Pentachlorophenol Biodegradation in Continuous Flow Bioreactors

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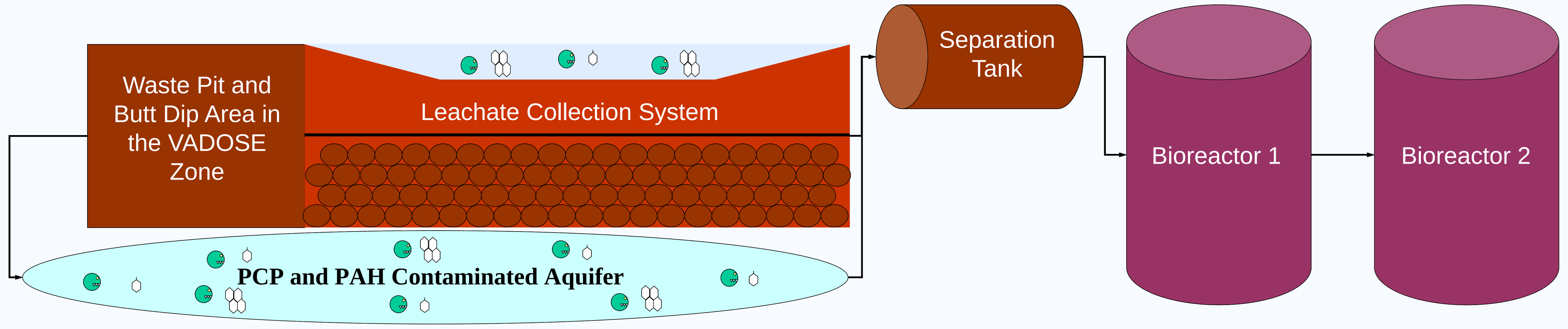
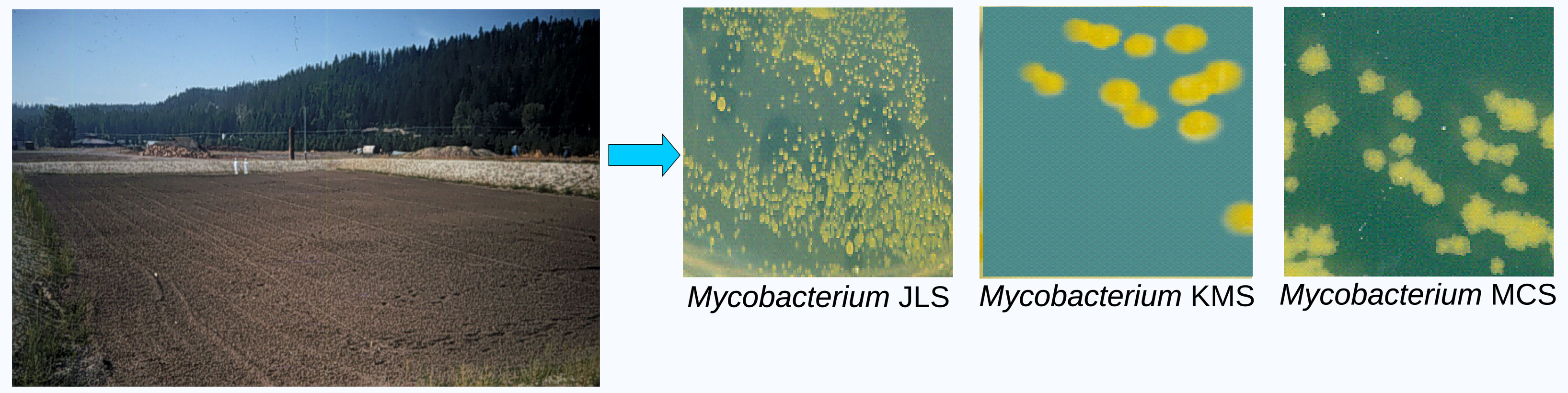


Figure 2. Groundwater remediation and continuous flow bioreactors at the Libby, Montana site.

Problem:

Pentachlorophenol (PCP) is a toxic and potentially carcinogenic compound that is used as a wood preservative and previously as a pesticide. PCP is often found associated with Polycyclic Aromatic Hydrocarbons (PAHs) in contaminated groundwater and soil near wood preservative sites. The immediate and effective removal of PCP is essential to the protection of environmental and public health. PCP acts as an uncoupler of oxidative phosphorylation decreasing the levels of ATP in the body's cells, and causes blisters or burns to exposed skin. A 100-acre contaminated wood preservative site in Libby, Montana has been a source of research for PCP and PAH biodegradation in both groundwater and soil. Bioreactors at this site are used to degrade PCP and PAHs from contaminated groundwater while Land Treatment Units have been used to clean contaminated soils. Up to 80% of PCP is removed from contaminated groundwater in the bioreactors. It is desirable to find the mechanism(s) by which this degradation occurs and implement them at other PCP contaminated sites. PCP in the groundwater is removed by natural attenuation: biodegradation by the naturally occurring microorganisms. Three strains of Mycobacteria from this site have been found and characterized that are capable of degrading PAHs and are assumed to be able to partially degrade PCP.



Land treatment unit – Libby, MT

Figure 3. Source of PAH-degrading Mycobacterium isolates from contaminated Libby soil and images on agar plates.

Approach:

Levels of PCP and PAHs at the site in Libby, Montana were found to decrease over time due to natural attenuation. Soils from the Land Treatment Units (LTUs) provided the source of microbes responsible for the removal of these contaminants. Three were found to be capable of degrading PAHs [reference]. These microbes were characterized as Mycobacterium strains. The genomes of all three microbes were sequenced along by the U.S. Department of Energy Joint Genome Institute. Analysis of the sequences revealed a single known pentachlorophenol monooxygenase protein in all three genomes. The three isolates were then tested to see if they were capable of mineralizing 14C-PCP by measuring 14CO2 production.

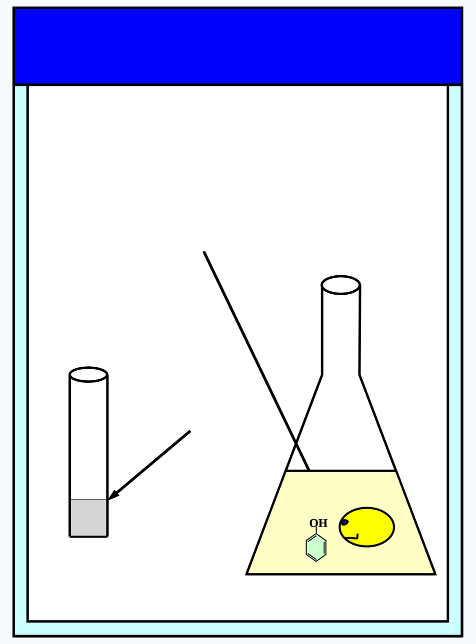
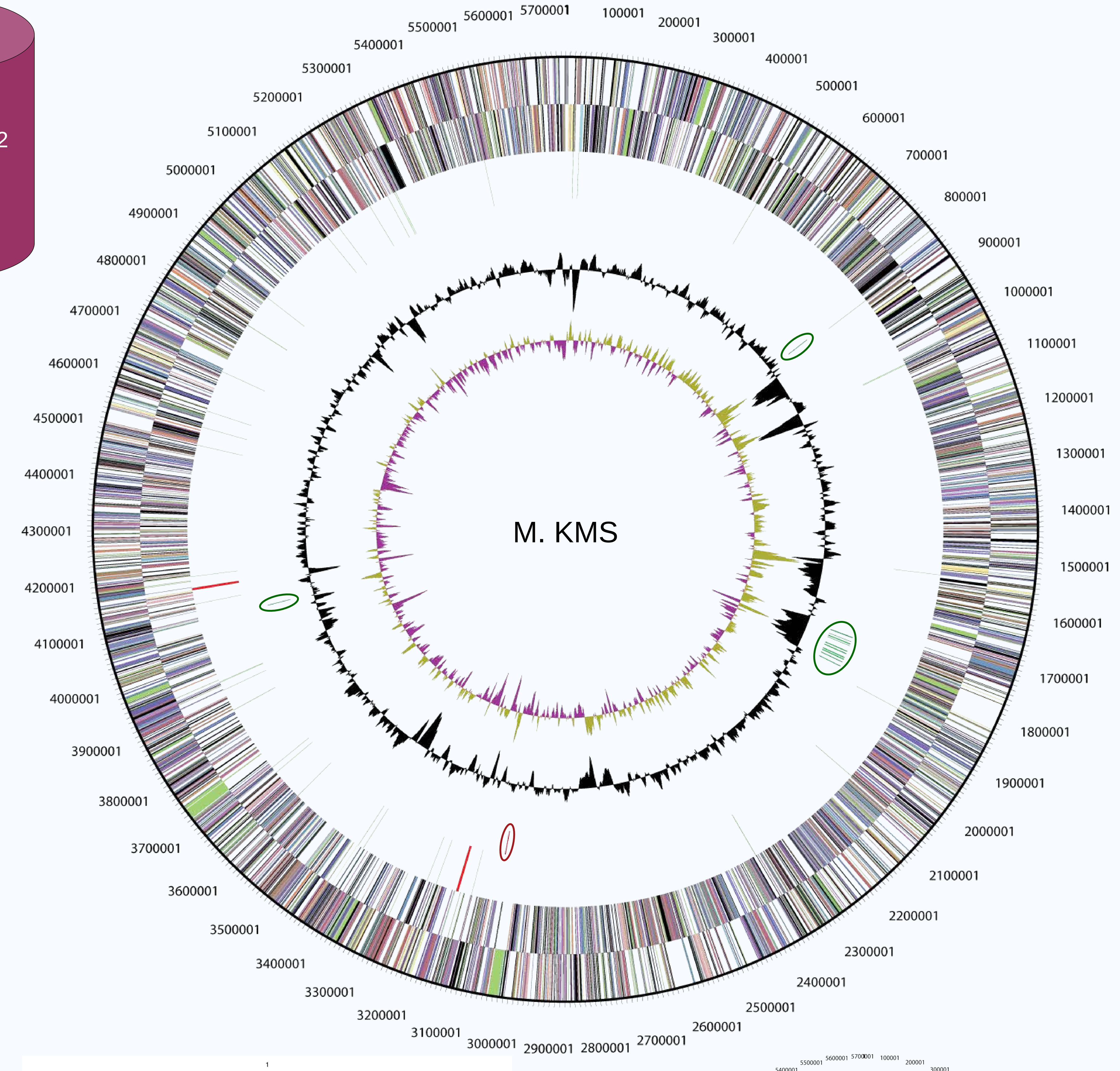
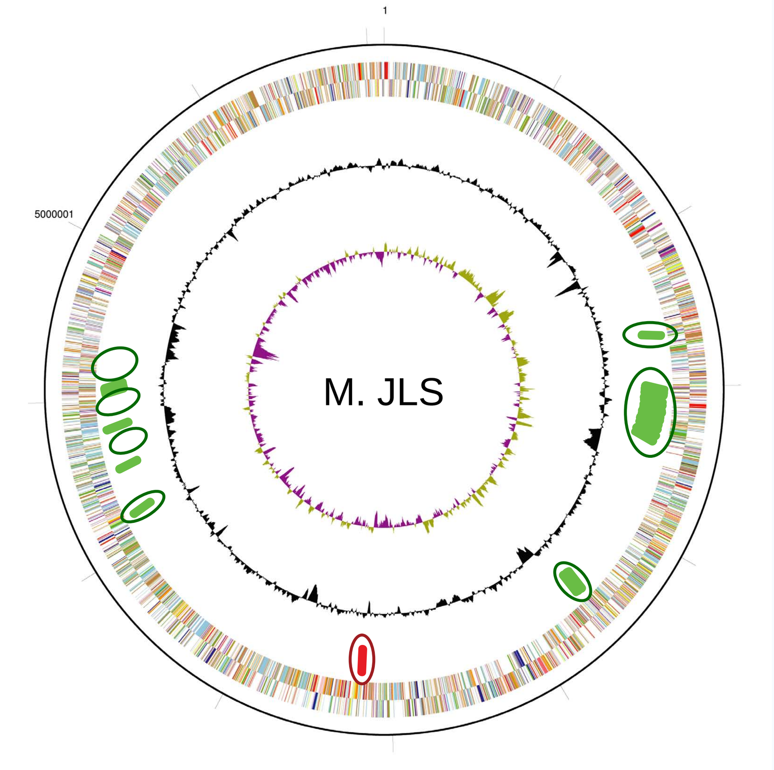


Figure 4. Example of a radioactive liquid microcosm.





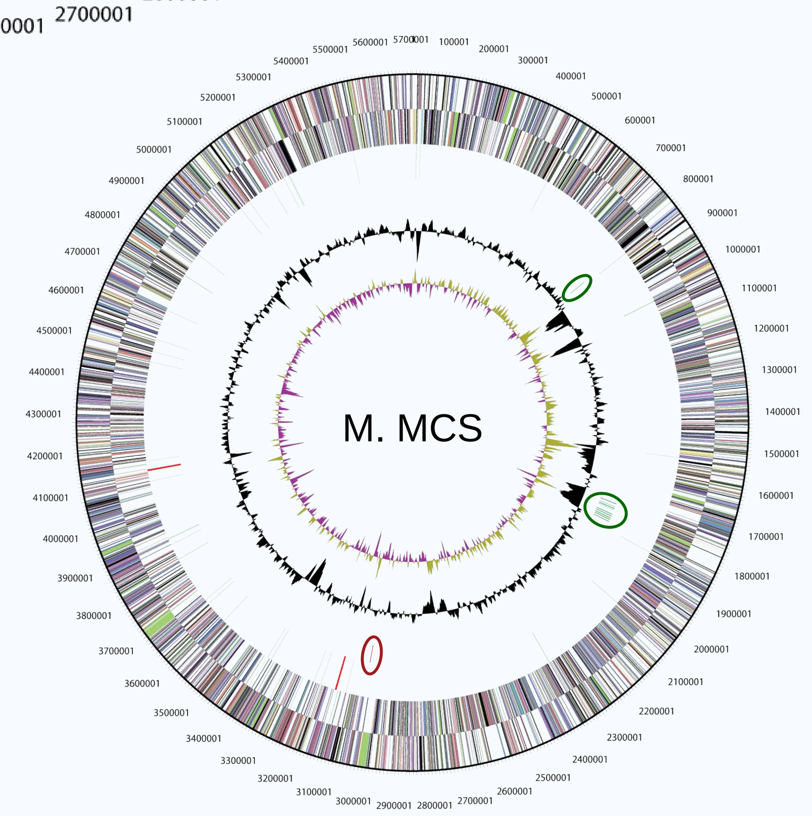


Figure 1. Isolated mycobacteria chromosomes with PAH-degrading encoded regions (green circles) and PCP monooxygenase protein encoding gene (red circles).

Figure 5. Separation tank DNAPL effluent.

Figure 6. Effluent from bioreactor 2.

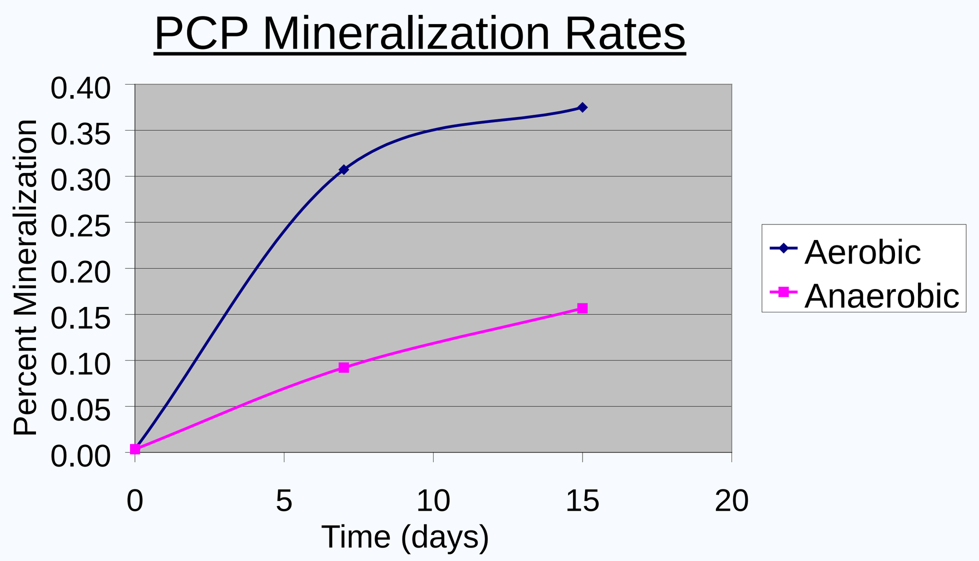


Figure 7. Mineralization results from PCP microcosm experiments.

Results & Discussion:

After two weeks of measuring 14C-PCP mineralization it was found that only the bioreactor samples were capable of mineralizing the 14C-PCP into 14C-CO2. All single strain samples were incapable of degrading the PCP under either aerobic or anaerobic conditions. The bioreactor samples were shown to be able to degrade PCP after only one week under both anaerobic and aerobic conditions. Further analysis needs to be performed to determine the organisms responsible and the mechanisms by which the organisms are capable of mineralizing PCP.

The three isolates were also found to be closely related to Mycobacterium tuberculosis, bacterium that causes Tuberculosis, allowing possible medicinal applications to be developed using nonpathogenic microbes. Applications in biomedical engineering for the discovery of a cure for Tuberculosis are also being researched. The information provided by the sequenced genome allows a unique approach to locate possible targeting sites for medicines fighting against M. tuberculosis.

Figure 8. Image of the interior of bioreactor one.

Acknowledgments:

- Utah Water Research Laboratory
- The Huntsman Environmental Research Center
- Department of Biological & Irrigation Engineering, USU
- Department of Biology, USU

References:

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Figure 9. Image of the exterior of bioreactor one.