Convert Agricultural Waste into Sustainable Profitable Green Energy

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Abstract

This paper includes a summary of technologies for treating wastes from agricultural and food production sources. Conventional anaerobic treatment achieves 40-50% solids reduction and thus half of the sludge remains for disposal. Much of the methane off-gas is simply released to atmosphere with powerful global warming and ozone depletion effects. Yet the millions of tons of waste organics generated each day represent a huge source of renewable and sustainable energy.

An innovative yet proven technology converts this waste to a valuable fuel resource at efficiencies of 75%-95%. The *AFC BioFuels* process is a catalyzed bioreactor system that is ideal for high efficiency waste-to-energy operation because it approaches 95% conversion of organics and generates little or no waste. The process can increase sustainable energy production from organic wastes by more than 90% compared to conventional anaerobic processes, and reduce final sludge disposal up to 90%.

Introduction and Overview

In the 21st century, most agricultural operations today use the same basic waste treatment processes that have been used since the beginning of farming: *let it drain to a septic pond, live upwind, and forget about it*. This traditional biological waste treatment process (anaerobic digestion) uses naturally occurring microbes to convert waste organics into methane, hydrogen sulfide, more microbes and generally harmless by-product materials. Many process configurations have been developed. Whether fixed-film or suspended growth, phased or mixed culture, anaerobic digestion is the most cost-effective process for treating large quantities of waste organics.

Among all the configurations, one characteristic is held in common however: *every* process produces lots of spent, wet, and odorous waste sludge. Sludge is an expensive and problematic byproduct of almost every waste 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 will 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 for many agricultural waste generators because their waste contains pathogenic organisms, viruses, prions, antibiotics, Endocrine Disrupter Compounds (EDC's), grease, 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 Agricultural Waste Issue

The American Environmental Protection Agency (EPA) has struggled to resolve the problems posed by massive amounts of waste material produced by feedlots, slaughterhouses, agricultural and food processing factories, etc. Organic waste is generated by the agricultural and food production industry at the rate of *billions of tons each year*, just in the USA. Most waste treatment systems achieve less than 50% destruction of the waste organics generated by the production facility. Problems with the disposal of waste sludge from these facilities are receiving a tremendous amount of attention. Governments around the world have funded hundreds of research projects to find an efficacious waste treatment technology to handle this astonishing amount of material. Clearly, each method of wastewater treatment and of sludge treatment has separate impacts on the total cost. But most approach the problem as a waste treatment issue, and thus miss a profitable energy resource recovery opportunity.

Waste Treatment

There are a number of conventional treatment/stabilization alternatives on the market today for large quantities of agricultural wastes. Anaerobic treatment in the form of lagoons, vessels and vertical reactors (including huge egg-shapes) is well represented. Biomass can be attached or suspended, mesophilic or thermophilic, granulated or not. Flow patterns can be mixed or unmixed, horizontal or vertical, up or down, depending on the process. Each configuration has its niche, its particular set of advantages and disadvantages. But almost all of these processes produce great quantities of waste sludge (pure soluble sugar-rich waste streams are the exception). And that is where the costs get painful.

Whether waste or waste sludge treatment, the workhorse for the industry has always been "anaerobic digestion". The "*High-Tech Septic Tank"* processes in use today are mostly just variations on the simple septic tank, 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 process for large producers 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 dumped into a closed reactor for a duration of some weeks. Some of the waste solid material (generally less than 50%) is in turn converted to methane, carbon dioxide and water. The process is almost always operated at warm temperature (30°C). (Thermophilic (>45°C) variations exist and might offer some advantages, but the process dynamics are poorly understood and the advantages appear slight weighed against the potential for problems.)

Disadvantages of the conventional anaerobic process include: 1) a relatively fickle process equilibrium (prone to upsets); 2) long startup and upset-recovery times; 3) intolerance of fats/oils/grease and temperature variations; and 4) the production of odiferous and poorly dewatered waste sludge. In open systems, as are typical throughout the world, the methane end-product is released to the atmosphere with terrible results: methane causes *60 times* the global warming effect that carbon dioxide causes. This is a doubly destructive waste of a valuable energy resource.

In fact, the methane produced by anaerobic decomposition of organics is energy-rich and can be converted readily to infinitely renewable electrical energy through a commercially available generator package. But energy recovery is an expensive process to build and maintain and therefore is only cost effective for large plants.

Treatment/Stabilization Alternatives for Waste Organics

Agricultural waste typically contains a slurry of liquid and mostly organic solids. The liquid usually contains a large amount of dissolved organics. Purification processes inevitably produce additional waste organic solids, or sludge. Often the solids are recombined with those separated at the front of the process, and sent to composting for land application or to landfills. Various commercial composting operations have done a laudable job of returning waste organic material back to the land. But there is only so much compost needed; and it is only needed at certain times of the year.

The EPA estimates that the cost for sludge handling and disposal account for 40% to 60% of the total budget for a wastewater treatment facility. These costs are increasing, and this is *before* the regulation of endocrine disruptors, prions (e.g.: Mad Cow disease), and viruses.

When asked to quantify the cost to dispose of waste sludge, most plant operators respond with only the cost of the sludge disposal step itself (e.g.: land spreading fee as $/m^3), and thus fail to realize 50% to 75% of their real sludge-related costs. It is important to include all necessary steps:

- Thickening the sludge to reduce downstream costs
- Stabilization where appropriate or required
- 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

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 (2008), and coming legislation and liability rulings for sludge-borne infectious agents, more facilities are considering onsite destruction of the residual sludge produced by the initial waste treatment process. But labyrinthine permitting requirements have all but eliminated the construction of new incinerators. More exotic processes like High-Pressure/High-Temperature sludge cookers achieve destruction of pathogens but are quite expensive to own and operate; and achieve little reduction in waste sludge mass. Further, the liability aspects associated with heated and pressurized reactors are intimidating.

Sludge Disposal Alternatives

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

- Incineration processes: "*Truck it and burn it"*. Hauling sludge to an incinerator can be 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 unlikely that there will be no new incinerators built.

- Off-site treatment: "*Dump it on them"*. Small operations 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, for disposal. 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 large amounts of sludge will benefit by providing for the treatment themselves.

- Landfills: "*Bury it"*. Landfilling is a popular method for disposing of wastes because it is easy to do and cheap. It is popular but can be problematic. The common misconception is that landfilling is cheap because only the tipping fees are considered. However it can be quite expensive when all of the costs for all sludge preparation required are accounted, as in the list above. The cost for burying organic wastes and sludge in landfills varies widely – where it is allowed. Again the total costs include sludge dewatering and transportation. 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 or already gone in most countries; 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.

  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 and carbon dioxide. Subsequent release of methane to the atmosphere (in spite of collection and flaring systems) has a powerfully negative effect on global warming and ozone depletion.

- Ocean Dumping (*Dump it out there).* Banned in the USA since 1992, ocean dumping is a common practice in many countries. Needless to say, it is a practice which must be stopped internationally

Land application. (*Dumping)*. Spreading agricultural waste on farmland is easily the oldest method of disposal. Nutrients are recycled back to the land, but then so are any toxins. And with modern farming techniques, the toxic load can be appreciable. The federal 503 regulations and its European equivalents require varying degrees of treatment and stabilization prior to land application of municipal sludge, depending on the intended use of the land. Equivalent legislation for agricultural wastes is passed or proposed in most states in the U.S. and in Europe. And it is important that this happen: there is over 100 times more agricultural waste produced each day than there is municipal (human-generated sanitary) waste.

Widespread concern over groundwater contamination from poorly designed waste collection and treatment systems at animal farms has sparked a rapid escalation in regulatory efforts. There are many different opinions about how to regulate the disposal of agricultural and food production wastes. There is vigorous debate over the ultimate safety of land application due to the many unfriendly compounds present in the waste from animal operations, particularly from the very large Confined Animal Feeding Operations (CAFO's). Land application is generally safe and appropriate for many wastes (e.g.: vegetable processing). And proper composting practices are acceptable for many smaller farms. However, large-scale operations are missing a prime profit opportunity by treating this as a waste disposal issue rather than an energy-generation resource.

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

1. It is cheap since the EPA has not yet vigorously enforced or strengthened the regulations. This *will* change.
2. Processes that would insure destruction of pathogens are costly to build, to operate, and to insure.
3. There are few other good options

However it is also true that very few people want sludge disposed in their own backyard. And it is expensive to do it right: to destroy *all* of the numerous substances that pose human health risks. Land application is increasingly risky because it proliferates numerous substances that pose human health risks. Waste material generated growing or slaughtering animals for example, can contain:

- Pathogens (infectious bacteria, cysts, viruses, prions).
- Endocrine Disruptor Compounds (EDC's)
- Antibiotics
- Carcinogenic disinfection agents
- Dangerously high levels of ammonia

For this reason, land application of certain wastes is rife with the potential for torte liability; if the waste applied contains substances that can compromise human health: anyone downwind or downstream that suffers serious morbidity issues is a potential litigant.

- Combined Anaerobic Digestion with Sludge Drying and Pelletization. There are several commercial variations on this theme, mainly in Europe. It offers the advantages of: 1) reliable high-temperature destruction of pathogens with 2) some degree of energy recovery and 3) the production of a fertilizer source in the dried sludge pellets produced. Disadvantages include: 1) a high capital cost; 2) complicated mechanical processes; 3) an unreliable and seasonal market for the fertilizer pellets, and 4) a significant cost for air pollution control with the sludge drying process.

The essential facts of agricultural waste disposal are:

- Treatment and disposal of organic waste is an expensive necessity
- The traditional technological "solutions" are neither complete nor economically sensible for large generators of organic waste
- Incomplete or incorrect waste treatment is often harmful to the environment.
- *The millions of tons of agricultural and food production waste generated each day can be a valuable source of energy.*

With the irreversible rise of energy prices, large agricultural and food production operations have an unprecedented opportunity to turn a costly liability into a profitable resource; they can solve the problem of disposing organic waste by taking the opportunity to harvest organic fuel and produce sustainable, renewable energy - *profitably*. The agricultural and food processing waste generated in the USA alone represents a sustainable energy resource of *more than a billion megawatts annually.* This is especially important in light of the rising tide of governmental and private initiatives requiring "green" investments.

The technology for profitably producing renewable energy 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 energy-rich methane, with little organic residual to dispose. These are "triple-green" technologies:

1. They are green for the environment because both water and air resources are protected.
2. They are green for sustainable energy production.
3. They are "green" for investors and owners because the cost of energy and the immediacy of global warming have permanently altered the economics of the situation.

The History

One of the great canards of the waste treatment business is the regular appearance and disappearance of processes that claim to treat wastewater and yet 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 super-heated "cooking vessels" used by some processes.

The professional literature shows enhanced sludge destruction can be achieved with a variety of powerful mechanisms: Peroxide, Ozone, Sodium Hydroxide and Sulfuric Acid hydrolysis have all worked in the lab or on limited applications. Aggressive or hazardous chemicals or operating conditions can sometimes do the trick of preventing sludge *production* (called "biochemical uncoupling") as opposed to achieving sludge *destruction*. But few of these tricks have been commercially viable or operationally sensible. And almost all of them are waste-treatment *cost* processes, rather than *profit*-making operations. Even the award-winning PMC BioTec *AFC*^sm^ process is not a profit generator by itself but a radical cost-reduction opportunity for waste generators; its profit potential lies in charging tolling fees to waste generators who will pay for the service.

An Innovative Alternative

The AFC^{sm} process upon which *AFC BioFuels*^{sm} is based, is a catalyzed membrane bioreactor (CMBR) system that operates as an accelerated biological treatment process with negligible organic sludge production. It is catalyzed with the aide of an inherent conditioning side-stream oxidation or hydrolysis, and accelerated by the positive retention of component biosolids. It has proven to be extremely robust and aggressive. The process 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. It works by effectively integrating microbial and catalyzed chemical reactions to achieve near-total mineralization of organic waste to carbon dioxide, minerals and water. 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.

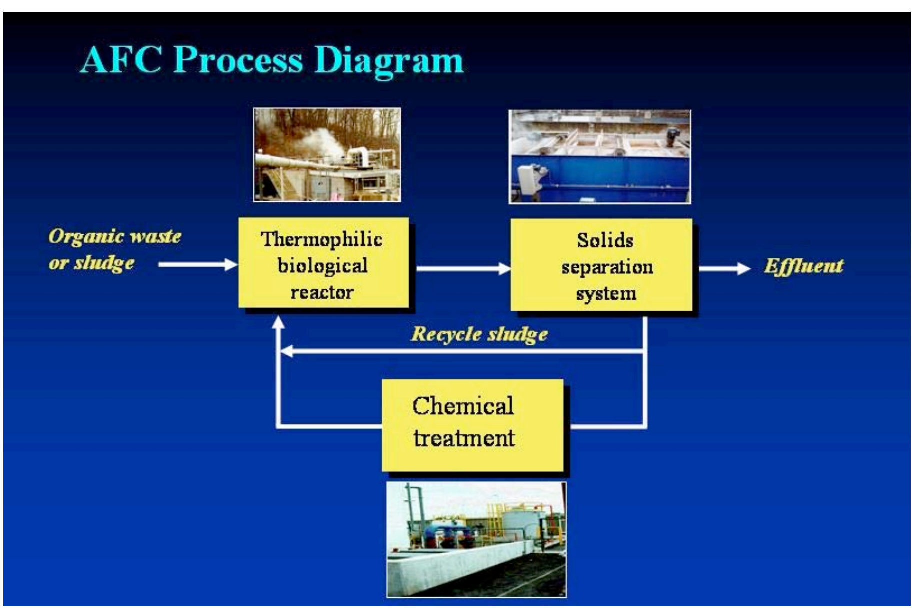
The Technology

The core AFC^{sm} 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 AFC 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 (up to 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 AFC^{sm} process can reduce organic sludge residuals by as much as 100% destruction.

The basic AFC^{sm} process schematic is simple:



As shown, the catalyzed biological incineration of sludge involves just three unit process steps yet offers a process that is less expensive and safer than wet air oxidation, yet just as effective in most applications:

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 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 is 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 minimization or elimination of sludge handling/disposal processes saves cost and space; 3) the high temperature of operation affords greatly accelerated kinetics and thus easier oxidation of the type of complex organics likely to be found in sludges; 4) fats, oils, and greases (FOG) are easily biodegradable above 45°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 AFC^{sm} system is safe and fundamentally simple.

2. Solids Separation: The clean water must be separated from the biomass. Most AFC installations are designed with Ultrafilters for this purpose, due to the operational simplicity, exceptional efficiencies achievable, and high-quality water produced. Further, the ultrafilter imposes an impenetrable barrier to insure that the material cannot leave the treatment system. Thus high concentrations of biomass can be maintained, greater treatment capacity per unit volume is achieved, and reactor volumetric requirements are smaller.

   Air flotation of the solids has also been applied successfully as a solids-separation step in the AFC. Flotation has the benefit of lower capital requirements; with the negatives of lower solids capture efficiency than ultrafilters, higher operating costs due to the expense and variable effectiveness of polymers and the additional oversight required, and the odorous off-gas produced.

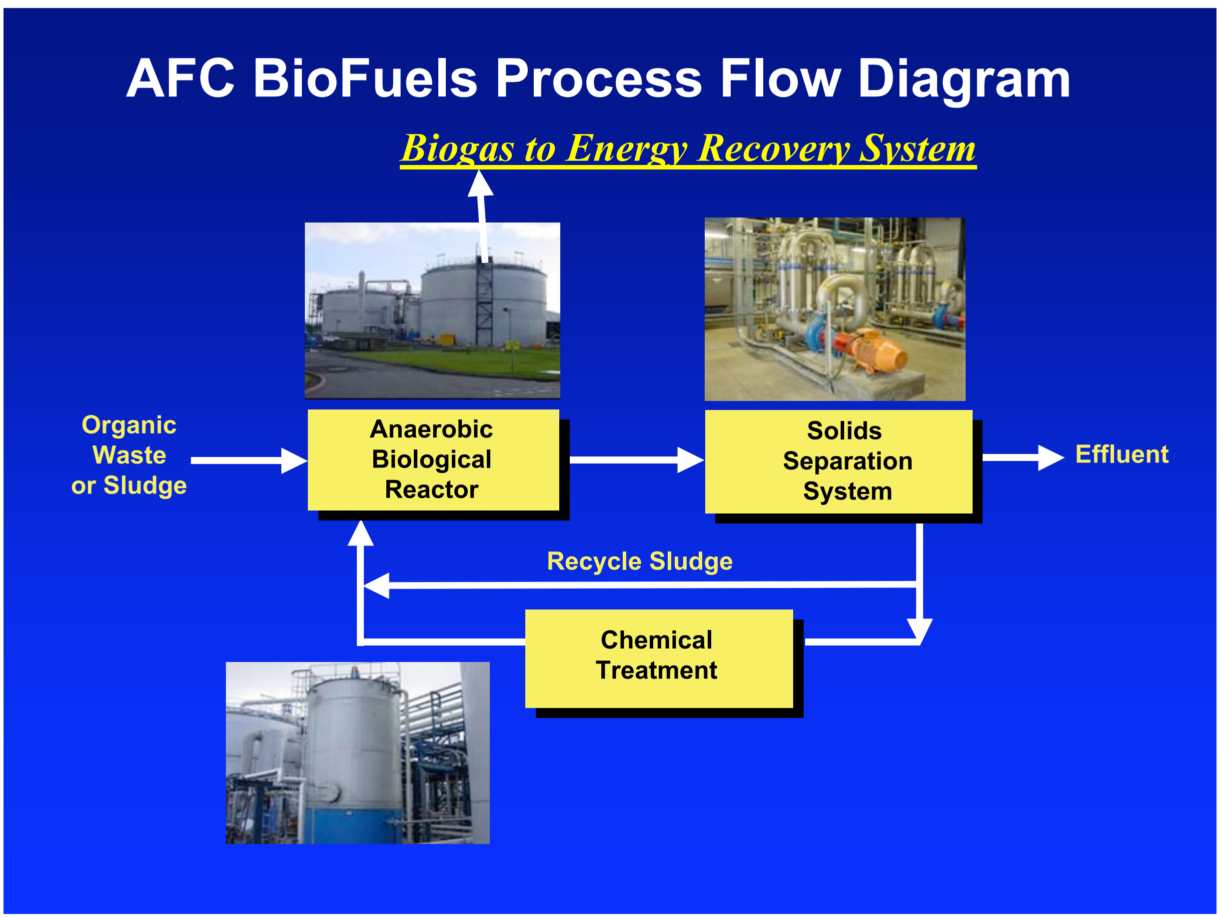
3. Chemical Treatment: One of the keys to efficient sludge destruction is to effectively catalyze the breakdown of the large molecular compounds that are resistant to biological degradation. In the AFC^{sm} process, this is achieved in the combination of thermophilic operation and the ChemTreat^{SM} 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 that then undergo microbial destruction 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 AFC^{sm} 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, low-maintenance and safety-friendly operation. This proprietary and innovative combination of conventional technologies is the first commercially viable process that achieves total organic sludge destruction at such a low cost of operation; and yet it is applicable to both medium and large waste streams and makes no concessions to safety.

AFC BioFuels^{sm} Process Configuration

For large generators of organic waste, aerobic processes are too energy-intensive because of the cost of aeration energy Therefore, PMC BioTec modified the venerable anaerobic digestion process so that it is capable of 1) treating wastes while generating little or no waste sludge. The *AFC BioFuels^{sm}* process is a modification of the core AFC^{sm} process, configured for anaerobic conversion of organics into energy-rich methane, carbon dioxide, minerals and water. As is shown below, *AFC BioFuels^{sm}* is little changed from the essential *AFC ^{sm}* process. The key difference is the use of a mesophilic anaerobic reactor to provide the low sludge yield and conversion of organics that was accomplished with the thermophilic aerobic reactor in *AFC^{sm}*. This variation is particularly appropriate where energy recovery is a priority or a pragmatic potential.



Again, the simplicity of the process belies its uniquely profitable characteristics:

- *AFC BioFuels*[sm] provides enhanced conversion of sludge solids to biogas at efficiencies up to 95%, vs. 45-50% for conventional technology.

- This is a critical advantage because there is thus twice as much methane energy to recover and turn into profit. This alone is a quantum shift in the financial rationalization of biomass-to-energy projects. Such projects are traditionally not cost effective because the energy generated from 45% conversion of solids to biogas is not much more than the costs of doing so. But when the gas quantity is doubled at little extra cost, the projects Internal Rate of Return values are highly attractive.

- Even better, the *AFC BioFuels*[sm] process yields little or no spent sludge for disposal (typically 5% to 20% compared to conventional systems). Thus there is little cost for waste disposal to counter the highly profitable generation of green, renewable energy. This in turn enhances profitability while simplifying operation.

- Further, there are no high-pressure reactors or dangerous temperatures, so operational Health and Safety liabilities are low and insurance costs are modest.

- Another potential benefit of the process is that the destruction of solids and the conversion of organics to biogas means that the essential nutrients are released and left in solution. Thus fertilizer-quality nitrogen, phosphorus and trace minerals can be recovered with conventional technology and sold to market.

- Yet another key aspect of the technology involves the use of membrane filtration to retain all solids: this then includes the potentially pathogenic bacteria, cysts, viruses, and prions. These will ultimately be destroyed biologically or chemically.

  - Further, the extreme ORP environment exerted in the ChemTreat Reactor to affect solids disruption will also destroy most growth hormones, EDC's, antibiotics, etc, if they survive the initial biodegradation efforts.

  - The traditional proscription against using an Ultrafiltration membrane in an anaerobic environment is circumvented by routine washing of the UF with a radical disinfection treatment generated as a byproduct of the ChemTreat[sm] process. This essential feature is yet another proprietary feature.

- Finally, in keeping with PMC BioTec tradition, all mechanical components and unit processes of the *AFC BioFuels*[sm] system are conventional, proven technologies. Again, the proprietary innovation is in the combination and application of these technologies to achieve a breakthrough return.

Applications

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

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

For the sake of clarity, only Large Agricultural and Food Processing applications are discussed in this paper. Industrial wastewater, contaminated groundwater type applications, and municipal sludge processing, are discussed in other white papers available from PMC BioTec.

Cost Effectiveness

Energy experts predict the cost of energy to continue to escalate through the foreseeable future. The rising cost will be driven by the voracious energy demand in the emerging mega-economies in China and India. This in turn is driving a quantum escalation in the financial incentive to convert waste into energy. *AFC BioFuels*^{sm} enhances profitability by cost-effectively augmenting energy production while minimizing residuals production. (It will still be more practical for small agricultural and food production facilities to pump-and-treat their wastes.)

Consider an example from two projects currently (2005) in the design phase:

1. CapEx for retrofit of the AFC 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 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 $640,000 annually even at an energy cost of $0.08/KWh.
   - Thus the payback is about two years. And since this is true sustainable energy derived from an alternative energy source, the actual financial benefits to investors are much greater.
   - The return on investment (ROI) would be much greater in most areas due to the higher cost of electricity, and because of tax credits for sustainable "green energy" production. At an energy cost of $0.15/KWh the system is paid for in 18 months.
2. A food production operation generates 60 dry tons/day of composted organic residual. The Owners found no affordable disposal option for this material, and the ongoing environmental impacts have been a costly headache for both the industry and the surrounding communities.
3. Frequent, negative publicity has been the routine.
4. Many alternatives have been examined over the years; none passed the economic feasibility tests.
5. The *AFC BioFuels*^{sm} process was tested and confirmed to offer seriously attractive financial returns as a profit-maker in its own right; the resolution of a waste disposal problem became a side benefit of the energy generation economics.
6. It is estimated the system will pay for itself in less than three years and offer Internal Rate of Return (IRR) values over 15% .

Summary

The following characteristics summarize the positive aspects of the *AFC BioFuels*^{sm} technology:

- *Low or No residual organic sludge production* – Large AFC^{sm} systems have treated millions of pounds of waste organics for years and produced ***no*** waste sludge. (Inerts in any waste will necessitate some hauling.)
- *Virtually eliminates pathogenic risk of infection from waste-borne organisms*
- *Easily operated* – safe for personnel; no exotic equipment; no pressurized or superheated reactors; simple process concepts
- *Minimizes or eliminates off-site liabilities* from sludge land application or landfill participation
- *Eco-Friendly in accord with KyotoGlobal Warming Protocol*- Biomass to energy conversion of waste organics eliminates methane release from decomposition of conventionally-disposed waste organics, thus providing 60x credit factor against global warming rating.
- *Exceeds 503Class A requirements* - for any sludge blowdown from the system
- *Enhanced COD Removal* – The ChemTreat^{SM} system achieves enhanced breakdown of complex organics. And the positive solids retention means that high molecular weight organics and retained for eventual destruction.

On the negative side:

- *Biological Process Operation* - The *AFC BioFuels*^{sm} 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 on agricultural land.

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 (AFC) for high-strength organic waste streams and sludges. He also assists with the design and operation of numerous pilot-scale AFC 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 AFC 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).