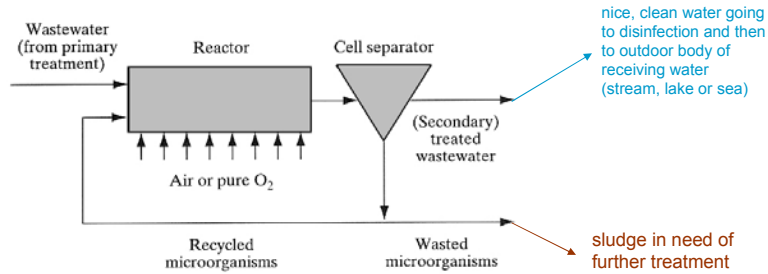


Anaerobic Digestion of Wastewater Sludge

(Nazaroff & Alvarez-Cohen, Section 6.E.3)
(Mines & Lackey, Section 10.9)



The goal is to reduce the amount of sludge that needs to be disposed.

The most widely employed method for sludge treatment is anaerobic digestion.

In this process, a large fraction of the organic matter (cells) is broken down into carbon dioxide (CO_2) and methane (CH_4), and this is accomplished in the absence of oxygen. About half of the amount is then converted into gases, while the remainder is dried and becomes a residual soil-like material.



What the equipment looks like

Enclosure exists to trap and save the methane. This methane, a fuel, can be used to meet some of the energy requirements of the wastewater treatment facility (co-generation).

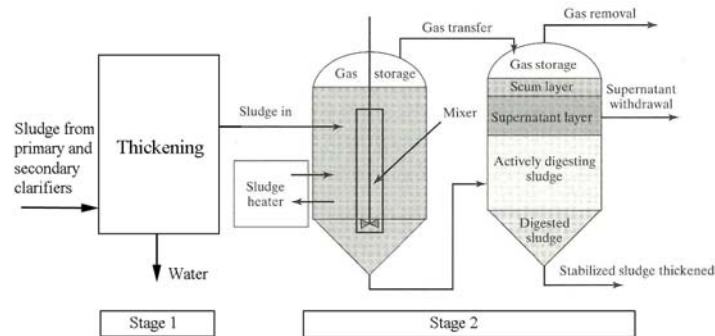
What the sludge looks like after anaerobic digestion.

It is rich in nitrates and performs well as a fertilizer.



(Photos from <http://www.madep-sa.com/english/wwtp.html>)

How the system works



Tanks are sealed to prevent both oxygen from entering and methane from escaping.

(Mines & lackey, Figure 10.12, augmented)

The treatment of wastewater sludge, from both primary and secondary treatment steps, consists of two main phases.

- In the 1st phase, in processes known as *thickening* and *dewatering*, the goal is to separate as much water as possible to decrease the volume of material.
- The 2nd phase is known as *sludge stabilization*; it reduces the level of pathogens in the residual solids, eliminates offensive odors, and reduces the potential for putrefaction.

Phase 1: Thickening

The purpose of thickening the sludge is to reduce its volume, which can be several fold.

Typical sludge comes at 1% solid fraction. Thickening it to 2% halves the volume, to 10% reduces the volume by a factor 10. [1% solid fraction \approx 10,000 mg/L]

The various existing methods are:

- Gravity thickening (can achieve up to 10% solid fraction)
- Gravity belt thickening (can achieve up to 6% solid fraction)
(uses a polymer to coagulate the solids, from which follows a rejection of water)
- Dissolved air flotation (can achieve up to 6% solid fraction)
- Thickening centrifuge (can achieve up to 8% solid fraction).

An example of gravity belt thickener and its product



www.cityofbatavia.net/



www.rendertech.co.nz/wastewater_treatment.htm

Phase 2: Stabilization by anaerobic digestion

Anaerobic digestion of municipal wastewater sludge has been widely practiced since the early 1900s and is the most widely used sludge treatment method.

Overall, the process converts about 40% to 60% of the organic solids to methane (CH₄) and carbon dioxide (CO₂). The chemical composition of the gas is 60-65% methane, 30-35% carbon dioxide, plus small quantities of H₂, N₂, H₂S and H₂O. Of these, methane is the most valuable because it is a hydrocarbon fuel (giving 36.5 MJ/m³ in combustion).

The residual organic matter is chemically stable, nearly odorless, and contains significantly reduced levels of pathogens.

The suspended solids are also more easily separated from water relative to the incoming sludge or aerobically treated sludge (such as in outdoor pond).

Controlling Municipal Energy Costs

(based on articles by Lyn Corum and Lori Lovely, *Distributed Energy*, Nov-Dec 2006, pages 16-26)

Fact:

Treating and pumping water and wastewater ranks near top of energy needs for municipalities across the United States.

Example:

According to the California Energy Commission, 56% of energy usage by municipalities is spent on water and wastewater treatment facilities.

Consequence:

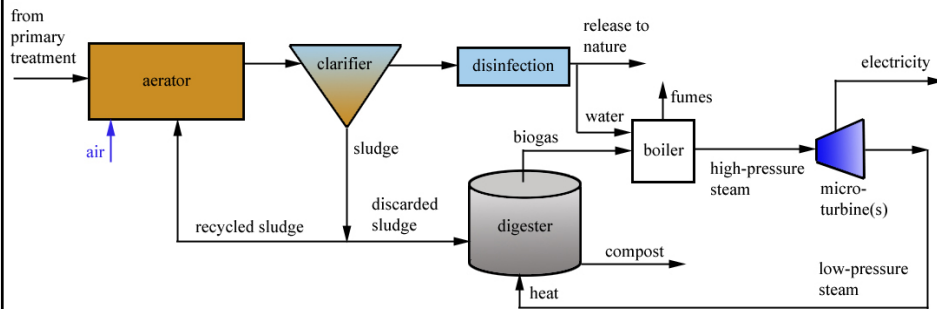
Energy efficiency in water and wastewater facilities translates into substantial savings benefiting agencies and taxpayers.

Energy source:

Anaerobic digestion of secondary-treatment sludge generates plentiful biogas.

In California, out of 242 sewage treatment plants, already 10 generate 38 MW from biogas, and another 12 burn biogas to produce hot water to heat digesters.

What about the 220 others?



Biogas emanating from digester = methane (CH_4), hydrogen sulfite (H_2S) and some siloxane (feedstock for personal care products)

Electricity is used to power pumps.

Variations:

1. Combust gas directly in the microturbine(s)
 - + no need for boiler
 - corrosion of turbine blades by sulfur (from H_2S)
 - deposition of SiO_2 (from siloxane)
 - need to scrub the biogas before passing it through the turbines
2. Pass biogas in fuel cells (molten carbonate type)
 - more electricity, less heat
3. Simply burn the biogas and use the heat (no electricity co-generation)
4. Complement energy source with solar



(<http://www.city.albertlea.org/wastewat.htm>)

Albert Lea facility in Minnesota:

12 million gallons/day of sewage

4.5 million gallons/day sludge

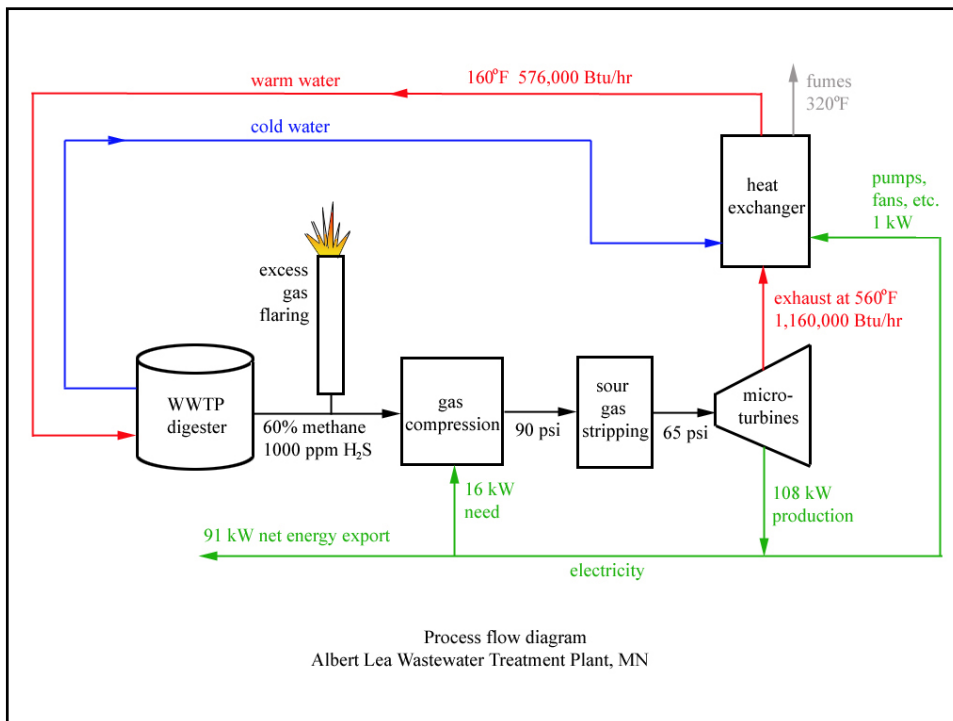
75,000 ft³/day of biogas

Biogas is 60% CH₄ and 10³ ppm H₂S
plus traces of siloxane

4 Capstone microturbines, 30 kW each
producing 2,500 kWh per day at peak production
plus 28,000 Btu/day of heat



Use of the system results in energy generation as well as the reduction of energy costs.



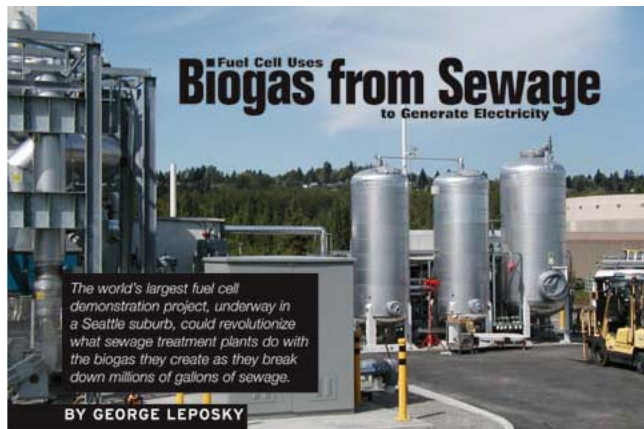
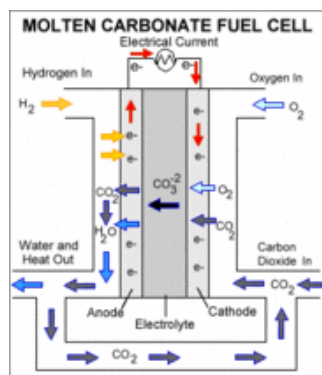


PHOTO: KING COUNTY

The fuel cell, located at the South Treatment Plant in Renton, WA, can consume about 154,000 cubic feet of biogas a day to produce up to 1 MW of electricity. That's enough to power 1,000 households, but it is being used instead to help operate the plant.

The fuel cell's electric output will save the Wastewater Treatment Division (WTD) of King County's Department of Natural Resources and Parks about \$400,000 a year—money that otherwise would be spent to buy electricity from the local utility.

(George Leposky – http://www.forester.net/de_0511_fuel.html)



(http://en.wikipedia.org/wiki/Molten-carbonate_fuel_cell)

Molten-carbonate fuel cells (MCFCs) are high-temperature fuel cells, that operate at temperatures of 600°C and above. They have the highest efficiencies of any type fuel cell, including solid-oxide fuel cells, proton-exchange membrane fuel cells and phosphoric-acid fuel cells and are not subject to the high-temperature material issues that affect solid-oxide technology.

(Excerpted from Wikipedia)

Performance of fuel cell at King County wastewater treatment plant:

- Continuous operation since 2004
- Currently generating 1 MW (90% of the time) and can easily be upgraded to generate 1.5 MW
- Efficiency in generating electricity: 43% to 47%
- With heat recovery, efficiency increases to 65%.

Initial cost: \$23.9 million



(http://www.fossil.energy.gov/programs/powersystems/fuelcells/fuelcells_moltencarb.html)

Other places where fuel cells are used in wastewater treatment facilities:

Los Angeles (downtown & Palmdale), Santa Barbara (El Estero), New York (Yonkers)