WHEN Richard Giani started in the Biosolids Section for the Division of Wastewater Management in the Pennsylvania Department of Environmental Protection (PADEP), he quickly learned that the majority of complaints regarding land application of biosolids centered around odors. “I asked if there weren’t odor complaints, how much the complaints would be knocked down,” Giani recalls. “The response was, ‘at least 90 percent.’”

Unlike biosolids quality and control parameters such as pollutant limits and pathogen and vector attraction reduction, management of odors does not lend itself to a regulatory framework. The science and technology for accurately collecting and analyzing odor emissions are not fully mature. Even if regulatory limits were set, adequate methods for controlling and measuring odors from biosolids have yet to be demonstrated. In addition, there is still a fair amount of subjectivity in determining levels of nuisance and what is objectionable.

Still, because of the universality of odor generation from biosolids, state and federal agencies have been under pressure to develop odor “standards” for the land application of biosolids. Significant progress has been made controlling odors from biosolids composting operations, and steps have been taken to minimize odors at land application sites themselves, e.g. provide storage if fields are inaccessible, develop adequate buffers, being sensitive to wind direction, incorporating applied biosolids, etc. While these measures help, there has been growing consensus over the past few years that the key to controlling odors at land application sites is to control the odors in the biosolids themselves. And that can only be done effectively at the wastewater treatment plant - the point of generation.

Because many states face similar odor dilemmas, some agencies are supporting research that focuses on creating tools to provide biosolids treatment facilities with standardized methods to index and catalogue odors associated with present treatment processes. In conjunction with these tools, there are several projects investigating techniques aimed at minimizing odors during the treatment process, subsequently reducing odor emissions in the field.

IDENTIFYING THE ISSUES

In November, 1999, the U.S. Environmental Protection Agency sponsored a two-day workshop, "Operations and Design To Control Ultimate Recycling and Disposal Odors of Biosolids," in Potomac, Maryland. The invitation-only workshop was designed to identify research and information needs on how the design and operation of wastewater treatment plants and solids processing impacts the potential for biosolids to produce or not to produce odors at the point of recycling or disposal. The sessions focused on the following issues: Links between wastewater treatment plant (WWTP) management to off-site management; The psychology and politics of odors in the field and in transport; Odor precursors, monitoring and standards; WWTP operations and design practices; Transport and field practice including storage; and Land application contracts.

Participants in each session were asked to define the issues and goals, describe the current knowledge, report on good practices and research needs, and contribute to a bibliography on this subject matter. Workshop organizers emphasized the link between the outcome of the workshop and the National Biosolids Partnership's Environmental Management System (EMS) initiative for biosolids. Part of the EMS implementation process is to identify critical control points within the treatment plant and biosolids management program. States a publication of the workshop: "An important thesis of the workshop is that one important critical control point for odor management is within the wastewater treatment plant. This critical control point for odor at the treatment plant involves issues associated with design and operation and requires close linkages among operations at the treatment plant and the subsequent processing and ultimate recycling or disposal practices."

Giani attended the workshop, anticipat-
is used for all erosion control jobs, has three- to four-inch shredded stump grindings instead of pine bark, as well as some soil and fines. EarthBoost Mulch is a finer version used for topdressing and soil amendment on golf courses and athletic fields, as well as commercial and residential turf.

EROSION CONTROL

The biggest growth sector for Groundscapes is in applying its blended materials for erosion control at development sites and highway right-of-ways. The company is applying its blended materials for erosion control at development sites and highway right-of-ways.

Two people are usually needed on a job. Training and experience increase proficiency at adjusting the feed of material in the airlock system and pushing out the right length of hose. “Material being too wet and having too much in the airlock system are the biggest potential problems,” notes Engwer. “The other problem is making sure the material is clean. With rocks, stumps and big pieces going through, the hoses won’t last long.”

In his experience, typical speed on an open field is nine to ten cy/hour, with a high of 15 cy/hour under optimum conditions. “You’re not using a ten-foot hose; you’re averaging 150 to 200 feet,” he notes. “You’re constantly moving between the truck and everything else. You also have setup time, breakdowns and clogging of hoses.”

Despite the advantages of the application system, Engwer’s marketing focus is on his “compost/mulch” products - mixtures that all include compost and wood or bark. “What I try to push are the benefits of the material that I use,” he explains. “The goal is to show the growth of grasses and plants with compost/mulch instead of traditional bark mulches — less disease, reduced water use, and no need for fertilizer.”

LAWNS AND LARGE PROJECTS

In the company’s first year of compost application, crews invigorated lawns by aerating them in the fall, then put down grass seed by hand and blew compost as a topdressing. The topdressing season runs roughly from August to November. Depending on the thickness of the lawn, an eight to a quarter inch of compost is applied, or one bag for every 1,000 to 1,200 square feet - not a feasible task if done by hand. The method has improved further since that first season through mixing drought-resistant seeds into compost and applying the product by blower truck. When dealing with clay soils, Groundscapes purchases gypsum for about $3/50-lb bag and mixes it into the compost with a loader at an initial rate of one bag/cy. Especially in areas near the ocean, the gypsum helps by neutralizing salts and loosening the soil.

“Some lawns need compost in the spring, but the best way to control weeds is to have a thick lawn,” adds Engwer. “Weeds germinate in bare spots, especially in a season like this, when there’s been a lot of snow followed by drought. The ground wasn’t warm enough for germination, and a lot of weed seeds take off faster than grasses, smothering the grass. If we do the job in fall by automatically aerating and top dressing with compost, we won’t have to apply compost in the spring or use herbicides.”

At an athletic club in Kingston, Massachusetts (far left), mulch with shredded stump grindings is applied to control dust and erosion. A mix of pine bark, coconut shells and screened compost is blown (above) on planting beds at a commercial property.

complete with rain simulation, to establish the superiority of filter berms and develop the best method.

For steep hills, filter berms are blown to measure two to three feet wide and about two feet high, acting as a seed bed, a sponge for runoff and a soil amendment as they break down. "One of the biggest benefits is that they don’t have to be removed like hay bale or silt fence — plus hay bales often have weed seeds that are invasive," explains Engwer. "I’ve also been promoting the fact that creatures like turtles and salamanders can crawl over filter berms." For less steep hills, Groundscapes blows layers of material a few inches deep.

USING BLOWER TRUCKS

Although Groundscapes went through some growing pains with the first generation of blower trucks it purchased, technological improvements have eliminated problems on later models. The company has three Finn blower trucks, one of which is a little more than a year old. "We can use a five-inch hose instead of four inches, which is really good for erosion control and bigger materials," he points out. Blower trucks decrease the volume of material expended because it gets spread uniformly. In addition, the mobility afforded by the hose avoids the compaction that wheelbarrows and vehicles inflict on sites and provides accessibility to steep slopes.

Despite the advantages of the application system, Engwer’s marketing focus is on his “compost/mulch” products — mixtures that all include compost and wood or bark. "What I try to push are the benefits of the material that I use," he explains. "The goal is to show the growth of grasses and plants with compost/mulch instead of traditional bark mulches — less disease, reduced water use, and no need for fertilizer."
ing he would be tapping into some important research findings and field experiences. "What I had expected to find wasn't there," he says. "And I wasn't alone in that discovery. But what did happen at that workshop was that the lack of concrete information set the research tone for what should be happening. We were able to learn what research was being conducted and what needed to be focused on from an operations standpoint. We walked away with questions such as how do we create a standard to measure odors."

**DEVELOPING, TESTING AN ODOR INDEX**

Giani wanted to get the research ball rolling, and connected with Dr. Bradley Striebig of The Applied Research Laboratory at The Pennsylvania State University (Penn State). Striebig already had carried out some research on analytical tools to measure and quantify odors related to the landfilling of biosolids. The PADEP applied to the U.S. EPA Region 3 office for a grant to work with Penn State. The goal of this research is to create a standardized method for odor measurement. Facilities and research scientists can use the method to develop treatment processes and management tools for odor control (including an odor index for a treatment plant).

Funding was received from the EPA Region 3 office; additional funding in 2001 is expected from both Regions 2 and 3. Striebig and Giani are the principal investigators for the project, which runs through December 2002. Phase I, which is near completion, involved developing a standard analysis procedure for collecting and analyzing samples (yielding data to develop an odor index). Phase II, underway now, involves collecting odor samples and applying an odor index at the facility level. The odor index also is being tested for comparison with olfactometry methods that involve a human odor panel that characterizes the intensity of the odor. Ned Ostojic from Odor Science & Engineering, Inc., with the support of Synagro, Inc., will be studying these comparisons.

A key goal of the PADEP/Penn State research is to create a tool to compare processes within a WWTP — from the sewer pipes and influent end through to solids processing — and between WWTPs with similar technologies. "The odor index is related to a specific sample," explains Striebig. "It involves coming up with one number at one point in time that is fairly representative of an odor so that the sample can be catalogued and compared to other samples as the data comes in from the facilities taking measurements. The process we utilize is to collect an air sample in a container and draw the air into a chemical analysis system that concentrates and separates the chemicals for identification. The purpose of our tool is to help define the chemistry and chemical complexity of the odor, then the WWTP can identify the odors that are most problematic and specifically address processes to minimize their problem. At this point, I view the odor index as a visualization tool. It's not accurate enough to say this number will cause a complaint and this number will not. However, if we can tie those numbers to olfactometry information, then the process can be standardized." (See sidebar.)

Chris Peot, biosolids manager for the District of Columbia Washington Area Sanitary Authority (DCWASA), has tested the odor index and provided data to the PADEP and Penn State. "Putting the psychological/olfactometry together with the analytical will let us know if we will be improving odors," says Peot.

The general methodology developed in

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The key to controlling odors at land application sites is to control odors in the biosolids at the treatment plant.
Phase I will be included in a report that Striebig expects to submit to the PADEP by the end of 2001. In the meantime, Giani and Striebig and several graduate students are taking measurements at different WWTPs within EPA Regions 2 and 3 and feeding that into a data base. They only are sampling at facilities managing biosolids through beneficial use practices as the overall goal is to address complaints that come in from the field. "We are looking at what we can do to this product before it leaves the WWTP to go out into the field," says Giani. "How can we make it the best it can be before it leaves the gates, because if it's odorous at the WWTP, it most likely will be odorous at the land application site."

**ODOR SAMPLING**

Because of limited funding resources, sampling is being narrowed to specific plants. Facilities are identified through the EPA regional offices and the state biosolids coordinators. Facilities are then chosen based on specific types of biosolids treatments and intensities of odors emitted (or not emitted) from their final product. "We ask them to give us plants with and without odor problems," he adds. "Then we will pick out three or four on that list and work with the states to decide where to go. Facilities that are not selected, or that are not in EPA Regions 2 and 3, are encouraged to participate in the project if they are interested. These particular plants may need to find ways to raise their own funds or solicit their particular state or EPA region to help provide funding."

Air, liquid and/or solids samples are taken from the wastewater solids treatment train, usually starting with the thickeners and through every subsequent process (including composting if done at the same site). Interviews also are done with the operators to obtain an understanding of the entire WWTP operations and water quality data (i.e., percent solids, BOD, pH, total suspended solids, etc.). Samples are brought to the Applied Research Lab at Penn State within 24 hours for analysis. "We analyze the samples for a wide variety of odors including sulfur-based compounds, nitrogen-based compounds and organic acids," says Striebig. "Because we are trying to do all of these, the limits for detection are not as good as if we were focusing on only one constituent. We do a general analysis and try to determine concentrations and then compare those to referenced odor thresholds in the literature. That gives us the odor index value over a range of samples — a value associated with a sample so it can be tracked from the holding tank for wastewater solids to the digester and any further handling."

The goal is to get as many WWTPs as possible feeding into the data base, especially plants that are using the same treatment technologies but are having different experiences in terms of odors. "If one has an odorous product and the other does not, we

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**STANDARDIZING IDENTIFICATION OF ODORANTS**

R. BRADLEY STRIEBIG of the Applied Research Laboratory at Penn State University and Richard Giani of the Division of Wastewater Management at the Pennsylvania Department of Environmental Protection presented two papers that provide excellent background on development of a standard process to analyze odors. Both papers had the title: "Critical Review of Odor Regulations And Shortcomings for Implementation in Biosolids Management." Part 1, "Overview of Regulatory Approaches To Odor Control," was presented at a special conference, "Odors and VOC Emissions 2000," organized by the Water Environment Federation. Part 2, "An Odor Index for Management Decisions," was presented at a meeting of the Air and Water Management Association. The following is excerpted from those papers:

"Odors associated with biosolids are complex due to the variety of odorants emitted from the materials and the wide variety of stabilization processes. Due to the complexity of odor emissions in biosolids, pathways for effective odor control cannot rely specifically on a set national, state or local regulatory standard. Instead, odor control should be structured within a management plan on the facility level. Good management practices and a combination of odor analysis techniques should be used in determining site-specific odor control levels within each community. A successful odor control policy should implement appropriate controls based upon location and community concerns."

Management plans should consider:

- Identifying the physical and chemical constituents which cause odorous emissions;
- Determining the best method for monitoring these constituents; and
- Reducing odor intensities to acceptable levels. A combination of analysis methods may help identify acceptable odor management practices for different types of situations. Proposed plans should incorporate the two fundamental issues of odors — chemical concentration and olfactory response — in order to be useful in the field of odor management.

European countries enacted guidelines for odors in the mid 1980s. A European odor standard was developed by the European de Normalisation (CEN). The proposed standard, "pREN 13725: Air Quality Determination of Odour Concentration by Dynamic Olfactometry," was under review until January, 2000. This rule sets stringent criteria for repeatability, reproducibility and accuracy of odor units based upon an n-butanol reference standard (1 oz/m³ = 40 ppb, n-butanol). This method, based upon dilution ratios, will be used to implement odor abatement policies within the European Union. These standardizations have improved the reliability of olfactometry methods. Several states and countries have adopted olfactometry methods to define and regulate odorous emissions. However, the dilution method used as the sole basis for odor control has several shortcomings. First, odor control regulations based solely on dilution factors do not adequately address the chemistry of the odor problem. A more effective measurement technique would yield information about the chemical
can get an odor index for both, break down the compounds and compare the concentrations," says Giani. "The next step is to backtrack using various parameters, e.g., water quality, chemicals added and in what concentration, storage time at various points in the process, and try to pinpoint the differences and hopefully the cause of the odors. Basically, we will have a stack of data for each plant, and the idea is to enter it into a data base and analyze the difference because we know, odor index wise, that there is a difference. The goal is to identify the difference and relay that information to the plant, where in turn, the operator can focus troubleshooting efforts. There are facilities that know they are having problems with odors, but don’t know how to start to address the situation. Conducting on-site sampling and developing an odor index gets them started down the road to a solution.”

As the sampling is done, the researchers will start to identify what are the most important measurements to take and what interferences there may be. The key is to get to a point where the methodology is acceptable for a wide variety of applications and odors.

Striebig emphasizes that the PADEP/Penn State project does not involve development of new analytical techniques, but instead is based on the idea of communication and agreeing upon a method to evaluate the data. “The analytical technology isn’t cutting edge but communication and coordination is allowing us to provide a useful tool. If we were doing this in a vacuum, for example, just giving the method to the DEP and only Pennsylvania WWTPs used it, we couldn’t compare how well it worked. The communication and sharing aspects are inherent in the obligations of our contract.” Facilities have to make a commitment to share the data gathered in return for receiving information from other WWTPs.

Eventually, there will be enough data available to identify patterns that lead to odor production or which minimize odors. “If we do enough systems, we expect to see patterns repeating, especially if a facility makes a change and that gets measured in the odor index,” says Giani. “We will have the information captured and it can be shared.”

While it isn’t a requirement, Striebig recommends that a WWTP do a preliminary assessment and sampling of odor sources to develop a baseline for odors associated with their products. That assessment should be done with fairly sophisticated analytical equipment and analyzed in a laboratory. “Once that is done, operators will know what specific compounds are most likely to cause a problem,” he says. “Then they can focus on testing for that particular chemical, which is more cost-effective.”

**ODOR RESEARCH GROUP**

Through contacts made at the EPA odor workshop in 1999 as well as through other avenues, Giani and Striebig became familiar with other research initiatives that di-

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**The researchers hope to get as many WWTPs as possible feeding into the data base, especially plants that are using the same treatment technologies.**
Eventually, there will be enough data available to identify patterns that lead to odor production or which minimize odors.

**FUNCTIONAL RESEARCH**

The Blue Plains Pollution Control Facility (Blue Plains) in Washington, D.C. produces over 1,200 wet tons/day of lime stabilized biosolids. Improperly handled, mixed and/or stored lime stabilized biosolids have the potential to create odor problems. The majority of the biosolids generated at Blue Plains are land applied on farms in Virginia. To maintain a viable land application program, the District of Columbia Water and Sewer Authority (DCWASA), which operates the wastewater treatment plant, embarked on odor research to identify and determine the mechanisms of odor generation from lime-stabilized biosolids. This work is helping Blue Plains predict and prevent the generation of odorous biosolids.

Studies completed to date include:
- Evaluation of odors from lime stabilized biosolids.
- Investigation of compounds and mechanisms for odor generation.
- Evaluation of relationship between lime dose and odors.
- Evaluation of lime stabilization odor from poor lime incorporation.
- Evaluation of impact of polymer conditioners on odors.

Investigation of the impact of upstream conditions (thickening and storage) on biosolids odors, and impact of storage on odor generation.

Chris Peot, DCWASA’s biosolids manager, and some of the agency’s consultants (Dr. Sudhir Murthy, CH2M Hill) and contracted university researchers (U.S. Department of Agriculture, University of Maryland, Virginia Tech) are part of the odor control research group described in the accompanying article. Some of the experiments grew out of or were modified based on information shared at the group’s meetings. “I view what we are doing at Blue Plains as ‘functional research,’” explains Peot. “We have a very limited amount of money for research and we try to maximize those dollars. We could have spent the whole budget on one concentrated, replicate study. Instead, we have opted to take the research and use it right away in small tests. We recognize that not all of our results are peer-reviewable or publishable, but they are giving us incredible insights and have led to some process changes.

We are beginning to understand how the product quality varies based on the treatment plant process parameters.”

Ultimately, Peot would like to take the concept of the odor index being developed by Brad Striebig at Penn State and develop a product index to determine—on an odor basis—how biosolids are for that day. “We would take a sample and assign a number from one to ten, with one being good,” he says. “At the same time, we would have a site index, ranking the application sites on a one to ten basis, with one being a site in a more densely populated area and ten being a remote site. Contractors would let us know what sites they are using, and if the product index doesn’t match the site index, those loads would be directed to a landfill. This won’t be a foolproof system, but right now, we don’t know if we have an odorous product until the biosolids are land applied. With a product index, we can give contractors some knowledge about the material before application.”

For the product index, Peot is interested in three compounds—trimethylamines
implementation. Each project adds an important piece to the odor generation and management puzzle, and maximizes the research dollars being invested.

The overall goals of the group are to: Gain a better understanding of the compounds responsible for odors in biosolids; Understand the conditions at the plant that promote production of these compounds; Evaluate the mechanisms responsible for generating these compounds; and Determine the critical control points in the treatment process and the process parameters that can be monitored to help predict and prevent nuisance odors. It was decided that in order to compare sampling data collected from the various research experiments, that everyone should be using the same types of methodology. Methodologies like those being developed by Penn State are being utilized by the research group.

One of the concerns about involving EPA and state regulatory personnel in the group was the perception that the goal was to work toward regulatory limits for odor emissions. "The science really isn’t there to regulate odors," notes Peot. "But in the process of getting various states involved with sampling at WWTPs, biosolids coordinators and regulators are seeing what is going on at plants and learning along with everyone else. They are seeing that the outcome of this process shouldn’t be a regulation."

The group also has managed to sidestep the competitiveness and intellectual property issues often associated with research. "What we have at universities, companies and government agencies involved and what it all came down to is there is a lot of work to be done," adds Giani. "To get a complete study done, the reality is that we should be working together, which has helped in getting around the standard competitiveness of research." Adds Peot: "Naturally, people like to protect interests and intellectual property, but everyone has been very open."

The odor research group will consider other research proposals from WWTPs or a group of WWTPs if the financing is available to support the work. "The more facilities that come on board, the more situations we can look at and learn from," says Giani. "In turn, facilities can take advantage of various expertise and benefit from the focus of the whole group."

Most projects’ results will be published individually over the next two years. At the end of 2002, the group hopes to provide a compilation of all the research conducted into a manual that can be used as a management tool for facility managers, design engineers and government agencies to control and optimize odors emitted from biosolids products.

For more information, contact Richard Giani, Pennsylvania Department of Environmental Protection, Division of Wastewater Management, rgiani@state.pa.us.

(TMA), ammonia and total reduced sulfur (TRS). "If we could get a fast, accurate reading of those three, we would have a go-to number," he notes. "That is the direction we are heading and we will need analytical equipment that can give us a fairly quick reading on a sample taken." In DCWASA’s most recent contract with the three land application companies it uses, language was added that says if DCWASA directs the contractor to take the biosolids to the landfill, they must take it there and DCWASA will pay the difference between what it costs to land apply versus landfill.

He credits DCWASA’s involvement with the National Biosolids Partnership’s (NBP) Environmental Management System initiative as being the spark to the functional research approach being used and how to apply what is learned directly into improving the land application program. Blue Plains is one of 27 wastewater treatment agencies developing an EMS as part of the NBP’s demonstration program. One of the first steps is to do a “gap analysis” of current management methods and biosolids practices to identify gaps or vulnerabilities in the system. "In the gap analysis, one of the first things we had to do was look at critical control points in the wastewater treatment system and biosolids management program that could affect biosolids in a negative way," says Peot. "Much of what we found in the analysis pointed to areas and control points that contribute to, or impact, odor generation. The EMS development process has provided an excellent framework to conduct the functional odor research because we can see the beneficial effects at the critical control points."

Some of the research results at Blue Plains include: The optimum lime dose required to reduce odors is affected by blending and proper incorporation of lime into the biosolids. Attaining a pH of 12 using currently recommended methods is a poor indicator of optimum lime dose; Addition of lime to sludge appears to be a catalyst for TMA production, as none was detected prior to lime addition; Higher lime doses do not increase the odors generated meaning that the amount of lime added (15%) is not a limiting criteria for TMA production; Mercaptan concentration is typically very low in lime-stabilized biosolids that are properly mixed and stabilized; Polymer dosing research found that cationic polymers used for conditioning in centrifuges break down and produce aminated odors after liming; Dimethyldisulfide (DMDS) is the main reduced sulfur constituent in Blue Plains lime-stabilized biosolids (contributing as much as 70 percent of TRS compounds); and if the sludge is odorous prior to stabilization (such as from back-ups during processing), it will remain odorous after stabilization and the biosolids will contain odorous reduced sulfur compounds or volatile fatty acids generated in upstream processes.

Expanding on several of the findings listed above, Peot notes that dosing with lime to 15 percent on a dry weight basis to meet pH would meet regulatory standards but still can create odorous product, depending upon the quality of the mix. "We did experiments and dosed at different amounts, and now we have a policy to lime to 25 percent on a dry weight basis. We find that controls odors a lot better. In addition, research showed that when digested biosolids were blended with lime, TMA’s were released; conversely, when lime is added to undigested biosolids, TMA generation is much less. "As a result, we stopped doing lime doses with digested biosolids," says Peot. "In fact, we have quit running the digesters all together.” New digesters are being built.