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The Multi-Billion Dollar Waste Treatment Opportunity: Environmental Biotechnology Advances Are Converting Sludge into a Reliable and Massive New Source of Renewable Energy

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"Water is the new oil," according to T. Boone Pickens. Indeed, the waste treatment industry is at the precipice of fundamental change, driven by the kinds of innovations that now propel electronics and medicine. One such pivotal change is that waste biosolids now represent an economical and ongoing source of energy, in the form of biogas, as well as valuable fertilizer components and clean water.

What is Sludge?

Sludge is the residual, semi-solid material left over from industrial wastewater and municipal sewage treatment processes. The term can also mean the settled suspension obtained from conventional drinking water treatment, as well as other industrial processes. Sludge is often referred to with the term *biosolids*, created in 1991 by the Name Change Task Force of the Water Environment Federation (formerly known as the Federation of Sewage Works Associations) to differentiate raw, untreated sewage sludge from treated and tested sewage sludge that can legally be utilized as soil amendment and fertilizer.

Millions of megawatts of renewable energy per year are waiting to be harvested by waste treatment operations in the U.S. and Europe. But until plant operators adopt the latest forms of biological treatment technologies to convert this enormous reservoir of biosolids, or sludge, into natural gas, this attainable source of renewable energy will continue to be squandered.

To appreciate the challenges of changing waste treatment practices to exploit that opportunity, it helps to understand why sludge is such an important problem.

Sludge is Expensive, Hazardous and Wasteful

Despite increasingly sophisticated environmental intervention strategies taking hold across a wide range of industries, the nearly 39,000 waste treatment facilities in the U.S. today use the same basic biological treatment processes developed nearly a century ago. While many such processes have been developed, such as fixed-film, suspended growth, trickling filter variant and activated sludge modification, they all hold one thing in common: they annually result in over 19 million tons of sludge needing stabilization and disposal at a burdened cost of up to $300 per ton.

In fact, the Environmental Protection Agency (EPA) estimates that the cost for sludge handling and disposal account for *40 to 60 percent of the total budget for a waste treatment facility* [http://www.epa.gov/nrmrl/lrpcd/esm/projects/117990.htm]. Costs stem from the need to thicken sludge before disposal and stabilize it per Federal 503 Regulations for volatile solidsand vector attraction reduction, pathogen destruction, reduction of toxic heavy metals content, and control over nitrogen and phosphorus loading rates to prevent over-fertilization.

Biosolids are problematic beyond just volume and disposal cost—they contain sewage contaminants not broken down in the treatment process or carried away by the water effluent leaving the treatment plant. The most commonly detected trace contaminants of concern are heavy metals (arsenic, cadmium, copper, etc., some of which are also critical plant micronutrients), and toxic chemicals (e.g., plasticizers, PDBEs, and others, including personal care products and pharmaceuticals).

All of these factors make sludge a high-value target for biotechnological solutions. The widespread impact of these innovations will be clear after briefly reviewing the nature and limitations of current approaches to sludge handling, stabilization and disposal.

Existing Sludge Treatment Approaches Are Inadequate

There are a number of conventional sludge treatment/stabilization approaches. Both biological and physical/chemical processes exist that will provide pathogen reduction and sludge stabilization. However, they do not achieve much reduction in sludge mass, and the physical/chemical processes (e.g., lime treatment) generally increase the mass of sludge to be disposed significantly; this is a serious drawback since a key measure of waste treatment is the conversion rate of biosolids to clean water, biogas, recoverable minerals and nutrients.

The conventional alternatives for stabilizing sludge can be summarized as follows:

- **Aerobic sludge digestion**: Common at small treatment plants (less than 20,000 cubic meters per day, that is, 5 million gallons per day), aerobic digestion is simple, stable and predictable. In this process, the sludge is aerated for many weeks. Some of the sludge (less than 30%) is converted to mainly carbon dioxide and water. Thermophilic variations achieve rapid results in smaller volume. Negatives include the energy required for aeration, the small amount of waste sludge destroyed and the high cost of contaminated sludge dewatering and disposal.

- **Anaerobic sludge digestion**: Anaerobic sludge treatment is essentially a large septic tank with mixing and electrical instrumentation for monitoring, controls and troubleshooting. This is the most common sludge treatment for large plants, with low operating costs since aeration is not required. However, often less than 50% is converted to methane, carbon dioxide and water.

- **Anaerobic CAMBI process:** The CAMBI system utilizes high-temperature hydrolysis of sludge solids to improve anaerobic digester results and achieve complete pathogen destruction. CAMBI has enjoyed some success in the past decade. This process operates at lower pressure (12 bars, or 176 psi) and temperature (160°C) and utilizes the released organics to anaerobically generate more methane for heat recovery and reduce sludge disposal. A net increase in sludge destruction is reported to boost volatile solids conversion rates from 30-50% to 60%. CAMBI suffers from high capital and operating costs, odorous off-gas handling requirements, complex operation, and liabilities associated with pressurized and heated vessels.

Legacy aerobic and anaerobic processes produce treated sludge (40 to 60% of the feed amount on average) that must be disposed of in some fashion. Sludge disposal is conventionally handled via costly and environmentally damaging options, summarized as *Burn It, Dump It or Bury It,* as follows:

- **Incineration processes**: Hauling sludge to an incinerator is convenient, though it does require a collection, dewatering and truck filling system. Costs vary widely depending on location and incinerator availability. In addition, incinerators have become increasingly regulated and the costs for permitting and building a new waste incinerator are becoming prohibitive.

- **Landfills**: Burying sludge looks inexpensive when only the tipping fees are considered. Rather, it is quite expensive when all costs for sludge preparation are accounted for—most landfills require a minimum dryness, so liquid waste streams require significant pretreatment prior to disposal.

- **Land application:** Dumping waste sludge on farmland is common. Federal 503 regulations require varying degrees of sludge treatment and stabilization beforehand, depending on the land's intended use. Land application safety is controversial due to the many undesirable compounds (viruses, heavy metals, pathogens, endocrine disruptors, etc.) present in sludge.

- **Anaerobic digestion with sludge drying and pelletization:** There are several commercial variations on this theme, mainly in Europe. It offers the advantages of reliable high temperature destruction of pathogens with some degree of energy recovery and production of dried sludge fertilizer pellets. Disadvantages include a huge capital cost, an unreliable and seasonal market for the pellets, high energy requirements to dry the sludge, and a sludge drying off-gas issue.

- **Ultra-screening**: This loophole technology for waste sludge reduction consists of ultra-screening and hauling tons of sludge to a landfill as "screenings". This fails to meet the intent of the Federal 503 regulations and will not meet the proposed regulations to ban such organics-rich material from the rapidly shrinking landfill space.

Simply put, sludge is an extraordinarily resource-intensive and problematic byproduct of every waste treatment and disposal process to date.

A Better Way – Efficient Microbiological Conversion of Sludge to Energy

As described above, the existing approaches to dealing with millions of tons of sludge are outdated, expensive and environmentally damaging. By contrast, the new advanced biotechnological approach described here is more efficient and cost-effective, obviating the need for most post-treatment sludge disposal and enabling nutrient recapture while generating more energy. It features the following characteristics:

- **Particle size reduction and molecular manipulation**: State-of-the-art, custom industrial particle size grinding equipment is combined with biokinetic measurements and respirometric testing to break down complex molecules and long chain polymers into very small (even nano-level) particle sizes and much lower molecular weights, increasing the "digestibility" of the biomass. The microbes (methanogens) in the anaerobic reactors are now able to convert these previously indigestible molecules into biogas in much less time.

- **Nutrient recapture**: Ultrafiltration combined with a nitrogen and phosphorus removal process eliminates these nutrients from sludge and makes them available for repurposing as valuable fertilizer.

- **Biosolids elimination:** With the high conversion rate to biogas and recovery of nitrogen and phosphorus, there is no need for energy-intensive, expensive treatment and disposal of residual sludge.

- **Biogas (methane) generation:** The acceleration of the biological treatment enables extremely high conversion rates of sludge solids to biogas—up to 90% or more, compared to just 45% in conventional processes. Thus, much more biogas is generated.

These anaerobic treatment innovations are being retrofitted at facilities around the world, and designed into new anaerobic facilities. New plants include traditional municipal and industrial treatment plants as well as cellulosic ethanol, palm oil processing, algae biofuels and other biorefineries where residual biomass can now be converted to renewable natural gas (methane) as a valuable energy co-product.

What are the Potential Cost Savings?

Consider a 20 million gallon per day plant that generates 18 dry tons of thickened waste sludge. By improving the efficiency of organic solids destruction from an industry average of 45% to at least 80% with biotechnology processes, annual savings in reduced sludge disposal can reach $460,000 a year (assuming an operating cost of $100 per ton and a cost for sludge dewatering/disposal of $300 per ton). On top of these savings, the generation of additional biogas in this scenario has a real recoverable value of about $400,000 annually, even at a low energy cost of $0.05/KWh. And since this is sustainable energy derived from an alternative energy source, the actual financial benefits are much greater.

The Future of Waste Treatment is Here

Environmental biotechnology, as shown in this article, is revolutionizing waste treatment. With the continuing emergence of biotechnology-based infrastructures that can essentially eliminate biosolids, waste plant operating costs can be reduced by millions of dollars annually, depending on a given plant's volume. Biosolids-to-renewable natural gas conversion can yield equally compelling cost savings.

Now that the technology exists, the next challenge will be for the waste treatment industry to embrace the entrepreneurs offering this and many other game-changing products and services.

About the Author

Frank Sinton Jr. is Chief Executive Officer with PMC BioTec , a global environmental biotechnology leader enabling waste water treatment plants, bio-refineries and agricultural biogas operators to double their production of biogas, recover nitrogen and phosphorus fertilizer, and virtually eliminate damaging residuals disposal. As a seasoned Silicon Valley executive, Mr. Sinton founded and ran multiple successful startups including Think Technologies (ThinkC, ThinkPascal, InBox), MediLife Software (BalancePC, Lighten-Up), Rapport Inc. (KiloCore) and Holox Technologies. Prior to his innovative successes in high technology, Mr. Sinton acquired chemical industry expertise in executive marketing and management positions at Celanese Chemical and Union Carbide Chemicals. Mr. Sinton sits on the Board of PMC BioTec, Mefeedia.com and Holox Technologies.