REFERENCE MATERIALS FOR ANAEROBIC DIGESTION

Anaerobic digestion is well-studied process. It occurs naturally in water bodies, in landfills, swamps, aboveground tanks, ponds, deep below the ground surface, and in collapsible aboveground containers. Anaerobic digesters can operate with temperature and pH controlled within a few degrees and a few pH units. Or they can operate with widely varying temperature and pH. Some digesters are mixed, some are unmixed, some are plug flow, some employ multiple chambers. The refinements developed were historically oriented toward the more rapid reduction of waste materials into less harmful constituents of water and carbon dioxide. More rapid reduction allows a smaller container to accomplish the same waste reduction.

Virtually all experience running anaerobic processes has been used for treating wastewater at 1-2 atmospheres and 30° C. However, anaerobic digesters can operate at cooler temperatures for animal waste treatment and energy production. Los Angeles has started construction of an anaerobic digester operating at 100 atmosphere pressures and warmer temperatures using deep well injection for biosolids disposal and carbon sequestering.

Also, returning the nutrients from an algae anaerobic digester is important to the sustainability of both the methane production and the carbon sequestering. Algae require nutrients to grow. In the natural state, the nutrients for growing algae remain in the water or settle slowly to the bottom of the water body. Issues arise when humans add unnatural nutrients (fossil fuel derived fertilizers and fecal matter from unnaturally high density animal/human populations). Issues would also arise (decreasing fish population and reduced biodiversity) should humans remove all the nutrients from the water, a distinct possibility with unsustainable algae growth (as a means to sequester carbon dioxide) and decay or unsustainable algae growth and harvesting.

A sustainable operation would include pumping the nutrient laden liquid from the POD to the water surface to grow more algae or to land for growing food crops. As a product of the biologic reaction, ammonium will be present at relatively high concentration in the POD water. Metering the POD water to the surface water or to land will allow time for algae to increase surface water dissolved oxygen, allowing bacteria to convert the ammonium to nitrate, and the nitrate to be absorbed by the algae. A similar process has been employed for wastewater treatment. (On land, unsaturated soils contain the necessary oxygen and bacteria.)

A sampling of published literature is listed below:

Books

A Look Back at the U.S. Department of Energy's Aquatic Species Program: Biodiesel from Algae., Sheehan, J., Dunahay, T., Benemann J., Roessler P., U.S. National Renewable Energy Laboratory, July 1998.

Anaerobic Digestion of Biomass, Chynoweth, D.P. and Isaacson, R., New York: Elsevier Applied Science Publishers LTD, 1987

High-Rate Anaerobic Treatment of Wastewater at Low Temperatures, Lettinga, Rebac, Parshina, Nozhevhikova, van Lier, & Stams, Wageninge Agricultural University, Netherlands & Russia January 1999

Marine biomass: Algae as source of energy, by Edler, L.; Vonwachenfeldt, T.; Emmelin, L., April 1980

Seaweed Cultivation for Renewable Resources, K.T. Bird & P.H. Benson, 1987 ISBN: 0-444-42864

Articles / Chapters

Bruno, M.S., Young, J.T., Moghaddam, O, Wong, H., and Apps, J.A., "Chapter 46: Thermal Treatment, Carbon Sequestration, and Methane Generation Through Deep-Well Injection of Biosolids", in Underground Injection Science and Technology, C.F. Tang and J. Apps, ed., Elsevier, Amsterdam, 2005

Greenpeace Research, March 1999, British Government Panel on Sustainable Development - Sequestration of Carbon Dioxide, Annex B. Sequestration of carbon dioxide by ocean fertilisation.

B. van der Meer (2005), "Carbon Dioxide Storage in Natural Gas Reservoirs," Revue de l'Institut Français du Pétrole, Vol. 60, pp 527ˆ536.

Zhenhao Duan and Shide Mao (2006), "A thermodynamic model for calculating methane solubility, density and gas phase composition of methane-bearing aqueous fluids from 273 to 523 K and from 1 to 2000 bar," Geochimica et Cosmochimica Acta, Vol. 70, pp 3369ˆ3386.