Sludge Blanket Mixing in Wastewater Stabilization Pond Systems

Steve Harris, President and Owner of H & S Environmental, LLC

A facultative or partially mixed lagoon treatment cell is like having three wastewater reactors stacked one on top of the other. These reactors influence each other by generating waste products unique to the microbial community that lives within each of them. In facultative or partially mixed treatment cells, there is an aerobic reactor at the top, an anoxic selector in the middle, and an anaerobic digester at the bottom depending on treatment cell depth, oxygen currents, loading, mixing, and other factors.

The focus of this brief discussion is on the value of mixing the sludge blanket at the bottom part of the treatment cell; the anaerobic / anoxic portion.

Mass Removal by Digestion

In its simplist terms, anaerobic digestion is the breakdown of sludge into methane, carbon dioxide, and water by anaerobic microorganisms. Aerobic digestion is the breakdown of sludge into carbon dioxide and water by aerobic microbes. Both of these are multi-step processes used to reduce the volume of wastewater sludge. A digester (or sludge blanket in a pond system) is composed of countless trillions of microbes consuming organic and inorganic materials and then generating waste products that MUST get to other microbes to complete the stabilization process. If these waste products cannot get to the other microbes, toxicity builds and the process stops.

Because acids are formed before methane is produced in anaerobic systems, these acids MUST get to the methanogens responsible for methane production for mass to be reduced. Mixing is one of the key elements in the process of anaerobic digestion. In aerobic digestion, nitric acid, ammonia, and nitrates are produced that MUST be converted by microbes to safer less toxic by-products.

The importance of good mixing in anaerobic and aerobic digesters cannot be overstated. Mixing provides:

- The uniform availability of food for microbes
- The dispersion of waste products to avoid self-limitation (toxicity)
- pH balance due to acid formation
- A closely maintained association between living/active biomass and incoming food
- Enhanced biological reaction rates
- Improved VSS reduction efficiency
- Increased gas production
- Decreased sludge blanket mass

When sludge solids are converted into a gas and water (CO_2, CH_4, H_2O) there is a “mass transfer”. Mass that was once solid, is now mass in the form of gas and liquid (water).

Looking at the chemical composition of wastewater pond sludge (dead and living bacteria, algae, raw organic matter, duckweed, plant material and other organic material) we see that a large portion of sludge can be converted into “something else”:

The building blocks of sludge

Table 3.1 Elemental composition of microbial cells.

Elemental	Variations in composition of microbial cells, dry weight %
Carbon	45 – 55
Oxygen	16 – 22
Nitrogen	12 – 16
Hydrogen	7 – 10
Phosphorus	2 – 5
Sulfur	0.8 – 1.5
Potassium	0.8 – 1.5
Sodium	0.5 – 2.0
Calcium	0.4 – 0.7
Magnesium	0.4 – 0.7
Chlorine	0.4 – 0.7
Iron	0.1 – 0.4
All others*	0.2 – 0.5

* Includes trace elements.

These elements can form gasses

85% of dead bacteria and algae mass can be converted to gas

Sludge is mostly composed of Carbon, Oxygen, Nitrogen, and Hydrogen, and under the right conditions, these elements can be converted into gas.

			Organic Fraction (%)			
Emprical Formula	**Carbon**	**Oxygen**	**Hydrogen**	**Nitrogen**	**Phosphorous**	**References**
	52.4	26.8	6.3	12.2	2.3	McCarty (1970)
Activated Sludge	53	30.5	6.4	8.9	1.2	Sawyer (1956)
$C_{60}H_{87}O_{23}N_{12}P$	44.9	35.4	6.9	10.7	2.1	Speece and McCarty (1964)
$C_{118}H_{170}O_{51}N_{17}P$	52.4	29.7	7.4	9.2	1.3	Strumm and Tenney (1964)
Anaerobic Sludge						
$C_{54}H_{99}O_{32}N_{11}P$						
Algae						
$C_{106}H_{181}O_{45}N_{16}P$						
Gasses Produced	CO_2	CO_2	NH_4	NH_4		
from sludge blankets	CH_4	H_20	CH_4	N_2		
			H_20			
			H_20			
Adapted from Wastewater Biology: The Life Processes, 1994						

Image Adapted from: WEF, (1994) Wastewater Biology: The Life Processes, A Special Publication. Prepared by the Task Force on Wastewater Biology: The Life Process. Water Environment, Federation, Alexandria, VA ISBN 1-881369-93-5

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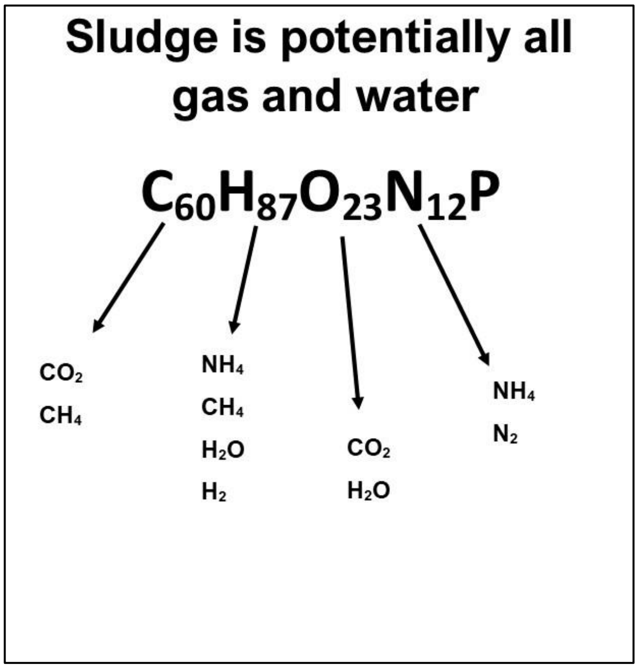
Because sludge is potentially gas, water, and nutrients, mixing becomes a key element in sludge's conversion to other products. This explains the emphasis that is placed on mixing in aerobic and anaerobic digesters.



Compared to digesters, sludge at the bottom of a lagoon does not mix well.

When sludge judged, large amounts of gas are typically released from the sludge blanket that has been disturbed. In theory, this gas is composed of 70% methane and 30% carbon dioxide. Because lagoon sludge blankets do not mix well, the waste by-products from one microbe are not efficiently delivered to the next microbe who can use them, consume them, and convert them…Nature's Self-Purification process is diminished. This is similar in principle to why a maximum of 12% by volume of alcohol is all that can be produced by a standard batch of yeast and sugar…the yeast self-limits…dies in its own waste products. Toxicity accumulation in a sludge blanket limits mass reduction in a similar manner.

Mixing can also reduce the impact of toxic material (i.e. ammonia) accumulation by diluting it in the pond volume below levels that would inhibit methane formation. Toxicity is also reduced by delivering toxic materials to microbes that can consume them, H_2S (Hydrogen Sulfide) as an example. Essentially, mixing adds capacity to a treatment cell. It uses the existing capacity more efficiently.

In the 1983 ASCE Nationwide Survey of Anaerobic Digesters, active mixing was found to be the most significant factor in reducing volatile solids. In this survey, 13 WWTPs reported "inadequate" mixing but still reported >50% VSS Reduction.

In the 2005/06 Carollo Survey on Digesters, VSS reduction varied between 44% - 68% whereas the most common range of reduction was between 50% - 55%.

"The mixing characteristics of a reactor, and the manner in which wastewater is introduced into the reactor, exert a considerable influence on the efficiency of treatment. Many important parameters are influenced by these hydraulic flow characteristics including BOD removal, settling characteristics…and pathogen removal in waste stabilization ponds"

-Biological Wastewater Treatment Systems: Theory and Operation, N.J. Horan

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One of the keys to effective anaerobic or aerobic digestion is mixing. On the average, suspended sediments (mixed sediments) consume as much as 4.96 mg O_2/day which is 900 times more than unmixed sediments. As sediments are mixed, respiration rates can increase by 300 times.

In anaerobic systems, the acids formed by acidogenic bacteria and other essential nutrients must find their way to the methane producing bacteria. The more efficiently this happens, the faster and more complete the solids are stabilized…mass reduced. In aerobic systems, mixing is equally important to improve efficiency. This is why there is a mixing phase in the air-off cycle of aerobic digester operation. During the air-off phase, mixing delivers the nitrates to the denitrifying biomass and the nitrates are consumed.

In short, the two basic reasons for mixing aerobic and anaerobic biomass are to:

1. Maintain the viability of the biomass by:
    a. improving the consistency of food delivery to the biomass
    b. by-product toxicity removal
2. Minimize the mass and volume of lagoon sludge blankets

Anaerobic and aerobic digestion is highly dependent upon effective sludge mixing. Without assistance, lagoon sludge blankets mix poorly, and solids accumulate. With mixing, lagoon sludge blankets are reduced.

WARNING!! BE CAREFUL NOT TO OVER MIX!! Mix a small portion of the lagoon's sludge blanket at any given time as nutrients will be released, dissolved oxygen will plummet, and the potential for permit violations increase.

Steve Harris is the President and Owner of H&S Environmental in Mesa, AZ. Since his beginning in February 1993, Steve has worked with wastewater operators across the United States and in various parts of the world to identify and troubleshoot wastewater lagoon problems, optimize lagoon performance, and assist wastewater lagoon systems in removing sludge. Steve was the featured wastewater presenter at MRWA's 2018 Bootheel Expo and 2018 Fall Operations & Maintenance Symposium.

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