High-Strength Waste Treatment to Eliminate Sludge, Save Money, and Improve Environmental Public Relations

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Abstract

This paper includes a summary of technologies for treating high strength organic waste streams and sludges. Conventional aerobic biological treatment is effective for these applications but produces 0.25-0.5 g Waste Sludge per g COD (Organic material) treated. The sludge is expensive to treat 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.

An innovative technology that offers some distinct advantages is discussed. The AFC system is a catalyzed MBR (membrane bioreactor) which achieves biological incineration, a form of mild wet air oxidation that is ideal for high strength waste streams and sludges because it is field proven to generate little or no waste sludge and requires a fractional footprint compared to conventional technologies. Cost of treatment is about $150-$250/DT of COD compared to $300-$500 for conventional technologies.

Introduction and Overview

The goal for most industrial waste treatment systems is to treat low-flow, high-strength wastes efficiently and to produce a clean effluent. Waste material comes in two flavors: *organic* (carbon-based compounds associated at one time or another with living things) and *inorganic*, (dissolved metals, salts, etc.). This paper is concerned with the fate of waste organics contained in industrial wastewater discharges. Every waste stream has an inorganic component, but for most wastes, these are of less significance than the organic content.

Biological treatment uses microbes to convert waste organics to more microbes and harmless by-product materials. Biotreatment is inevitably the most cost-effective option for biodegradable waste streams. Many process configurations have been developed in response to the great number of applications: Aerobic and Anaerobic systems each have their general characteristic advantages and disadvantages and constraints. Thermophilic and mesophilic variations of each add to the mix. One characteristic is held in common however: *every* treatment process produces unwanted waste sludge, (or "excess biosolids" for the politically correct).

Sludge is an expensive and problematic byproduct of the wastewater treatment process. There are numerous traditional options for its 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.

This issue is compounded at Industrial plants because the sludge can contain aggressive and/or RCRA-listed compounds, carcinogens, Endocrine Disrupter Compounds (EDCs), and high salt content. In some cases the waste stream can contain proprietary or problematic genetic material or GMO's that are best destroyed on-site. Agricultural or Food Processing wastes often struggle with contamination from pathogenic organisms, virus, prions, and EDCs and thus pose a similar challenge. Either way, the Total Costs and Health-and-Safety issues associated with concentrated wastes and sludges and their treatment, dewatering, transport, and ultimate disposal are steadily increasing.

Alternatives

There are a number of conventional wastewater treatment alternatives on the market today. Of the biological wastewater treatment processes, aerobic systems tend to be more resilient to a variety of waste streams and variable loading conditions. Anaerobic systems on the other hand, produce less sludge and have lower operating costs since there is no energy requirement for aeration.

Conventional approaches for handling high strength industrial waste or sludge streams include off-site disposal (including land disposal); on-site treatment via biological, physical-chemical or thermal (incineration) processes; and contract treatment in which the waste is sent to another site for treatment in their facilities. With recent regulations in Europe prohibiting land disposal of organic wastes, more facilities are considering onsite treatment of their high strength wastes and sludges. 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.

The conventional alternatives for treating high strength organic waste or sludges can be summarized as follows:

- Aerobic Wastewater Treatment Processes: "*The Usual"* This is easily the most common wastewater treatment methodology because it is well understood and relatively predictable. In this process, aeration is provided to a microbial consortium that in turn converts pollutants to mainly carbon dioxide and water. The byproducts from this biological oxidation of waste organics are additional microbes and of course residual waste compounds not biodegraded. These generate a "waste sludge" that must be disposed. High levels of COD conversion efficiency are attainable and process-troubleshooting techniques are generally reliable.

  They tolerate a wide range of operational conditions and waste feed components. In addition, there are many industrial compounds that are biodegradable in an aerobic system; these are generally robust systems that recover from upsets readily with a little help.
  Negatives include the high cost of energy required for aeration; the large amount of waste sludge generated (typically 25% to 50% of the organic load treated); contamination of that sludge with industrial waste compounds; the high cost of contaminated sludge treatment and disposal. In addition, it is another process that must be supported and operated; and it is a process with which the manufacturer usually has little prior experience.

- Anaerobic Wastewater Treatment Processes: "*High-Tech Septic Tanks".* Most food producers/processors are well familiar with anaerobic waste treatment, which employs an anaerobic (without oxygen) microbial consortium to convert organics to mostly methane and water with a small amount of CO_2. It has long been used as a low-cost method to treat relatively clean wastes with high concentrations of organics such as juices, soft drinks, vegetable processing, etc.). The industrial anaerobic treatment processes in use today are little different from large septic tanks, except they include electrical instrumentation and controls to facilitate ease of process monitoring and preventive troubleshooting. The chief advantages are low waste sludge production (about 5% to 10% of the organics converted); and the low mixing energy requirement, (since there is no need for aeration energy input.) In fact, the methane produced from the influent organics is energy-rich and converts readily to electricity through a conventional generator package.

  Disadvantages include a relatively fickle process equilibrium (prone to upsets); intolerance of salts, sulfates, fats/oils/grease and temperature variations; poor degradation rate of solids (best with soluble organics; poor efficiencies with complex organics (best with simple sugars and starches); and the production of an odiferous and poorly-dewatered waste sludge. In short, it acts like a human digestive system and is just as disagreeable to live with when upset; and anaerobic system upsets tend to be very serious business indeed. And again, it is another process that must be supported and operated by the manufacturer; and it is a process with which the manufacturer usually has little prior experience.

- Incineration processes: "*Truck it and burn it",* or hauling wastes to an incinerator for incineration is a convenient solution that requires no onsite treatment facility to be operated other than a collection and truck filling system. However costs vary widely depending on location and the availability of a suitable 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. Associated dewatering, handling, transportation and insurance costs are significant. 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.

- Wet Air Oxidation: *"Huge Pressures and Temperatures will blast it".* And it will: almost any organic compound will oxidize if you squeeze it hard enough (many atmospheres pressure) and cook it hot enough (hundreds of °C) and blast extremely-high pressure air into it. This is a slick process in that the reactor itself is small (only a few hours retention are required), and the results oxidation of troublesome organics is efficient. But the capital and operating costs are massive; and the Health and Safety liabilities of such pressurized and super-heated reactors are obviously severe.

- *Off-site treatment*: "*Pay them to deal with it"* For manufacturers who create very small amounts of wastes, it is often easiest to pay a contract hauler to take the waste to a permitted waste treatment facility, and pay the tolling facility to dispose of it. This is certainly a simple solution and leaves the manufacturer free to concentrate all resources on running the core business. However the service is quite expensive on a weight or volume basis, typically two to three times the cost of onsite treatment. So those who generate significant amounts of waste will benefit by providing for the treatment themselves.

- Landfills: "*Bury it"* is clearly the oldest method for disposing of wastes. 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 is happening in Europe. 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 has a dramatically bad effect on global warming and ozone depletion.

- Land application. *Dumping* wastes on farmland is common for many food production wastes; most of the organics are eco-friendly in small doses, and were grown on the land in any event. However land application is unsuitable for most other industrial wastes. 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. Once again, total costs must include waste/sludge stabilization/transport etc.

- 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 falls well short of proposed regulations to ban such organics-rich material from the rapidly shrinking landfill space.

Clearly, there are numerous 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. Technological advances can greatly enhance the efficacy of a conventional process.

The History

Obviously, the conventional methods described above, whether aerobic or anaerobic, each has a critical drawback: they generate the expensive nuisance of waste sludge. The ideal technology would simply avoid the generation and disposal of sludge in the first place.

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 great untouched brass ring 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.

One of the only successfully marketed processes to claim this ability was the infamous Heat Treat process, which applied enormous pressure and temperature to break the microbial cells open: cell walls and membranes came out largely resistant to biodegradation but the liquid cellular material was highly biodegradable and exerted dramatic load increases on the wastewater treatment facilities that originally generated the microbes in the first place! Severe odor problems resulted from the "cooking" of waste sludge; exorbitant costs were incurred attempting to resolve the odor and organic loading issues; and a host of other problems led to the end for the process many years ago. Most or all were shut down long ago.

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; 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. Wet Air Oxidation is a commercially available, but prohibitively expensive, exception.

An Innovative Alternative

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 AFC^{sm} 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; it is wet-air oxidation without the ultra-high temperatures and pressures and costs. 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 AFC^{sm} process is a modified thermophilic aerobic system that operates as an accelerated aerobic biological treatment process with a small sludge production similar to that of an anaerobic process; and this minimal excess sludge is destroyed with the aide of an inherent side-stream oxidation process. Further, it is extremely robust and aggressive. Therefore the AFC^{sm} process combines the best features of both aerobic and anaerobic processes. As an aerobic process it still requires a high level of aeration, but the extremely high kinetic rates granted by the high 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 treat high strength industrial waste streams.

The innovative AFC^{sm} 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 are attached as an appendix to this paper. Detailed technical papers describing these operations on detail have been presented at major technical conferences and are available at the PMC BioTec website.

The Technology

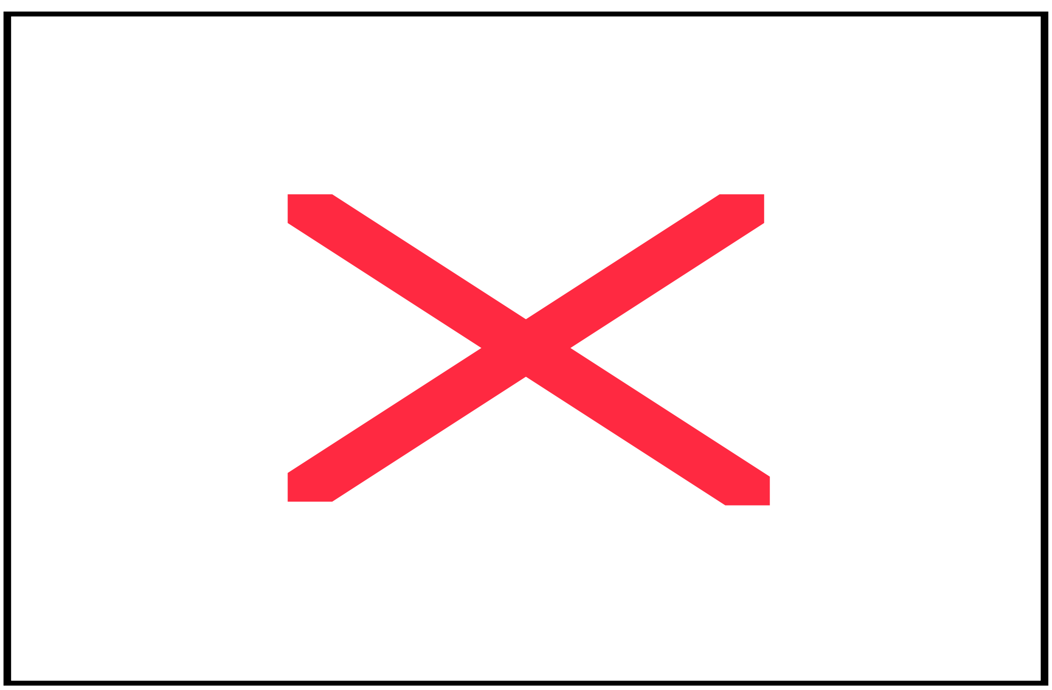
The core AFC^{sm} technology concept began 30 years ago like many innovative concepts do: as a bet. In this case, Dr. Tony Gaudy wagered that a biological wastewater treatment process could be implemented which resulted in a net-zero biosolids production regime. Dr. Gaudy and Dr. Alan Rozich proved that 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 RCRA-generated 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.

Results from large full-scale systems have proven that the AFC^{sm} process can reduce organic residuals by as much as 100% destruction. The high destruction efficiency is achievable because 1) the high temperature characteristics of the thermophilic process facilitates the biodegradation of organic components that are more soluble at high temperature and 2) the kinetic rates of biodegradation are vastly more aggressive at high temperature. Therefore up to 99% of the soluble organics are rapidly converted to carbon dioxide and water. Residual organics or organic solids resistant to biodegradation are “softened” in the chemical treatment step and then converted to carbon dioxide and water upon re-entering the thermophilic reactor.

This technology has successfully been applied to a variety of waste streams including, but not limited to: High strength organic acids, fermentation wastes (spent mycelia), solvents, high salt waste streams (3%-8% salt), viscose fiber sludges, waste activated 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.

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



As shown, the catalyzed biological incineration of wastes 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. For many industrial, non-food waste streams, anaerobic operation is too problematic, and mesophilic operation too slow. 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 10% 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 usually free: the heat of bio-oxidation of the wastes is enough in these high-strength applications to self-heat the reactors to the temperatures required for these many benefits.

   This can be a critical advantage in these applications for several reasons: 1) the very small footprint of a thermophilic MBR saves valuable real estate on industrial 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 high strength industrial wastes and sludges; 3) A number of compounds are biodegradable above 45 degrees C and yet are problematic at ambient temperatures, these include fats, oils, and greases (FOG) among others. 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 cleaned water must be separated from the biomass. Most AFC 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. This accelerated MBR (membrane bioreactor) design is thus free of many of the traditional operational problems typical of biological waste treatment. None of the plant operator's ubiquitous nightmares have relevance in this MBR: mixed liquor settleability, flocculation, filamentous bacteria, settling behavior, sludge return rates: all of these factors are irrelevant in the AFC.

   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 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 AFC^{sm} process, this is achieved with the combination of thermophilic operation and with 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 and let the microbes mineralize them back in the main process reactor. In addition, it is preferable to avoid the use of extreme temperatures and pressures or exotic metallurgy and chemicals.

   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 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 process belies its capabilities. Each of the three unit process steps employs technology that has been used for decades. This intentional design aspect insures consistent and reliable plant operation. The innovative combination of the systems in this proprietary biotechnology is the epitome of synergy: this is the first commercially viable process technology which achieves total organic sludge destruction at a low cost of operation, and yet is applicable to waste streams of all sizes (except for the very small).

Note that the "high" temperatures used in the AFC are below boiling, and in non-pressurized reactors; yet the process can achieve equivalent results to expensive Wet Air Oxidation processes for most waste streams at much less cost.

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 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.

Industrial waste streams such as those from Chemical Plants, Refineries, Pharmaceutical Manufacturing, and smaller Agricultural or Food Processors are usually best treated with aerobic technology. As noted above, these conventional plants generate a great deal of waste sludge; but the plant operational fundamentals are well understood and the results generally reliable. For these applications, the AFC process can be installed either as a bolt-on sludge destruction system or as a retrofit of the waste treatment process to eliminate or greatly reduce sludge production.

For Greenfield systems, the design of an AFC waste treatment system has the distinct advantages as noted above.

Cost Effectiveness

Most industries 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/Operator-time/Liability, most generators have a real cost of $300 to $500 per dry ton of waste organics processed, (higher in Europe and land-limited countries) with contingent liabilities far into the future associated with the disposed sludge. Existing PMC BioTec clients have documented reductions in operating costs with complete or near-total destruction of waste residuals to save millions of dollars with the AFC^{sm} process. Typical operating costs are $100 to $150 per dry ton of organics. Therefore a plant generating 10 tons of organic waste per day could save up to $1.5 million annually by installing an AFC^{sm} process and destroying the sludge onsite; it would also eliminate any liabilities associated with the transportation and disposal of that sludge.

Summary

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

- *Low or No waste sludge production* – Large AFC^{sm} systems have operated for years with ***no*** excess sludge production.
- *Vastly Reduces or Eliminates off-site sludge disposalcosts and liabilities*
- *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 503Class A requirements* - for any sludge blowdown from the system
- *Enhanced COD Removal* – The ChemTreat^{SM} 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 ChemTreat^{SM} system is simple and *extremely* cost-effective.

On the negative side:

- *Biological Process Operation* - The AFC^{sm} system is a three-step treatment process and as such is vastly simpler than most industrial plant processes. However 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.) Of course, AFC^{sm} treatment is cheap at \$100 to \$150 per dry ton of organics; typical contract treatment or incineration of wastes is \$300 to \$400 per dry ton when all costs are included.

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 29 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.

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).