Existence Hypothesis: Resource Recovery Plant

To Extract Maximum Energy From Municipal Wastewater

By

Melvin W. Cook

Existence Hypothesis: Resource Recovery Plant

To Extract Maximum Energy From Municipal Wastewater

By

Melvin W. Cook

Abstract

In the U.S., there are 21,600 Publicly Owned Treatment Works (POTWs), treating 8.2 trillion gallons of wastewater (WW) from 226 million people; and therein, a potential to produce 43.5 billion kWh of electricity, annually: equivalent to reducing CO_2 pollution by more than 40 million tons. Instead, to treat that same volume of WW, those POTWs are consuming 18.6 billion kWh of electricity, an unintended consequence of incorporating the same basic designs, as those of the past 100 years. The Existence is based on the fact that current WW treatment and AD (anaerobic digester) technologies do not isolate, nor do they provide for the treatment of isolated Energy Latent Organics (ELOs). This shortcoming has resulted in a limited energy recovery of 729 kWh/MG (million gallons), out of a potential 5,260 kWh/MG. The Hypothesis is based on the assertion that the ELOs can be concentrated and quantitatively recovered, by a unique centrifugation method; prior to flowing into an AD containing four independent, sequential stages; with stage specific enzymes, controlled environments, and the ability to achieve complete conversion within one hour of retention time; thus, maximizing the production of methane to energy. This Existence Hypothesis maintains that the Resource Recovery Plant has the potential to become the fundamental technology that will ultimately transform all energy consuming Wastewater Treatment Plants into net-energy producing Resource Recovery Plants.

Overview

"Wastewater is a renewable source of energy and nutrients. In the twentieth century, we aimed to get rid of these. In the twenty-first century, we must recover the energy, nutrients and potable water. We are still using the same [wastewater treatment plant] designs of 100 years ago. This has had a negative impact on many treatment plants, as the unintended consequences of old designs have impacted on current designs, and will have an impact on future designs. The new basis of design and refit for all wastewater treatment plants must be the aim of not only making the plants more efficient, but also extracting and reusing the energy nutrients and potable water found in wastewater, says **George Tchobanoglous.**" Professor Emeritus, Department of Civil and Environmental Engineering, University of California, Davis. Quote from Engineering News Online, available at: http://www.engineeringnews.co.za/article/recovery-reuse-to-reshape-wastewater-treatment-plant-designs-2012-11-02

Existence

- 43.5 billion kWh[1,2,3,4] of electricity is available, each year, from the Energy Latent Organics in municipal wastewater, at 21,600 U.S. Publicly Owned Treatment Works[1] (POTWs). An energy potential that is more than 2.1 times the 2014 output of the mighty Grand Coulee Dam, at (20.2 billion kWh[5]). This also represents an energy potential that is equivalent to reducing CO_2 pollution by more than 40 million tons[6].
- Each year, 18.6 billion kWh[1,2,3,4] of electricity is required to treat 8.2 trillion gallons[1] of municipal wastewater, at the POTWs that serve 226 million people[1].
- Each year, 11.2 billion kWh[1,2,3,4] of electricity is required to produce an untenable wastewater byproduct of 7.24 million tons[1,7] of sewage sludge, at those same POTWs.
- 8.2 trillion gallons of municipal wastewater contain 7.0 million tons[1] of Energy Latent Organics.

- One million gallons (MG) of municipal wastewater contains an average 1,700 pounds[8] of Energy Latent Organics, measured as biological oxygen demand (BOD), with an energy potential equal to 5,260 kWh[2] of electricity.
- In an ongoing attempt to reduce costs and extract energy from municipal wastewater, recent advances in Anaerobic Digestion (AD) have increased energy recoveries by 38.3%; from 450 kWh/MG[9] in 2003 to 729 kWh/MG[10] in 2011. A slight 5.3% increase in available energy recovery: The result of 8 years of rigorous effort.
- Current wastewater treatment and AD technologies do not isolate, nor do they provide for the treatment of isolated Energy Latent Organics (ELOs); hence, the inherent, limited recovery of only 13.9% of the available 5,260 kWh/MG.

Hypothesis

- Subsequent to preliminary treatment of the wastewater influent—screening, shredding, separating, and washing and dewatering of the solids/grit debris—if there are additional micro screens in the system that are designed to remove grit larger than 300 micron; then, that inert grit can be recovered, washed, dewatered, and added to the already present solids/grit stockpile, for immediate disposal. In addition, the wash water can be recovered, by recycling back to the influent stream.
- After micro screening, if the influent stream flows directly into a volume equalization tank; then, that tank can serve as a reservoir, to compensate for the irregular 24-hour influent flow.
- If the stream flowing from the equalization tank is subjected to centrifugation, with a unique configuration of filters (30-micron, to remove the 30 to 300 micron grit; and 0.2-micron, to remove the 0.2 to 30 micron ELOs); then, the generated Coriolis, centrifugal, and Euler forces can efficiently concentrate the grit and ELOs; and simultaneously recover the water.
- If, during centrifugation, 97.5% of the processed influent volume, with an average BOD concentration of 200 mg/L[7], flows through the 30-micron filters; then, the 30 to 300 micron grit can be concentrated and quantitatively recovered in the remaining 2.5% volume, with an average BOD of 5.0 mg/L. The grit can then be washed, dewatered, and added to the solids/grit stockpile, for disposal. In addition, the wash water, containing residual BOD, can be recycled back to the influent stream.
- If the filtered ELO water is subjected to further centrifugation, wherein, 95% of that volume flows through the 0.2-micron filters, with an average BOD of 10 mg/L (well within EPA's 30 mg/L[11] effluent limit), and out of the centrifuge; then, that water can flow directly into a trickling filter to efficiently remove ammonia, and any remaining organics. Then, prior to release into the environment, the effluent can be disinfected, efficiently, by U.V. radiation.
- If the recovered ELOs can be concentrated in the 5% retentate volume (with an average BOD of 3,800 mg/L); then, that ELO enriched fluid can flow directly into a unique Anaerobic Digester (AD), designed to efficiently extract maximum energy.
- If the design of the AD has four independent, sequential stages: Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis; then, each stand-alone stage can be self-contained, have stage specific enzymes, have a controlled environment (pH, temperature, and flow), and be capable of complete conversion; within one hour of retention time.

- If the Hydrolysis Stage contains specific, immobilized enzymes; then those enzymes can efficiently convert the complex organic polymers (carbohydrates, fats, and proteins) into solubilized monomers.
- If the Acidogenesis Stage contains specific, immobilized enzymes; then those enzymes can efficiently convert the solubilized monomers (sugars, fatty acids, and amino acids) into intermediate products.
- If the Acetogenesis Stage contains specific, immobilized enzymes; then those enzymes can efficiently convert the intermediate products (carbonic acids, alcohols, hydrogen, carbon dioxide, and ammonia) into simple molecules.
- If the Methanogenesis Stage contains specific, immobilized enzymes; then those enzymes can efficiently convert the simple molecules (hydrogen, acetic acid, and carbon dioxide) into biogas: $\geq$ 65% methane and $\leq$ 35% carbon dioxide.
- If the methane is recovered, refined, and used as a fuel to run a gas engine to power an electric generator; then two useable products can be produced. The first will be electrical power. The second will be thermal; which can be used to heat the AD and the facilities. Thus, if the RRP has the ability to produce onsite electricity and heat, independent of the grid; then, that facility can meet EPA's requirement for a Combined Heat and Power (CHP) Partnership[12].
- If 5,000 kWh of electricity is produced, from each million gallons of municipal wastewater processed (MGP), and 850 kWh (conservative estimate) are consumed internally; there will then be an excess 4,150 kWh of electricity that can be sold to local grids.
- If all the ELOs that flow into the AD are completely digested; then, in addition to biogas, there can be a useable digestate byproduct, which can be dewatered and sold as fertilizer; with the recovered water recycled back to the influent stream. Additionally, because the dewatered digestate will be essentially pathogen-free and environment friendly, the fertilizer can be designated Class A[13] by EPA standards.

Resource Recovery Plant

- The innovative Resource Recovery Plant has the potential to become the disruptive technology that will transform those twentieth century, energy consuming, municipal wastewater treatment plants (WWTPs); into twenty-first century, net-energy producing, Resource Recovery Plants (RRPs).
- The RRPs will be capable of producing a net energy advantage of 6,400 kWh/MGP: The summation of avoiding the consumption of 2,250 kWh[3,4] of electricity (conservative average, per MGP); plus, selling 4,150 kWh of excess electricity, per MGP, to local grids. Thus, the net energy advantage, from all 21,600 POTWs, will produce extra, eco-friendly benefits. Provide an abundance of electricity to local grids. Reduce the unrelenting strain on the ageing, electricity grid infrastructure by 52.5 billion kWh (52.5 million-megawatt hours) annually. In so doing, the RRPs will have the potential to produce an energy advantage that is more than 5.7 times greater than that proposed by the $8 billion Wyoming/Utah wind farms: 9.2 million MWh[13].

In addition to occupying a footprint less than 20% of that required for current WWTPs, and a similar reduction in capital and operation and maintenance costs, the RRPs will be 24/7 volume adjustable; scalable (up or down); indoor capable; avoid sedimentation tanks, aeration tanks, aeration/evaporation ponds, and lagoons; and most importantly, avoid sewage sludge. By design, the RRPs will mitigate those chronic environmental, waste disposal, and sustainability problems; currently associated with the annual production of 7.24 million tons of sewage sludge, at an ongoing cost of 11.2 billion kWh of electricity.

- In the U.S., in predominantly small cities and towns, there are more than 8,000 wastewater treatment ponds[14], occupying a land mass equal to 48,000 acres[15] (75 square miles). Because each pond is exposed to the atmosphere, evaporation will occur 24/7. Also by design, the RRPs will deliver an added bonus: The avoidance of ponds; thereby, realizing an annual gain of more than 114 billion gallons[14] of water (350,000 acre feet) that would have been lost, due to evaporation.

"In the popular myth, science is neat and tidy: We know what we know. But real science is replete with controversy, doubts, and debates about what we really know." (Daniel J. Levitin)

References

1 U.S. Wastewater Treatment, Fact Sheets, University of Michigan, October 2012. Available at: www.css.snre.umich.edu/css_doc/CSS04-14.pdf

2 Energy in Chicago's Wastewater, greentechmedia, September 2009. Available at: http://www.greentechmedia.com/articles/read/11-great-things-to-do-with-sewage/

3 California Energy Commission, California's Water-Energy Relationship, March 2006. Available at: http://www.energy.ca.gov/process/water/2006-03-28_symposium/WHITE_CEC.PDF

4 EPRI, Water & Sustainability (Volume 4), March 2002. Available at: http://www.circleofblue.org/waternews/wp-content/uploads/2010/08/EPRI-Volume-4.pdf

5 U.S. Department of the Interior, Grand Coulee Powerplant, January 2015. Available at: http://www.usbr.gov/projects/Powerplant.jsp?fac_Name=Grand+Coulee+Powerplant

6 U.S. Energy Information Administration, Carbon dioxide per kilowatt hour from fossil fuels, March 2015. Available at: http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11

7 Environmental News Network, From: Water Environment Research Foundation, April 2008. Available at: http://www.enn.com/press_releases/2448

8 EPA, Energy Star, Municipal Wastewater Treatment Plant, 2013. Available at: https://www.energystar.gov/istar/pmpam/help/Wastewater_Treatment_Plant_Space_Use_Information.htm

9 Anaerobic Digester Methane to Energy, A Statewide Assessment, Focus on Energy, Wisconsin, January 2003. Available at: http://www.mrec.org/pubs/Anaerobic_Report.pdf

10 EPA, Opportunities for Combined Heat and Power at Wastewater Treatment Facilities, October 2011. Available at: http://www.epa.gov/chp/documents/wwtf_opportunities.pdf

11 EPA, Clean Water Act, Section 40 CFR § 133.102, 2006. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2006-title40-vol21/pdf/CFR-2006-title40-vol21-sec133-102.pdf

12 EPA, Combined Heat and Power Partnership, December 2012. Available at: http://www.epa.gov/chp/partnership/index.html

13 Milwaukee-Wisconsin Journal Sentinel, September 23, 2014. http://www.jsonline.com/business/duke-atc-power-line-would-link-wyoming-wind-farm-utah-energy-storage-b99357883z1-276856381.html?subscriber_login=y

14 EPA, Process Design Manual, Land Application of Sewage Sludge and Domestic Septage. EPA/625/R-95/001, September 1995. Available at: http://nepis.epa.gov/Adobe/PDF/30004O9U.pdf

15 EPA, NPDES, New Wastewater Treatment Ponds Manual, Principles of Design and Operations of Wastewater Treatment Pond Systems for Plant Operators, Engineers, and Managers. EPA/600/R-11/088, August 2011. Available at: http://www.epa.gov/nrmrl/lrpcd/projects/ponds.htm

Melvin W. Cook
Consultant
Water•Energy Recovery
Los Gatos, California
Email: mel_w_cook@hotmail.com

Beyond delving into the technologies of wastewater treatment, during the past twelve years, Mel has more than 30 years of research, development, application, and administrative experience in three disparate disciplines: centrifugation, filters/filtration, and protein/enzyme immobilization. His two prior patents on filtration, separation, and quantitative recovery of antigen and antibody molecules and his diverse background; subsequently led to the developmental concept of the net-energy producing Resource Recovery Plant. For this unique process, he has two patents, with follow-on patents anticipated. In addition to having performed basic research in immunology, at the Oregon Regional Primate Research Center, Beaverton, Oregon; Mel holds a Pre-Med A.A. degree from Bismarck Junior College, Bismarck, North Dakota.