA in a new bacterial cell.

So when a bacterial cell utilizes glucose, a portion is used as an energy source, a portion as a carbon source, and the remainder is oxidized with the energy being lost as heat.

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B. Autotrophs

The nitrifying bacetria utilize carbon dioxide (inorganic carbon) as a sole carbon source and considered autotrophic organisms. The growth of autotrophic bacteria is inhibited by a high concentration of organic material as measured by BOD.

3. A nitrogen source. In addition to being an energy source for nitrifiers, Nitrogen is a component in the amino acids of both structural and enzymatic proteins and also in the purines and pyrimidines of RNA and DNA. Bacteria are very versatile as to their nitrogen source as some can use atmospheric nitrogen (gas), ammonia, nitrite, nitrate, and organic nitrogen.

As an example both heterotrophs and autotrophs can utilize ammonia as a nitrogen source.
ammonia → organic nitrogen → Proteins, DNA, and RNA in new bacterial cells.

4. A phosphorus source. Phosphate is a component part of the nucleotides composing RNA and DNA and is also required for energy transfer reactions. It is utilized in sugar metabolism and is found in cell membranes as phopholipids. As an example, inorganic phosphate is utilized to make organic phosphate esters.

Orthophosphate---------organic phosphate------DNA, RNA, lipophosphates, and phosphorylated sugar intermediates.

5. A mineral source. Minerals such as magnesium, manganese, iron, and essentially every mineral found in the human body are required.

6. An oxygen source. With aerobic organisms, oxygen is necessary as a hydrogen acceptor for energy production and growth. The organisms in EmTec-FM are aerobic and facultative anaerobic and have been selected because they do not produce foul odors even when growing anaerobically. The function of oxygen is quite different in biological hydrocarbon degradation as a oxygen is actually incorporated into the hydrocarbon molecule to produce long chain fatty acids. Approximately four pounds of oxygen is needed for metabolism of one pound of hydrocarbon.

II Physical requirements

1. pH. Since the biochemical reactions in the degradation of the organic polymers (fats, proteins, starch, cellulose etc.) are primarily hydrolytic, optimal results with the heterotrophic population will be achieved if the pH is in the 7-8 range. There will still be activity outside this range but below pH 6 and above pH 8.5, the adjustment of the pH or the addition of specialialized bacteria should be considered. The 7-8 pH range would also be the pH range optimum for the nitrifier bacteria naturally in the lake.

2. Temperature. The bacteria utilized are all isolates from the soil and laboratory studies have shown their optimum temperature for growth and contaminant degradation is 28°C. They will still have considerable activity on both sides of the optimum.

If all of the listed chemical and physical growth requirements are met, the bacteria have to grow and in doing so they consume either organic compounds (cell biomass) or inorganic compounds (ammonia, nitrite, or nitrate). The conditions and the population of the bacteria can be manipulated to degrade any particular contaminant such as constituent parts of dead algae (proteins, complex carbohydrates, lipids), as well as, ammonia and nitrate.

Rational of ELR (Eutrophic Lake Restoration)

The bacteria in EmTec-FM will change the eutrophic pond or lake in a stepwise fashion: first the heterotrophic bacteria in the product will begin to consume the dead algae and other excess organic material in the lake converting it to carbon dioxide, water, and new bacteria..This will improve water clarity by reducing the BOD, sludge and total solids. In addition it will, by competitive inhibition and direct oxidation, eliminate the bad odors produced by the previous growth of anaerobic bacteria.

The reduction of inorganic nutrients in the lake occurs by two different mechanisms.

1. As the heterotrophic bacteria degrade the dead algae biomass they will utilize ammonia and phosphate for their growth requirements converting them to organic nitrogen and organic phosphate.

2. With the heterotrophic bacteria degrading the organic material and lowering the BOD, the natural nitrifying bacteria will function much more efficiently in oxidizing the ammonia and nitrite to nitrate for their energy requirements for growth. The increased oxidation will result in increased growth and the increased uptake of ammonia and phosphate for biosynthetic purposes.

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