



*Destroy Municipal Sludge, Save
Money or Make Profit, and Improve
Environmental Public Relations*



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Abstract

This paper includes a summary of technologies for treating waste sludge generated at municipal wastewater treatment plants. Conventional aerobic and anaerobic treatment each produces too much noxious sludge for disposal. The sludge is expensive to stabilize, disinfect and dispose; and disposal options are rapidly shrinking and becoming more expensive: new incinerators are not being built, and both landfill and land application regulations are tightening as disposal of organics in landfills is eliminated.

An innovative yet proven technology offers some distinct advantages. The AFCsm system is a catalyzed MBR (membrane bioreactor) that is ideal for waste sludge because it is field proven to generate little or no excess biosolids and requires a fractional footprint compared to conventional technologies. In the anaerobic mode, the process can increase sustainable energy production from waste sludge by more than 70%, and reduce final sludge disposal by 70%. The cost of treatment ranges from \$100-\$300 USD per dry ton of COD, compared to \$200 to \$500/DT for conventional technologies.

Introduction and Overview

As we roll into the 21st century, most wastewater treatment systems built and operating today use the same basic biological treatment processes developed almost a century ago. Biological treatment uses microbes to convert waste organics into more microbes and harmless by-product materials. Many process configurations have been developed. Whether fixed-film or suspended growth, trickling filter variant or activated sludge modification, biological wastewater treatment is the most cost-effective choice for treating sewage.

One characteristic is held in common however: *every* treatment process produces unwanted waste sludge, or “excess biosolids”. Again, many sludge treatment process configurations have been developed to respond to this problem: Aerobic and Anaerobic systems each have their characteristic advantages and disadvantages and constraints. Thermophilic and mesophilic variations of each add to the mix.

Sludge is an expensive and problematic byproduct of the wastewater treatment process. There are numerous traditional options for its ultimate fate, none of them appealing: whether the choice is to burn it, dump it or bury it, the process is costly, time-intensive and laden with contingent liabilities both immediate and future. Health and Safety issues abound. Current and future legislation impose generator-owned responsibility and liabilities that are open-ended. Off-site transport of sludges is an invitation to trouble. And coming bans against disposal of organics in landfills will mandate for new alternatives.

This issue is compounded at Municipal plants because the sludge contains pathogenic organisms, viruses, prions, potentially toxic heavy metals, RCRA-listed compounds, Endocrine Disrupter Compounds (EDCs), and large amounts of nitrogen and phosphorus. The Total Costs for sludge treatment-stabilization-dewatering-transport-disposal and the associated Health and Safety issues are steadily increasing.

The Sludge Issue

The American Environmental Protection Agency (EPA) estimates that the costs for sludge handling and disposal account for 40% to 60% of the total budget for a wastewater treatment facility, and increasing. When asked the cost for sludge treatment and disposal, most plant operators respond with only the cost of sludge disposal (e.g.: tipping fee as \$/m³), and thus fail to realize 50% to 75% of their real sludge-related costs.

These must include all necessary steps:

- Thickening the sludge to reduce downstream costs
- Stabilization per federal 503 Regulations to reduce negative impacts on the environment. These considerations include:
 - VSS Reduction and Stabilization to reduce vector attraction
 - Pathogen Destruction (bacterial only, *currently*)
 - Heavy Metals content to reduce toxicity
 - Nitrogen and Phosphorus loading rates to prevent over fertilization
 - And *Coming Soon to a Permit near you*:
 - Endocrine Disrupter Compounds
 - Viruses, Prions
- Dewatering to reduce hauling and disposal costs
- Odor Control to keep the neighbors happy
- Handling the sludge in its various phases described here
- Storage, because you cannot dump sludge whenever it is convenient. Requirements vary widely
- Transportation to its ultimate disposal site
- Disposal onto farmland or into a landfill or into an incinerator

Clearly, each method of wastewater treatment and of sludge treatment has separate impacts on the total cost. In general, the sludge treatment alternatives can be summarized as follows.

Sludge Treatment Alternatives

There are a number of conventional sludge treatment/stabilization alternatives on the market today. Both biological and physical/chemical processes exist that will provide pathogen reduction and sludge stabilization. Neither achieves much reduction in sludge mass, and the physical/chemical processes (e.g.: lime treatment) generally increase the mass of sludge to be disposed significantly.

With the coming European ban on disposal of organic wastes in landfills, more facilities are considering onsite destruction of their sludge. But incineration-permitting requirements have all but eliminated the construction of new incinerators. Chemical waste-treatment processes tend to be expensive and are prone to generating large quantities of chemical sludge, which can be very costly for off-site disposal. More exotic processes like High-Pressure/High-Temperature sludge cookers achieve destruction of pathogens but are quite expensive to own and operate; and achieve no reduction in sludge mass. Further, the liability aspects associated with heated and pressurized reactors are intimidating.

Sludge Treatment/Stabilization Alternatives

The conventional alternatives for Stabilization of sludges can be summarized as follows:

- Aerobic Sludge Digestion: “*The Usual*” This is easily the most common sludge treatment for small treatment plants (less than 20,000 m³/d (5 MGD)) because it is simple, stable and predictable. In this process, the sludge is simply aerated for a duration of many weeks. Some of the sludge (less than 30%) in turn is converted to mainly carbon dioxide and water. Thermophilic variations (e.g.: ATAD) achieve rapid results in smaller volume.

Negatives include the high cost of energy required for aeration; the small amount of waste sludge destroyed; and the high cost of contaminated sludge dewatering and disposal.

- Anaerobic Sludge Digestion: “*High-Tech Septic Tanks*”. The anaerobic sludge treatment processes in use today are little different from large septic tanks, except they can include mixing and electrical instrumentation and controls to facilitate ease of process monitoring and preventive maintenance troubleshooting. This is the most common sludge treatment for large plants (>12,000 m³/d (3 MGD)) because it is relatively simple and well understood, and has a low cost of operation since aeration is not required. In this process, the sludge is simply mixed in a closed reactor for a duration of many weeks. Some of the sludge (less than 50%) in turn is converted to mainly methane, carbon dioxide and water. Thermophilic variations are poorly understood but might offer some advantages.

Disadvantages include a relatively fickle process equilibrium (prone to upsets); intolerance of fats/oils/grease and temperature variations; and the production of odiferous and poorly dewatered waste sludge.

In fact, the methane produced by anaerobic decomposition of organics is energy-rich and converts readily to infinitely renewable energy as electricity through a generator package, with appropriate pretreatment. But energy recovery is an expensive process to build and maintain and therefore is only cost effective for very large plants (>80,000 m³/d (20 MGD)).

A subset of the anaerobic process is the *CAMBI Process*: an innovative and patented system from Norway that utilizes high-temperature hydrolysis of feed sludge solids to improve anaerobic digester results and achieve complete pathogen destruction. CAMBI’s predecessor was the infamous *Heat Treat* process. Both processes apply very high pressure and temperatures to break the microbial cells open: cell walls and membranes come out largely resistant to biodegradation. The liquid cellular material released is highly biodegradable and must be degraded in downstream processes. In the case of the *Heat Treat* process these released cellular materials exerted dramatic load increases on the wastewater treatment facilities that originally generated the microbes in the first place! Severe odor problems result from the “cooking” of waste sludge; exorbitant costs were incurred attempting to resolve the odor and organic loading issues. Many such operational problems led to the end for the *Heat Treat* process many years ago. Most installations have long been shut down.

However the less-intensive CAMBI process has enjoyed some success in the past decade. CAMBI operates at lower pressure (12 bar, 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%. Still, CAMBI suffers from similar drawbacks: high capital and operating costs, odorous off-gas handling requirements, complex operation, and large liabilities associated with pressurized and heated vessels.

The aerobic and anaerobic processes described above achieve sludge stabilization, but do not meet the pathogen destruction requirements unless significantly modified and/or in conjunction with an additional process, (as the CAMBI). There are many alternatives that have been approved for application; most are not cost-effective or even practical. In any event, both produce treated sludge (40 to 60% of the feed amount) that must be disposed somehow.

Sludge Disposal Alternatives

There are numerous alternatives for sludge disposal, including the following. They can generally be summarized simply as *Burn It, Dump It or Bury It*.

- Incineration processes: “*Truck it and burn it*”, or hauling sludge to an incinerator is a convenient solution that requires no onsite treatment facility to be operated other than a collection, dewatering, and truck filling system. However costs vary widely depending on location and the availability of an incinerator. It is typically expensive and increasingly regulated. Long-term outlook is bleak for incineration due to the regulatory environment and the public’s antipathy. The costs for permitting and building a new waste incinerator are so prohibitive that it is generally agreed there will be no new incinerators built.
- Off-site treatment: “*Pay them to deal with it*”. Small plants create small amounts of sludge. It is often easiest to pay a contract hauler to take the sludge to a large plant or a permitted waste treatment facility, and dispose of it there. However the service is usually expensive on a weight or volume basis, typically two to three times the cost of onsite treatment. So those who generate significant amounts of sludge will benefit by providing for the treatment themselves.
- Landfills: “*Bury it*” is clearly the oldest method for disposing of wastes. It is popular but senseless: land is too valuable to waste. The common misconception is that landfilling is cheap because only the tipping fees are considered. However it is quite expensive when all of the costs for all sludge preparation required are accounted, as in the list above. The burying of organic wastes and sludge in landfills is another option with widely varying costs; and again the total costs include sludge dewatering and transportation, with attached costs and liabilities. Most landfills have a minimum dryness requirement, meaning that liquid waste streams require significant pretreatment prior to disposal.

The easy landfill space is rapidly shrinking; this will inevitably drive up landfill disposal costs. In any event, sludge is a potentially recyclable material and as such will eventually be banned from landfills, as has already been legislated in Europe for 2008. This legislation has already passed in California. Many worry about the ultimate fate of wastes discharged to landfills due to the potential for a Superfund-type of legacy, since the wastes are not destroyed, just buried.

Finally, there is a cost burden with landfilling that is as yet only partially realized: the ultimate fate of organics in landfills is to undergo anaerobic conversion to methane. Subsequent release of methane to the atmosphere (in spite of collection and flaring systems) has a dramatically bad effect on global warming and ozone depletion.

Land application. *Dumping* waste sludge on farmland is common. The federal 503 regulations require varying degrees of sludge treatment and stabilization prior to land application, depending on the intended use of the land. There is vigorous debate over the ultimate safety of land application due to the many unfriendly compounds present in sludge. Land application is becoming increasingly risky because it proliferates numerous substances that pose human health risks (viruses, heavy metals, pathogens, endocrine disruptors, etc.). The contingent liability associated with potential down-wind morbidity is huge.

The fact is that land application of sludge remains the most popular method of disposal because:

1. It can be cheap in some places because the EPA has not enforced or strengthened the 503 regulations, as they would like to do; this *will* change.
2. Exotic high temperature and high-pressure sludge destruction processes are costly to build, to operate, and especially to *insure*.
3. There are few other good options



However, very few people want sludge disposed in his or her backyard. And it's just too expensive to do it right: to destroy *all* of the numerous substances that pose human health risks: pathogens (bacteria, cysts, viral, prions, etc.), endocrine disrupters and carcinogens; and we should remove toxic heavy metals.

Both the costs and the contingent liabilities of land application will continue to escalate. Land application of municipal sludge is rife with the potential for tort liability: any person that suffers serious morbidity issues downwind or downstream of the sludge represents a potential lawsuit.

- Combined 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 the production of a fertilizer source in the dried sludge pellets produced. Disadvantages include a huge capital cost, an unreliable and seasonal market for the fertilizer pellets, and a significant off-gas issue with the sludge drying process.
- Ultrascreening. This loophole technology for “waste sludge reduction” simply consists of ultrascreening and hauling tons of sludge to a landfill as “screenings”. This fails to meet the intent of the EPA 503 regulations and will not meet the proposed regulations to ban such organics-rich material from the rapidly shrinking landfill space.

There are numerous other alternatives, each with their idiosyncratic niches. Some of these alternatives are sunset options: they will be only sparingly available and at ever-increasing costs. Others are only limited by their cost effectiveness. Key technological advances can greatly enhance the efficacy of a conventional process.

The essential fact is that sludge treatment and disposal is an expensive nuisance and the traditional technological “solutions” are just not economically sensible. Clearly, sludge should *not* be contaminating millions of acres of farmland, nor filling up thousands of valuable landfills nor compromising critical hunks of our ecosystem.

For small waste treatment facilities, the simple answer is to avoid the generation of waste sludge from the start. At large facilities, the simple answer is to turn from sludge disposal to sludge utilization: *the millions of tons of sludge generated each day are a valuable and sustainable energy resource. Why not tap into it on a global scale?* The municipal waste sludge generated in the USA and Europe alone represents *an eternally renewable energy source of more than 100 million megawatts annually.*

The technology for efficiently achieving these goals has existed for decades. PMC BioTec has assembled a unique combination of conventional technologies to achieve a quite uncommon result: the total or near-total conversion of organic wastes and sludges into either carbon dioxide (AFCSM) or energy-rich methane (B2ESM), with little organic residual to dispose.

The History

One of the great canards of the wastewater treatment business is the regular appearance and disappearance of processes that claim to produce no sludge. Indeed, it has been the unachievable dream of the industry for many decades. And for good reason: microbes have had to survive through hundreds of millions of years of evolution and during that time, they had to endure environmental, physical, chemical and biological attacks of all kinds. The only path to survival was to develop protective, durable and resilient “skin and bones.” It takes something truly powerful to break up sludge solids; thus the highly pressurized “cooking vessels” used by such as the CAMBI Process.



The professional literature has papers that show enhanced sludge destruction can be achieved with a variety of powerful mechanisms: the Japanese have applied steam injection to the RAS line successfully (a simpler form of heat hydrolysis); Peroxide, Ozone, Caustic Hydroxide, and Sulfuric Acid have all worked in the lab. Aggressive or hazardous chemicals can sometimes do the trick of preventing sludge *production* (called “uncoupling”) as opposed to achieving sludge *destruction*. But none of these tricks have been commercially viable or operationally sensible, with the exception of the AFCsm process.

An Innovative Alternative

Each of the conventional wastewater or sludge treatment methods, whether aerobic or anaerobic, has a critical drawback: they generate great amounts of waste sludge. The ideal technology would simply avoid the generation and disposal of sludge in the first place.

PMC BioTec has developed processes that are capable of 1) treating wastewater without generating waste sludge or 2) cost-effectively destroying sludge generated by conventional processes. The core technology, the AFCsm process, works by effectively integrating microbial and targeted chemical reactions to achieve total mineralization of organic waste to carbon dioxide, water and dissolved minerals. The resulting process is basically a microbiological version of incineration. This biotechnology can also be configured for anaerobic conversion of organics to energy-rich methane and water; this variation is particularly appropriate where energy recovery is a priority or a pragmatic potential.

The AFCsm process is a catalyzed membrane bioreactor (CMBR) system that operates as an accelerated biological treatment process with negligible organic sludge production; and is catalyzed with the aide of an inherent side-stream oxidation or hydrolysis process. It is extremely robust and aggressive. The AFCsm process combines the best features of both aerobic and anaerobic processes. Configured as an aerobic thermophilic process it still requires a high level of aeration, but the extremely high kinetic rates generated by the elevated temperature of operation (45 to 75 degrees Celsius), coupled with resistance to shock loads and low residual sludge production make it an attractive process to waste sludge streams. When configured as an anaerobic system the AFCsm provides both unprecedented high conversions of sludge solids to biogas and radically reduced amounts of residual solids for disposal. And there are no high-pressure reactors or dangerous temperatures, so operation liabilities are low and insurance costs are modest.

The innovative AFCsm process described in this paper is field-proven with millions of pounds of sludge *not* produced as evidence of its effectiveness, and millions of dollars *saved* as proof of its efficacy. Case studies and technical papers describing these operations in detail have been presented at major technical conferences and are available at the PMC BioTec website.

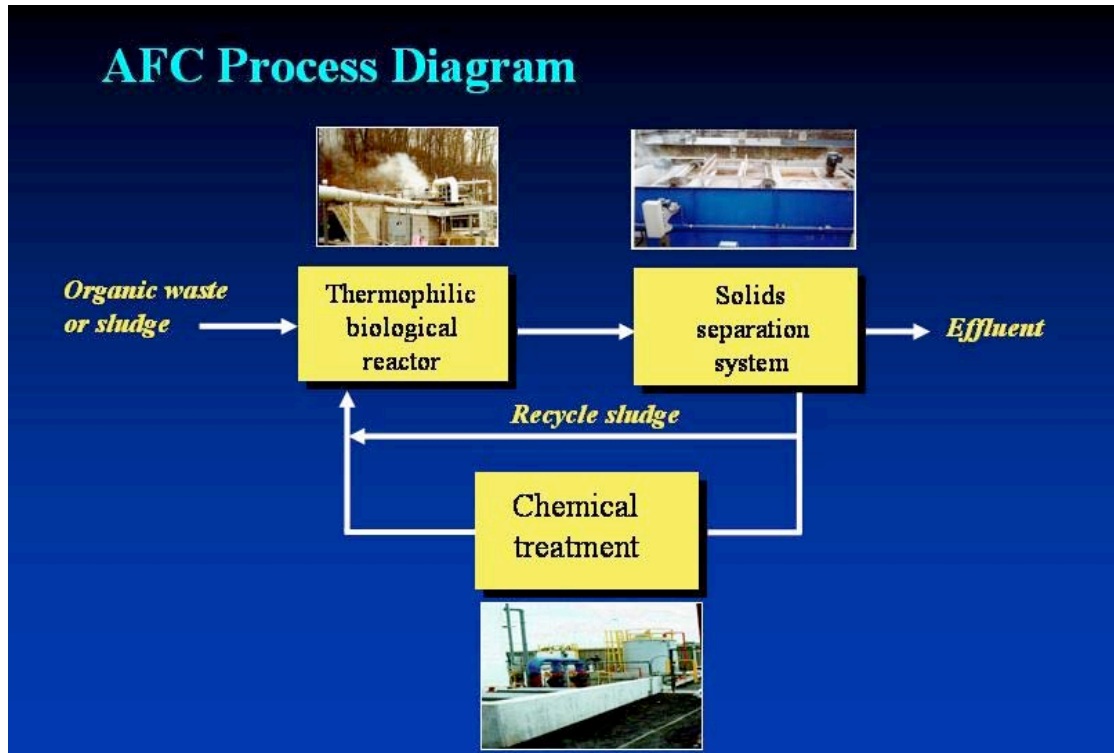
The Technology

The core AFCsm technology concept began 30 years ago like many innovative concepts do: as a bet. In this case, Dr. Tony Gaudy wagered that a biological wastewater treatment process could be implemented which resulted in a net-zero biosolids production regime. Dr. Gaudy and Dr. Alan Rozich proved that a simple-but-effective alkaline (hydroxide) hydrolysis could successfully achieve this goal, albeit with high costs and unacceptable operational aspects.

Dr. Alan Rozich, President of PMC BioTec, continued the effort to achieve cost-effective sludge destruction, targeting hazardous or RCRA sludges since these had associated high costs of hazardous waste disposal. However, continued improvements in the technology brought the AFCsm operating costs down the curve to the point that the process is efficacious for most wastes and sludges.

This technology has successfully been applied to a variety of waste streams including, but not limited to: waste sludge from a municipal plant, high strength organic acids, fermentation wastes (spent mycelia), solvents, high salt waste streams (3%-8% salt), viscose fiber sludges, Phenolic streams, high strength methanol streams, high strength nitrate streams, cosmetic wastes with high fats, oils and greases (FOG), dairy wastes with high FOG, metal stamping oils and greases, and food processing wastes. Results from large full-scale systems have proven that the AFCsm process can reduce organic sludge residuals by as much as 100% destruction.

The basic AFCsm process schematic is simple:



As shown, the catalyzed biological incineration of sludge involves just three unit process steps:

1. Biological Treatment: which can be aerobic or anaerobic, thermophilic or mesophilic, depending on the waste character, waste quantity, and the Owner's objectives and existing facilities. Under thermophilic, aerobic conditions, biokinetic activity is massively accelerated. This results in a reduction of required reactor volume, and thus footprint, to as little as 20% of that required with conventional technology.

A number of other advantages accrue, as are discussed in some of the technical papers presented by Dr. Rozich and his team. The beauty of it is that the thermophilic temperatures are free: the heat of bio-oxidation of the wastes is enough in these applications to self-heat the reactors to the temperatures required for these many benefits.

- This can be a critical advantage for several reasons: 1) the very small footprint of a thermophilic MBR saves valuable real estate on land-restricted sites; 2) the high temperature of operation affords greatly accelerated kinetics and thus easier oxidation of the type of difficult organics likely to be found in sludges; 3) fats, oils, and greases (FOG) are easily biodegradable above 45 degrees C and yet are problematic at ambient temperatures. These benefits are achieved with a system that requires no hazardous chemicals, no pressurized reactors, and liquid temperatures that do not approach boiling: in other words, the AFCsm system is safe and fundamentally simple.
2. **Solids Separation:** The clean water must be separated from the biomass. Most AFCsm installations are designed with Ultrafilters for this purpose, due to the operational simplicity and exceptional efficiencies achievable. Further, the ultrafilter imposes an impenetrable barrier to insure that the material cannot leave the treatment system. Air flotation of the solids has also been applied successfully as a solids-separation step in the AFCsm. Flotation has the benefit of lower capital requirements; with the negatives of lower solids capture efficiency and higher operating costs due to the expense of polymers and additional oversight required.
 3. **Chemical Treatment:** The key to the sludge destruction process is to efficiently catalyze the biological destruction of the large molecular compounds that are resistant to biological degradation. In the AFCsm process, this is achieved through the combination of thermophilic operation and the ChemTreatSM step. Numerous generations of chemical treatment techniques have evolved and been successfully developed, tested and applied by PMC BioTec engineers. The goal is to crack the large bio-resistant organic compounds into smaller, readily biodegradable molecules and let the microbes mineralize them back in the main process reactor. This critical feature avoids the use of extreme temperatures and pressures or exotic metallurgy and chemicals that equivalent processes require.

In the ChemTreat reactor, highly aggressive conditions (extreme localized ORP's and free-radical production) are applied to crack the recalcitrant macromolecules. (Actually, the ChemTreat system could destroy most compounds completely, but typically at greater expense). Each new application is evaluated to determine the most cost-effective mode of ChemTreat for the unique constraints of the project. When required, rigorous bench studies are completed in PMC BioTec's process laboratory facility to insure appropriate unit process sizing.

The simplicity of the AFCsm process belies its capabilities. Reliability is assured because each of the three unit process steps employs technology that has been used for decades. This is an intentional design aspect to insure consistent and low-maintenance operation. The innovative combination of the systems in this proprietary technology is the epitome of synergy: this is the first commercially viable process technology which achieves total organic sludge destruction at such a low cost of operation, and yet is applicable to waste streams of all sizes (except for the very small).

Configurations

There are three different configurations of this critical technology. They can be described as follows:

- ***Bioflexsm process***

For smaller plants (less than 20000 m³/d (5 MGD)), the *Bioflexsm* modification of the AFCsm process can be appropriate. In this configuration, the same 3-step AFCsm process described above is applied. However the *Bioflexsm* process operates at mesophilic, or ambient temperature. The most cost-effective application of *Bioflexsm* can be achieved with the simple conversion of a membrane



bioreactor (MBR) to a catalyzed membrane reactor (CMBR) just by adding the ChemTreat system to a mixed liquor recycle loop. This simple modification should virtually eliminate the production of waste sludge from the CMBR system.

Alternatively, a Bioflex can be installed by adding a solids recovery system (ultrafilter or flotation) to an existing digester, and a ChemTreat system to the recycle loop.

These retrofits are simple and yet can reduce waste organic sludge disposal up to 100%. Disposal of inorganics and screenings at the front of the plant will still be required.

- **AFCsm process**

For small treatment plants (less than 40,000 m³/d (10 MGD)) The classic AFCsm process is a catalyzed membrane reactor (CMBR) that operates aerobically at elevated temperature (thermophilic) with heat generated only by the microbial decomposition of sludge. It can also be described as a catalyzed ATAD (autothermal aerobic digester) with dramatic efficiency gains provided by the ChemTreat system. At the elevated temperature of operation (45-75°C), sludge digestion is rapid and pathogen destruction assured. In addition, the noxious fats, oils and greases that plague conventional digesters are easily solubilized and destroyed. The ChemTreat system catalyzes the extremely high efficiency of the process.

The AFCsm process is for any plant where reliability, stability and simplicity of operation are valued over net energy usage and operating costs.

- **AFC BioFuelssm process**

For large treatment plants, the most cost effective operation is with the AFC BioFuelssm process (Biomass-to-Energy). This is the anaerobic configuration of the AFCsm process, wherein the organics in sludge are converted to energy-rich methane, carbon dioxide and water. Conversion efficiencies up to 85% are achieved, compared to 40% for typical anaerobic digesters. This means almost twice the energy recovery potential, with as much as 75% reduction in residual sludge disposal costs.

Applications

The applications for PMC BioTec's technologies generally fall into four large categories:

- Industrial waste processing
- Agricultural waste processing
- Municipal sludge processing
- Contaminated groundwater or waste streams with poor biodegradability

Large Agricultural and Food Processing applications contain so much organic material that the anaerobic processes are easily the most cost-effective solution; further, these wastes usually do not have the high sulfate or high salt concentrations that are typically problematic for anaerobic processes. Thus they are ideal candidates for energy recovery. Contaminated groundwater type applications are easily dealt with using a non-biological technology. For the sake of clarity, these and other applications are discussed in other white papers available from PMC BioTec.



Cost Effectiveness

Most professionals recognize the escalating risks and costs of sludge hauling and disposal. Few recognize the total costs involved. After reconciling the real, total burdened costs involved for sludge Thickening-Dewatering-Handling-Transport-Disposal-Manifesting-Operation-Liability, most generators have a real operating cost of \$200 to \$500 per dry ton of waste organics processed, (generally higher in Europe and land-limited countries like Japan). There is no direct cost associated with the contingent liabilities far into the future associated with the disposed sludge, but they are real. Existing PMC BioTec clients have documented reductions in operating costs with complete or near-total destruction of waste residuals to save millions of dollars annually with the AFCsm process. Typical operating costs are \$100 to \$300 per dry ton of organics, with most applications less than \$200 per dry ton.

These costs are operating-only and do not include capital amortization. Capital costs (CapEx) are highly variable depending upon the process and the pre-existing equipment at the plant in the case of retrofits. Consider a few examples using some assumed numbers:

- Any existing MBR would need only the ChemTreatsm system and an increase in aeration capacity to achieve full AFCsm process status. Thus CapEx is negligible for the benefits received. For a 2 MGD plant the retrofit cost would be about \$170,000. Waste sludge from the MBR would be virtually eliminated. Assuming a typical waste sludge rate of about 1.5 DT/d, a total disposal cost of \$300/DT, and an operating cost for the ChemTreatsm system plus additional aeration (to oxidize the sludge organics) of about \$130/DT, the annual cost savings are \$93,000/yr for a payback less than two years.
- CapEx for retrofit of the AFCsm BioFuels process to an existing anaerobic digestion system will require only the ChemTreat and Solids Recovery systems, and thus be in the range of \$120,000/DT/d, or about \$2.2 million for a 20 MGD plant generating 18 DT/d of thickened waste sludge.
 - In this case, organic solids destruction efficiency should go from 45% to at least 80%. Assume an operating cost of \$100/DT and a cost for sludge dewatering/disposal of \$300/DT. The annual savings in reduced sludge disposal is about \$460,000/yr. The additional biogas generated has a real recoverable value of about \$400,000 annually even at a low energy cost of \$0.05/KWh. Thus the payback is very attractive. And since this is true sustainable energy derived from an alternative energy source, the actual financial benefits are much greater.
- An industrial plant on the East Coast in the USA installed a greenfield AFCsm system for \$3.8 million and is saving over \$2.5 million annually on hauling costs, completely eliminating sludge hauling for over two years. It also eliminated any liabilities associated with the transportation and disposal of that sludge.

Summary

The following characteristics summarize the positive aspects of the AFCsm technology:

- *Low or No residual sludge production* – Large AFCsm systems have operated on industrial waste (low inorganics) for years with **no** excess sludge production. (Inerts in municipal sludge will necessitate some hauling.)
- *Small footprint* - as little as 10% of conventional systems
- *Easily operated* – safe for personnel, no exotic equipment; simple process concepts
- *Minimizes or eliminates off-site liabilities* from sludge land application or landfill participation
- *Meets 503 Class A requirements* - for any sludge blowdown from the system
- *Enhanced COD Removal* – The ChemTreatsm system achieves significant breakdown of complex organics. Also, thermophilic aerobic units have been observed to realize higher levels of COD removal than mesophilic systems.



- *High Loading Rate Capability* – inherent in the design.
- *Enhanced Biodegradability Capability* - as for “Enhanced COD Removal”, above.
- *Enhanced Synergies with membrane bioreactor systems (MBR)* – in existing MBR systems, the Reactor and the Solids separation processes already exist, so the retrofit of the PMC BioTec ChemTreatSM system is simple and *extremely* cost-effective.

On the negative side:

- *Biological Process Operation* - The AFCsm system is a three-step treatment process and as such it does require operation and maintenance, and thus is more complicated than simple off-site disposal (hauling to a tolling facility for contract treatment of the waste or to an incinerator.)

The Company

PMC BioTec (PMCB) is an environmental and energy technology company with an emphasis on catalyzed total destruction of organic wastes with little or no residual sludge production. PMCB offers a family of proprietary and patented technologies that process organic wastes and sludges for conversion to benign and/or usable products.

Key Personnel

Alan F. Rozich, Ph.D., P.E., DEE

Dr. Alan F. Rozich is the inventor and developer of these technologies. He has more than 25 years of experience in the areas of environmental consulting, project management, new technology implementation and commercialization, and executive management. He also has implemented numerous innovative waste conversion systems domestically as well as in Asia and Europe. He is also the holder of several patents in waste treatment technology. Rozich has held executive management positions in environmental companies dealing with all facets of sales, financial, and project management. Rozich is currently President of PMC BioTec out of West Chester, PA.

Kenneth L. Norcross, MSc

Ken Norcross served as a Vice President of Technology for the US Filter Corporation and also on Vivendi Environmental’s Steering Committee for R&D. He has 27 years of experience in the treatment of municipal and industrial wastewater and residuals. He has published/presented dozens of technical papers and has authored 13 related patents. He has directed the design, startup and operation of numerous municipal and industrial wastewater treatment plants.

Richard J. Colvin, P.E.

Mr. Colvin has over 19 years of experience in the areas of environmental consulting and research/technology development and he is a registered Professional Engineer in the State of Delaware. He has worked on formulating and applying new methodologies for designing and operating biological systems treating a variety of toxic wastes and has assisted with the development and implementation of a patented thermophilic biological treatment technology for high-strength solid and liquid wastestreams. Mr. Colvin has managed and performed a number of bench- and pilot-scale biodegradation studies involving municipal, industrial, and hazardous wastestreams. He developed laboratory techniques and computer software packages for use in obtaining and analyzing respirometry data to evaluate biological process performance for design and operational control purposes. He has designed and managed two process development/ treatability laboratories. He currently manages personnel focused on the



development, design, and implementation of new technologies to reduce waste treatment costs for industrial and municipal clients.

Krisztina Bordacs, Ph.D., P.E., DEE

Dr. Bordacs served as an Environmental Manager at GlaxoSmithKline, providing technical leadership to more than 80 facilities throughout the world. Contributions included: development and implementation of a worldwide Environment and Safety Management System; responsible for wastewater treatment and waste minimization/pollution prevention programs; design and construction management of numerous wastewater treatment plants. Management of waste minimization/pollution prevention projects; due-diligence to minimize long-term environmental liabilities; environmental and safety training courses; internal environmental and safety audits of worldwide manufacturing facilities. She is a member of the EPA Science Advisory Committee for TRI reform.

Prior to GlaxoSmithKline, she initiated and coordinated research projects to develop new environmental technologies including supercritical water oxidation and immobilized microorganisms. As a Research Engineer, she was responsible for troubleshooting and optimizing nutrient removal at treatment plants. She also developed a method for analysis of poly-B-hydroxybutyric acid (PHB); developed cultures for the removal of toxic compounds such as 2,4D and some PCBs in groundwater remediation; and as a Laboratory Manager, she was responsible for the performance of a 20MGD municipal wastewater treatment plant. Dr. Bordacs is now Senior Technical Liaison for PMC BioTec in Europe.

Christian D. Hahn, E.I.T.

Mr. Hahn has over 12 years experience in environmental consulting and research/technology development. He assisted in the development and implementation of a patented thermophilic biological treatment technology (AFCsm) for high-strength organic waste streams and sludges. He also assists with the design and operation of numerous pilot-scale AFCsm systems treating both municipal (WTP Sludge) and industrial (pharmaceutical, specialty chemical) waste streams. Mr. Hahn has over nine years experience performing and managing bench-scale treatability studies for wastewater treatment systems to identify methods to enhance performance and reduce operational requirements. He has provided the start-up and operator training services for several full-scale AFCsm installations including development of Operations Manuals and analytical training. He also assisted in the design and start-up of two treatability laboratories. He has performed numerous respirometer studies to evaluate biological process performance for design and operational control purposes.

H. Keith Johnston

Mr. H. Keith Johnston is a registered lobbyist with the Atoka partnership in Washington, DC and California, working primarily in technologies involved in Homeland Security, especially those that impact the environment such as anti-viral and bacterial agents and water treatment. Other areas of interest are identification and computer auditing designed to work against illegal intrusion into networked systems such as those used by the US government. Prior to this work, Mr. Johnston worked with Keystone Investments in Geneva, Switzerland, and American Partnership Communities (WESPAR) in Irvine, California. Mr. Johnston has also served as consultant to the Drug Task Force in Las Vegas, Nevada, and worked on the Managing Criminal Investigations Program under LEAA (U.S. Department of Justice). Mr. Johnston attended the United States Air Force Academy, Santa Clara University, and graduate school at the University of California, Berkeley (Systems Analysis).