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Waste Prevention, Recycling, and Management
by David Minott

In this month’s waste-themed issue, readers are first brought up to speed on a major crisis disrupting recycling efforts throughout the United States and Canada. Then, we explore newly emerging concerns over risks to air quality and ground water from landfill operations, and how to address those risks.

The Precarious State of Recycling as China Closes its Doors to Imports
by Susan Robinson

The Changing Dynamics for Recycling in the United States
by Marc Rogoff, Jeremy Morris, and Bill Gaffigan

Siloxanes in the Waste Stream—Environmental and Financial Impacts
by Matthew Estabrooks and Stephen Zemba

Landfills—Be Aware of Emerging Contaminants!
by Stephen Zemba, Russell Abell, and Harrison Roakes

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Columns
PM File: Multiplying Consulting Firm Success
by David Elam

A look at how environmental consulting firms develop billing rates for project staff using direct and indirect costs.

Regulatory Roundup: Proposed Changes to ‘Co-Benefits,’ ‘Ambient Air,’ and ‘Once In, Always In’
by William Haak

A summary of recent policy changes with potentially far-reaching impacts on the way EPA regulates the pollutant emissions under the U.S. Clean Air Act.

Departments
Message from the President:
Spotlight on Waste
by Michele E. Gehring, P.E.

Back In Time: March 2009
A look back at this month 10 years ago in EM Magazine.

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How is March already upon us? As we head into the final month of the first quarter, our Association volunteers and staff have been busy. We’ve now ticked off our first specialty conference of the year, with a new and timely program on wildfires held last month. I was lucky enough to join members and non-members alike at the two-day program in Santa Rosa, CA, and was quite impressed with the truly encompassing look that the program provided into both air quality and public health concerns arising from wildfires. For those of you who were not able to join us or want further information on the topic, stay tuned for more offerings on this issue.

In addition to the wildfires specialty conference, we’re also busy putting the final touches on the upcoming Air Quality Modeling and Measurements conferences that are scheduled for this month and next, as well as on our annual Leadership Training Academy (LTA) in Pittsburgh. If you have never been able to participate in LTA, you’re missing out. We not only delve into the workings of the Association, but we also tackle difficult management issues such as working with multiple generations and dealing with different personalities in the work place (or on your volunteer board). I look forward to meeting many of the new section and chapter leaders at LTA in April.

Shifting focus from ongoing programing to the content of this month’s EM, we find another topic that is near and dear to my heart. This month’s issue focuses on waste management and many moons ago, waste is where I found my first home in the environmental world. After graduating with an engineering degree from the University of Maryland and determined to focus on soil and water applications, I found myself working for a small engineering firm outside of Nashville that focused on the handling and thermal treatment of hazardous waste streams. (The how of all that happened is a bit of a long story and one that I’ll happily share with any of you during one of our networking events.) I quickly became highly specialized in the waste management industry, spending those first few years learning the ins and outs of the Resource Conservation and Recovery Act (RCRA). Despite regulatory programs driving the waste management industry into the air world, hazardous waste and the management and treatment of it still represents a large part of my day job. Nothing like a career in waste combustion to meld the two facets of our Association.

One of my goals over this next year is to help bring more waste-centered programming to our repertoire. Look for additional waste features in May and June also.

In the hazardous waste world, we talk about cradle-to-grave management of hazardous wastes, with RCRA focusing on management of the waste stream from the very minute it is “born” to the moment it is destroyed or disposed. That term “cradle-to-grave” management makes me think of the way the Association strives to serve our members—not perhaps from cradle to grave, but rather from the beginning of their career through retirement. Our student and young professional programs reach out to the environmental professional before they even start their career, engaging students with programs like career night events and offering mentoring opportunities. We also serve as a resource for our young professional (YP) members from the first day on the job through their early adventures into project and personnel management. As someone who preceded the YP program, I can confidently say the Association and our early career programs have provided so much opportunity to students and YPs and have provided an immeasurable return on investment to the Association.

Once members “age out” of the YP segment, A&WMA continues to be there, providing technical content to enrich our professional knowledgebase and offering networking opportunities to drive sales and client development. And then there are our Emeritus members—those who have served the industry so well for so many years and opt to continue to participate in the Association and foster the next round of environmental professionals long after they themselves have reached the traditional retirement age. At LTA, we have a session on promoting generational synergy and so often, we hear the senior members characterized as a group that has so much knowledge to share with our younger members and a determined readiness to do so. These Alpha-to-Omega member engagement opportunities make our Association stronger and I believe help us stand out from competing organizations.

There I go again, bending your ear on Association happenings and benefits, back to the topic at hand—waste management. As you page through this month’s issue of EM, I challenge those of you who work in the waste industry to think about how we can strengthen our offerings in that arena. Is there a specific topic we should be tackling through a webinar or a specialty conference on waste that would bring member value? Where would a revitalized focus help you most? For those of you who work in the air world, is there a waste topic that you need to know more about or one that you see as a bridge between the two worlds? Send me an email and let’s find time to chat!
In this month’s waste-themed issue, readers are first brought up to speed on a major crisis disrupting recycling efforts throughout the United States and Canada. Then, we explore newly emerging concerns over risks to air quality and ground water from landfill operations, and how to address those risks.
Perhaps you’ve heard the rumblings over the past year or so of the turmoil that is disrupting recycling programs throughout the United States and Canada. Unfortunately, the reports of upheaval are not exaggerated. Until last year, China was the main purchaser of many of the recycled materials collected in the developed world, especially recyclable paper and plastics. However, China abruptly stopped accepting this recyclable material last year. This, in many cases, has left our recycling programs without a viable purchase market, creating an existential threat to those programs.

The first two articles in this issue further explain the nature of the threat, then address what can be done to adapt. In the first article, Susan Robinson explains the basics of the Chinese import ban, its effects on recycling programs worldwide and locally, and addresses adaptive measures that can be implemented to ensure that recycling remains vibrant in the long term.

Next, Marc Rogoff, Jeremy Morris, and Bill Gaffigan relate further details of the Chinese import ban and its impacts, specifically on U.S. recycling programs, then suggest a variety of adaptive measures—technical, economic, and policy.

Switching our focus slightly, the following three articles address emerging concerns with emissions to the air and potentially to groundwater from landfill operations. In their article, Matthew Estabrooks and Stephen Zemba describe the negative effects of siloxanes—a silica compound—present in landfill gas in degrading the performance of landfill-gas-to-energy engines at landfills, and causing problems with emission levels of formaldehyde and other pollutants.

Using landfill gas beneficially as a fuel to generate energy at landfills is a sustainable, carbon-reducing practice; however, it also results in some emission to the air of the carcinogen, formaldehyde. Heather Little and Stephen Zemba demonstrate how a site-specific health risk assessment of the formaldehyde impacts can be used as an alternate method for compliance demonstration, specifically at those landfills where the conventional approach shows ambient formaldehyde limits would be exceeded.

The final article this month, by Stephen Zemba, Russell Abell, and Harrison Roakes, acquaints us with pollutants of emerging concern that are present specifically in landfill leachate. This is important because leachate contaminants can ultimately contaminate drinking water supplies, and new requirements to control these pollutants will impose further cost and legal burdens on landfill owners.

EM readers are invited to explore this waste-themed issue and get updated on important new developments in waste recycling and modern landfill management. em

David H. Minott, QEP, CCM, is President of Arc5 Environmental Consulting LLC. He also serves on the A&WMA Technical Council and is a member of EM’s Editorial Advisory Committee. E-mail: david.minott@arc5enviro.com.

Special Spotlight on Waste Management...

Following on from the overarching theme of this issue, look for an additional focus on waste management in both May and June, with planned articles that will consider landfill leachate problems, zero waste as an achievable goal, food waste challenges and opportunities, and waste-to-biofuels conversion in Canada.
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For the past year, recyclers across the globe have grappled with the evolution of their industry in response to one country’s sweeping policy changes. Almost overnight, China’s announcement of an impending series of import bans triggered lasting changes in one of the oldest industries in the world.
It's hard to overstate the importance of the impact of China's recycling policies on global commodity markets. For the past decade, about a third of all the paper collected for recycling in the United States, and most of the recyclable plastic from the West Coast, has been exported to China for recycling. Further, China was the recipient of over half of the world's mixed paper and mixed plastic collected for recycling. With the 2017 announcement that China would no longer accept these materials, recyclers from the United States—and across the globe—had to scramble to find alternative markets for over 43 million tons of material (see Figure 1).

A bit of history is important for context. Although we've been recycling for centuries, communities across the United States only began implementing curbside recycling collection programs for paper, bottles, and cans in the late 1980s and 1990s. The growth of these programs resulted in large increases in the volume of recyclables looking for end markets. This growth in collection of recyclable commodities coincided with a growing economy in resource-poor China. Chinese manufactures were desperate for materials to use to manufacture products and packages. Their products were mostly exported, further fueling the growth of their economy, which in turn compounded the need for recycled feedstock.

Fast forward to 2016, and recyclables shipped to China were the largest export item from the United States by weight (see Figure 2).

**Economic Growth versus the Environment**

We've all seen the photos of air pollution in China. In July 2017, with the long-term welfare of his country in mind, President Xi Jinping announced a suite of environmental goals for his country, including reducing air pollution, cleaning up the country's waterways, and improving the quality of farmland. He also created a goal to become self-sustaining in recycling by 2020.

These goals set in motion the policies now impacting recycling programs in the United States. The policies announced by China in 2017 and 2018 (see Figure 3) effectively eliminated the world's largest market for mixed paper and mixed plastics, forcing recyclers from around the globe to find new homes for over 43 million tons of materials; 13 million tons from the United States alone.

This has created a global oversupply of materials that is affecting recycling programs in communities across North America. Paper and plastic that were previously shipped to China are now competing for limited markets in the United States and other countries across the globe.
Benefits of Recycling

Recycling benefits the environment when recycled material offsets the use of virgin materials. Nonrecyclable material in the recycling cart is contamination, which requires additional collection and processing efforts, with added costs and environmental impacts.

The Local Impact of China’s Policies

Communities throughout the United States are seeing the impact of China’s policy changes at the local level. The changes are increasing communities’ recycling costs, and thus forcing cities to make difficult decisions about their programs. Should paper, plastics, or glass be eliminated from recycling programs to help keep costs down? What about materials that no longer have a market? Should we continue to collect these items even without markets in order to sustain existing recycling habits, or should we tell residents to put those previously-recycled materials in the trash? And how can we educate consumers on these changes and what they must do differently now to recycle correctly?

As communities grapple with these challenges, their response has been varied. In some places, material has been dropped from programs, and some cities are even curtailing their programs altogether. And there is no quick fix in sight.

Addressing the Challenges

Contamination includes non-recyclable materials mixed in with recyclables. Reducing non-recyclables in curbside programs is an area of focus for all recyclers as they work to curb the costly contamination that burdens our nation’s recycling programs. There is a direct connection between the

Figure 2. Top 100 U.S. exports in 2017.

Source: JCC.com
quality of materials collected for recycling and the quality of material sold to end markets. Unfortunately, materials collected for recycling in curbside recycling programs today and processed at materials recovery facilities (MRFs) contain on average almost 25-percent contamination. In other words, one-in-four items collected are not recyclable.

Improving the quality of recyclables collected is essential to assuring that they can in fact be recycled. This will take time and a concerted effort. Recycling education is the foundation for assuring consumers will recycle right.

Data supports using simple methods for changing recycling behavior. Research indicates that approximately 80 percent of consumers will make the effort to recycle right. These consumers appreciate recycling education and reminders or prompts to do so. For the 20 percent who do not respond to education prompts, enforcement is the next step. Consequences for recycling wrong, such as placing tags on carts noting contamination and even rejecting contaminated bins, can encourage the right behavior. This will not be a one-time fix. Research shows us that people need to be exposed to messages about how to recycle correctly multiple times and via multiple channels, and with periodic, follow-up reminders.

At Waste Management (WM), we are focusing on the basics of good recycling. For starters, we are simplifying the recycling message focusing on recycling paper, cardboard, cans and bottles. WM’s Recycle Often. Recycle Right. (https://recycleoftenrecycleright.com) education and outreach program provides tools for helping residents know how to recycle correctly. If we can educate consumers to recycle these basic commodities well enough to meet end user standards, we can go a long way toward putting recycling on a healthy footing.

The Path Ahead

For the past several decades, our collective efforts focused on growing the volume of material we collected for recycling. We’ve done everything we can to collect more—focusing on quantity—but we lost sight of the importance of recycling correctly. We’ve sent the message to consumers that we want everything. Unfortunately, we are receiving a wide range of items in curbside programs that are not recyclable, from bowling balls to garden hoses to engine blocks.

The success of recycling programs has been evaluated historically by the number of tons collected, based on the assumption that the more materials diverted from landfills, the better it was for the environment. We forgot the true goal: recycling benefits the environment when recyclables offset the use of virgin, raw materials, conserving resources, water, energy, and emissions. When we collect material that does not offset the use of virgin materials, we create negative environmental impacts and higher economic costs by processing materials that nevertheless end up disposed.

The bright side of our current recycling crisis is that it has refocused our priorities on the environmental benefits associated with recycling. Recyclers and their customers are now looking at the science associated with

Figure 3. China’s Environmental Challenge.
The Precarious State of Recycling

by Susan Robinson

which materials benefit the environment the most when recycled, and they are making program decisions based on this data.

Importantly, states are leading the way on this journey. They are beginning to shift their focus from aspirational weight-based recycling goals to realistic, material-specific goals that emphasize waste and emissions reduction principles. This shifts our attention to fundamental environmental goals, recognizing that recycling is not the goal itself; rather, it is a tool to achieve a cleaner, less wasteful environment.

As in many things in life, we see potential long-term benefits to be realized from our current recycling crisis. We’ve had to remind ourselves of why recycling matters, and how vitally important it is do what’s necessary to recycle the right things, for maximum environmental benefit, and thereby invest in sustainable recycling programs for the future.

Susan Robinson is Senior Public Affairs Director for Waste Management Inc. E-mail: srobinson@wm.com.

China’s Policies—Timeline

• July 2017—In response to aggressive new environmental goals, China announced to the World Trade Organization (WTO) they would ban 24 materials from entering their country, including mixed paper and mixed plastics.

• January 1, 2018—China’s ban of mixed paper and mixed plastics became effective.

• March 1, 2018—China began enforcing a new 0.5-percent contamination limit on imported recyclables.

• May 2018—China announced their plan to ban all imports of recyclable by 2020.

Guideline on Air Quality Models: Planning Ahead

March 19-21, 2019 Durham, North Carolina

Get the latest information and solutions on the implementation of the Appendix W promulgation and other issues related to the Guideline on Air Quality Models.

With the U.S. EPA’s 12th Conference on Air Quality Models expected to be held later in 2019, this is the perfect opportunity for air quality modelers to share their research, experience and thoughts on the state of air quality modeling science, assessment of current regulatory requirements and recommendations for enhancements and new developments needed to meet future regulatory air modeling needs and requirements.

The Town Hall Meeting will cover the future of regulatory atmospheric modeling. Invited presenters include:

• Tyler Fox, Group Leader, Air Modeling Group, U.S. EPA

• James W. Boylan, Ph.D, Manager, Planning & Support Program, Georgia Department of Natural Resources

• Ryan A. Gesser, CCM, Georgia-Pacific Environmental Affairs

• Rick Gillam, U.S. EPA Region 4

• Tim Allen, Federal Land Manager, U.S. Fish & Wildlife Service

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Thank you to our sponsors:
U.S. residential recycling programs with curbside collection have been in place for the better part of three decades. However, much of the collected material was exported to China. Over the past year, China has restructured its policies toward recyclable material imports. What are the impacts of China’s new policies on U.S. residential recycling?
For years, one of the most visible ways that Americans actively contributed to environmental sustainability and resource conservation has been through recycling materials such as paper, cardboard, plastics, and metal. Residential recycling programs with curbside collection have been in place for the better part of three decades. Throughout this time, recycling markets have seen many normal cyclical ups and downs. However, much of this material has been exported to China where it has been used as raw material to make new products. In recent years, China has been the single largest worldwide importer of post-consumer recyclables, consuming more than 50% of the world’s recycled paper and plastic and almost 30% of all recyclables collected in the United States.

**What Has Happened?**

Most dual- or multi-stream recycling programs, in which households separate recyclables into different bins prior to curbside collection, have been replaced with more convenient single-stream programs, in which all recyclables are collected in one bin or cart. Typically, single-stream loads are delivered to a materials recovery facility (MRF) for automated sorting. One of the challenges for reusing recycled material is the need to manage contamination. Examples of contamination include such waste residue such as liquid dregs in bottles, food stuck to cardboard packaging, and broken-glass shards mixed in with recyclable paper. Contamination is much harder to control with single-stream collection. In some cases, 10–20% of the weight of recyclables being shipped to China was contamination (usable waste that had to be removed).

In July 2017, China notified the World Trade Organization that effective January 2018 it would ban imports of some recycled materials, including mixed paper and most plastics. In March 2018, China went further and implemented a strict new policy limiting contamination levels to 0.5%, a near-impossible limit for most single-stream recycling programs. To ensure compliance, Chinese customs have implemented the Blue Sky 2018 program to inspect every container entering any Chinese port and reject and return all containers with more than 0.5% contamination. As a result, inspections are now meticulous at the point of delivery in China.

**What Are the Impacts of China’s New Policies on U.S. Recycling?**

The loss of the Chinese market has disrupted an entire global commodity industry, throwing the global recycling industry into turmoil as commodity recyclables prices crashed. U.S. exports of mixed paper to China fell by 95% in 2018. Only half of materials formerly shipped to China have found alternative end markets. This has reduced revenues as some materials must be sold at significantly lower prices, sometimes even at a loss. Some material cannot be sold even at a loss and must be redirected to waste-to-energy facilities or landfills. As a result, recycling revenues are significantly depressed.

Figure 1 shows that the national average price paid for a ton of mixed paper dropped precipitously from late 2016 to March 2018, when the Blue Sky program took effect. The

![Figure 1. Price impacts of Chinese import policy change on U.S. recyclables markets.](Source: RecyclingMarkets.net, 2018.)
The Changing Dynamics for Recycling by Marc Rogoff, Jeremy Morris, and Bill Gaffigan

Impacts of the import ban first appeared in the Pacific Northwest and Alaska, with several solid waste agencies requesting exemptions from state recycling mandates and landfill bans. During the first quarter of 2018, landfilling of recyclables also began in California. Some agencies like Sacramento County have reported that they will be expending much more effort on education and contamination enforcement. The new market realities have severely impacted the county’s recycling budget, with recycled commodities switching from about US$1.2 million in annual revenue to US$1.1 million in expenses. There are reports from several northeastern and mid-Atlantic states of “orphaned” stockpiles of recyclables. Will China eventually relax their standards and reopen their market for imports? Although no one can predict what China will do, signs indicate that the events of the past year represent a paradigm shift regarding how recyclables will be managed going forward. The China Council for International Cooperation on Environment and Development (CCICED) recently released a paper stating that a further stop to material imports will be in place by 2019. China’s government is justifiably concerned about their environment, and has given clear signals of their intent to eliminate the importation of contaminated waste for the sake of raw materials. This suggests that China’s recycling restrictions are here to stay.

Figure 2. Total value of U.S. waste and scrap exports, 2018.

Dynamics for Recycling
The traditional form of curbside residential recycling may no longer make real economic sense for many locales, unless user fees and customer rates are increased to enable the providers of these recycling services to recover their real costs. As an example, many MRF processors are now charging waste haulers and communities US$50 per ton or more to process recyclables, when they once paid them for these materials. There are two major issues that need to be addressed for any solution to this problem.

First is the issue of contamination. Prior to single-stream recycling, curbside customers with the traditional “blue box” were constrained by the size of the container to place all their recyclable materials into that small box—newspapers, cardboard boxes, plastic bottles, aluminum and ferrous cans, plastic bags, and junk mail. This discouraged filling the
limited volume with non-recyclable materials and materials of questionable recyclability. There was also a secondary check on contamination at the curbside with the hauler eyeballing the materials and leaving behind those materials not considered recyclable.

As most communities began to implement single-stream recycling during the last decade, customers were given large (64- or 96-gallon), lidded rolling carts for recyclables. Worse, many communities were given the impression that recycling was free while trash collection cost money. Accordingly, the customer was now incentivized to place all potentially recyclable material in the large recycling cart, rather than placing items of questionable recyclability in the trash can. As a result, MRFs have seen items such as strings of Christmas lights, car mufflers, plastic bags, bowling balls, dirty pizza boxes, and dirty diapers, none of which should be sent to these facilities. Consequently, contamination rates have skyrocketed upwards to 30% or more. This contamination results in complex and costly problems for MRF operators who oftentimes are unable to fully eliminate contamination from processed bales of materials sent to markets. Conveyors get jammed or must be slowed down, and additional human sorters must be added to help cull out these materials. All of this increases processing costs, while also lowering the ultimate prices received from the markets.

Second is the issue of the international market for U.S. recyclables. The Chinese market has now disappeared as the authorities there no longer accept their country being the dumping ground for other’s trash. This is part of an overall strategic plan to improve environmental quality in China for a rapidly growing and demanding middle class. As Chinese purchase-markets crashed in 2018, U.S. recyclers turned to other markets such as India, Indonesia, Malaysia, Turkey, and Vietnam as temporary fixes, flooding those markets. These nations, unable to meet processing demand, have either imposed bans or closed their markets, and prices have continued their downward spiral.

In summary, our recycling industry is facing an unprecedented turn of events as a result of policy changes halfway across the world. These changes are not the traditional commodity cycles that we have seen for recyclables. It is a commonly held opinion by most observers that the Chinese ban is not going away—indeed, some in the recycling industry have opined that China appears to be on a path to eliminate imports of all post-consumer recyclables by 2021. Current trade tensions between China and the United States are making this into a political issue as well.
Possible Solutions
Recyclers are adapting as quickly as they can, but there is no expectation of a return to the old status quo. Over time, help must come from the public in the form of cleaner materials; from regulators by allowing variances from recycling goals; and from municipalities by working with their recyclers to understand the options for retaining sustainable programs for the short and longer term. All this and more will be necessary to ensure the future of recycling as a key community service. In the interim, solid waste agencies will be forced to take steps at the local level to mitigate the current recyclables markets conditions.

State and Federal Support
At the U.S. state and federal levels, several concrete policy changes will need to be implemented to support recycling.

Change in Tax Policies
Currently, the Federal Tax Code provides significant financial advantages to manufacturers of virgin materials through investment tax credits, advanced depreciation write-offs and the like. These reduce the price of virgin materials. Changes in tax policy should be examined to “level the playing field” for recycled materials.

Extended Producer Responsibility
Extended producer responsibility (EPR) is a strategy designed to promote the integration of lifecycle disposal/recycling and other environmental costs in the market price of a product. EPR is based upon the principle that because producers (usually brand owners) have the greatest control over product design and packaging, they have the greatest ability and responsibility to reduce toxicity and waste. British Columbia has piloted a novel EPR program in recent years that has transferred the cost of recycling programs from local government to manufacturers and their trade associations (of course, the consumer of the manufactured goods ultimately pays the recycling costs under EPR). Perhaps in the United States, tax credits could be used as a means to encourage companies to adopt EPR.

Infrastructure Investment Program
SWANA and other solid waste organizations have argued that solid waste should be included in a comprehensive national infrastructure program. There are plans to include solid waste and recycling in a plan to improve public works funding and infrastructure development.

A Larger Policy
The far-reaching impacts of the China import ban have likely not yet played out fully. The current policy by China is part of a larger policy to improve environmental quality for an increasing middle class, as well as ongoing trade negotiations with the United States. However, some conclusions can be drawn at this juncture:

- The Chinese import ban was unexpected and represents a major disruption to the management of recyclables in the United States.
- There has always been—and always will be—pricing volatility in the recycling market; however, the current severely depressed U.S. market conditions are expected to persist for at least several years.
- Increased investment in recycling infrastructure and markets will have to be made to improve recyclables quality and to develop local demand for recycled products.
- Much of the cost for recycling will have to be paid by residents and businesses in the form of higher fees for service.
- Communities will have to pay more when they have higher levels of contamination in their recycled materials.
- Dual-stream recycling programs, although typically more expensive in terms of consumer education and collection effort than single-stream programs, may offer lower lifecycle costs and higher recycling rates for communities that are serious about diverting materials from disposal.

Authorities and municipalities are expanding services to stakeholders—doing more with less, while maintaining high standards for safety and environmental compliance. An experienced solid-waste advisory team is a trusted resource for guiding waste-authorities’ efforts to successfully meet these challenges. These private-sector and non-profit experts can help provide comprehensive solid waste advisory and engineering planning for your organization at a time of unprecedented economic disruption of recycling markets.

Sources
A look at the potential environmental and financial impacts for landfill owners and operators following the emergence of siloxane contaminants in landfill gas.
Siloxanes have emerged as common contaminants in landfill gas (LFG) and other biogas with potentially significant environmental and financial impacts for owners and operators of landfills and gas-to-energy (LFGTE) facilities. Siloxanes present in LFG can degrade the operating efficiency of LFGTE engines. Elevated siloxane concentrations can also potentially result in LFGTE facilities exceeding permitted emission limits for particulate matter (PM) and carbon monoxide (CO) and may also prevent landfills from demonstrating compliance with health-based guidelines for formaldehyde emissions. High siloxane concentrations can increase operating costs through the need for increased maintenance or replacement of equipment, and through fouling of post-combustion, catalytic emissions controls.

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</tr>
<tr>
<td>540-97-6</td>
<td>Dodecamethyldisiloxane (D6)</td>
</tr>
</tbody>
</table>

Table 1. Organosilicon compounds commonly detected in LFG.2

The Background on Siloxanes
Siloxanes belong to a functional group of organosilicon compounds (containing carbon-silicon bonds) that also includes silanes and silanols. Siloxanes are volatile organic compounds (VOCs) that are built on silicon (Si) instead of carbon and are generally categorized by their physical structure, either cyclical (D) or branched chains (L), and the number of Si atoms in the molecule (e.g., L2 or D3). Table 1 shows the most common organosilicon compounds, predominantly siloxanes, found in LFG. Physical properties, such as boiling point and water solubility, vary among the species.

Siloxanes themselves are non-toxic, not known as a health hazard and not regulated by the U.S. Environmental Protection Agency (EPA). They are used extensively in household products and cosmetics for their smoothing or softening effect. A solid antiperspirant deodorant may contain as much as 50 percent siloxanes. They are also a common component of many industrial products including plastics, adhesives, and lubrications, and they are even found in some fat-free or reduced fat synthetic food products such as salad dressings or potato chips.

Due to their widespread use, siloxanes are a common component in a variety of waste streams, particularly wastewater treatment plant sludge, household municipal solid waste, and industrial waste. As these wastes degrade in a landfill, the warm temperatures and negative pressure differential allow the siloxanes to volatilize and enter the gas stream. Due to the variable nature of waste streams, siloxane concentrations in LFG can vary significantly over time and between sites; therefore, it is important to test the gas during the early planning stages of a beneficial-use project and at six-month intervals throughout the life of the project.

Currently, siloxanes are not subject to air quality regulations; however, some states such as Vermont are now requiring testing for siloxanes in LFG to quantify siloxane combustion-product emissions of silicon dioxide (SiO2), or silica, which is regulated as PM. Because siloxanes are not regulated air pollutants themselves, there are no promulgated methods for testing siloxanes in LFG. However, there are a variety of commercially available siloxane sampling, analysis, and monitoring methods used to evaluate LFG quality in support of beneficial-use projects.

Common sample collection methods include sorbent tube/vial and whole-air with subsequent analysis at an air analytical laboratory by gas chromatography/mass spectrometry (GC/MS). For the sorbent method, a predetermined volume of gas (typically 6 liters) is passed through a sorbent-filled plastic tube or glass vial at a uniform, low flow rate (typically 200 milliliters per minute) and the siloxanes stick to the sorbent media. Figure 1 shows a sorbent tube filled with a solid media for sampling siloxanes in LFG. Typically, the sorbent media is either activated carbon, methanol, or oil. The whole-air method is generally simpler and involves collecting a grab sample or a time-integrated sample in a Tedlar bag or Summa canister.

Each sample collection method has its pros and cons and there are several factors to consider including cost, hold times, reporting limits, and dangerous goods shipping requirements. In addition, the target analyte list, reporting limits, and reporting units can vary significantly between analytical laboratories.

Typically, the analyte list can vary from 5 to 22 organosilicon compounds depending on the analytical laboratory; however,
Siloxanes in the Waste Stream by Matthew Estabrooks and Stephen Zemba

The compounds most commonly found in LFG include D3, D4, D5, L2, L3, and TMS, with D4 and D5 being the most prevalent (Table 1). Total organosilicon concentration in LFG can range from not detected to well over 100 mg/m³, with siloxanes generally accounting for 90 percent or more of the total concentration.

**Traditional Siloxane Concerns for Landfills**

The impacts of siloxanes on LFGTE equipment (e.g., engines, turbines, boilers, etc.) have been well-documented over the last couple of decades as more and more projects have come online. There is now a longstanding recognition that siloxanes present in the LFG can degrade the operating efficiency of the LFGTE equipment, which decreases energy generation and increases CO emissions.

During LFG combustion in the engine or boiler, the siloxane molecules break down and combine with oxygen and other elements present during combustion to form silica and silicates, which are chemically and physically similar to sand or glass. Silica deposits can form in the combustion chamber, exhaust manifold, turbine, and exhaust stack, and become thick, extremely hard, and difficult to remove.

In engines, deposits in the combustion chamber can be abrasive and cause premature degradation of the exhaust valve faces and seats. In addition, deposits on the valve seat can chip off and lead to valve guttering, which is when the combustion gases pass through a valve that is in the closed position and create a torch effect that can melt the valve. In turbines, deposits can cause bearing failure and wheel erosion, and reduce the effectiveness of heat recovery equipment.

The overall result is a reduction in combustion efficiency and energy production, increased equipment maintenance, and difficulty in meeting stringent CO standards as combustion efficiency degrades. Due to the significant damage that siloxanes can cause, engine and turbine manufacturers have set stringent limits on siloxane levels in LFG that, if exceeded, invalidate warranties. Caterpillar has set a silicon in gas limit of 0.60 µg Si/Btu for low energy fuel engines and requires gas treatment if the limit is exceeded. Limits for turbine equipment are more stringent, typically ranging from one to two orders of magnitude less than engine limits, depending on the type of turbine.

**New Concerns and Regulatory Implications**

Formaldehyde is a leading air toxic that is receiving increased regulatory attention. Like CO, formaldehyde is a product of incomplete combustion. Formaldehyde is emitted from LFG engines at rates that typically cause their ambient air impacts to exceed health-based maximum concentration guidelines for formaldehyde. For more detailed information about emerging health-risk concerns over formaldehyde emissions from LFG engines, see the Little and Zemba article appearing elsewhere in this issue of EM.

Principal control of formaldehyde emissions (and CO emissions) from LFG engines and other LFGTE equipment is achieved by maintaining good combustion efficiency. However, siloxanes present in the LFG fuel can actually increase those emissions when silica, formed from the siloxanes, deposits on engine cylinders and reduces combustion efficiency. As discussed in the next section, siloxane removal systems (SRSs) are now deployed ahead of LFGTE equipment to remove siloxanes, which then preserves good combustion efficiency and the attendant reduced emissions of CO and formaldehyde. Besides formaldehyde control by maintaining good combustion efficiency, further reduction of formaldehyde emissions could be achieved in theory by means of post-combustion control using catalytic oxidation. However, it is presently uncertain as to whether that is achievable.

Besides the concerns for formaldehyde and CO emissions, the combustion of LFG containing elevated concentrations of siloxanes can also generate silica emissions, a form of PM, at levels that could exceed ambient air limits for silica set by some states, depending on the structure (e.g., crystalline, amorphous) and particle size of the SiO₂ emitted. Since emission rates of silica per se are not typically measured directly, some state agencies have elected to use total PM₁₀ emissions as a surrogate for silica emissions and require annual siloxane testing with the results being used to calculate annual PM emissions. While SRSs can be useful for controlling CO and formaldehyde emissions, regenerative SRSs generally achieve no net reduction in PM emissions for

![Figure 1. Sorbent Tube Filled with Solid Adsorbent Media for Sampling Siloxanes in LFG.](image-url)
reasons explained in the next section. For LFGTE facilities that have high levels of siloxanes in the LFG, silica emissions can account for a significant portion of the facility's permitted PM emission limit.

**Siloxane Treatment**

An increasing number of LFGTE facilities are using SRSs ahead of the LFGTE equipment to reduce the potential for negative impacts associated with siloxanes in LFG. Removal of the siloxanes from the LFG fuel enables the LFG engine to maintain good combustion efficiency, thereby also restricting the formation and emission of CO and formaldehyde. These SRSs are demonstrated to be effective in this regard. However, as explained below, the SRSs currently used in larger-scale LFGTE projects do not reduce the substantial emissions of the silica PM that derive from those siloxanes. Nor are SRSs demonstrated as yet to be capable of reducing siloxanes in LFG sufficiently to enable efficient operation of a catalyst-based control system after the LFGTE equipment to further abate CO and formaldehyde emissions beyond the control achieved via good combustion efficiency.

Regenerative, siloxane-only removal systems are considered the industry standard for LFGTE projects, particularly projects that utilize LFG-fueled engines to generate electricity. These SRSs are placed ahead of the LFGTE equipment and work by passing the landfill gas across the surface of engineered catalytic media designed to target and remove the siloxanes by causing the siloxanes to bond to the media surface.

Figure 2 shows a typical regenerative SRS with two treatment vessels, as installed at an LFGTE facility. The SRSs are called regenerative because the captured siloxanes can be stripped off the spent media and the media can be used again.

Typically, two or more media vessels are used in the control system so that at least one can always be online while the other is being regenerated. The media can normally be regenerated and reused for about two years. Regeneration is achieved through a process wherein heated air is directed across the media in the vessel, breaking the bond between the siloxanes and the media, transferring the siloxanes to the heated air. This heated air containing the siloxanes is typically then delivered to a flare or thermal oxidizer to destroy the conventional contaminants present in the gas prior to its being vented to the atmosphere. However, when the flare or thermal oxidizer destroys the siloxanes that are present, silica is emitted in the exhaust gas. Accordingly, overall emissions of PM formed from LFG siloxanes (i.e., silica particles) are not reduced. However, those silica PM emissions are at least transferred from the energy recovery engine (where they can otherwise degrade engine performance and increase emissions of CO and formaldehyde) to the flare, an emission source having greater plume rise and hence enabling better dispersion.

Figure 3 shows a typical process flow for a regenerative SRS installed at an LFGTE facility. Capital costs for a mid-size (i.e., 2,500 scfm) regenerative SRS are on the order of US$1.5 million, with annual operating costs of approximately US$0.5 million, and a payback period of three years or less, depending on the inlet siloxane level. Costs can be recovered through reduced frequency of equipment maintenance, fewer engine rebuilds, and additional revenue from increased equipment availability and power generation.

While regenerative, catalytic SRSs are well-demonstrated to preserve good combustion efficiency, thus reducing emissions of formaldehyde and CO at LFGTE facilities, it is not yet established whether those SRSs can achieve sufficient siloxane

![Figure 2. Regenerative Siloxane Removal System Installed at an LFGTE Facility.](Photo Credit: Sanborn, Head & Associates, Inc.)

![Figure 3. Typical Process Flow for a Regenerative SRS Installed at an LFGTE Facility.](Image 321x101 to 532x250)
removal to also enable further control of formaldehyde and CO emissions using a catalytic control system after the LFGTE equipment. This is because the siloxanes present in the LFG can also cause silica deposits on the downstream control catalysts that quickly render them ineffective for achieving additional formaldehyde and CO control.\(^7\)

There are several landfill facilities throughout the United States that have installed catalytic treatment systems for additional control of formaldehyde and CO emissions; however, sufficient long-term performance data are not yet available to evaluate catalyst performance or longevity. In the absence of a demonstrated, downstream treatment system, formaldehyde emissions are controlled through good combustion practices, with CO emissions used as a surrogate to monitor engine combustion efficiency.

For smaller LFGTE projects, (i.e., LFG flow less than 1,000 standard cubic feet per minute [scfm]), activated carbon or other nonregenerative treatment systems for siloxane control may be more cost-effective.\(^5\) A properly sized activated carbon system can remove siloxanes to the level required; however, the media life may be limited by the presence of moisture, non-methane organic compounds, and hydrogen sulfide which also compete for adsorption surface area. Non-regenerative systems may also be more suitable for facilities where PM emissions are a concern because the siloxanes become trapped in the media and can be disposed of off-site rather than combusted on site and released as SiO\(_2\).

Conventional filtering systems will not remove siloxanes from LFG; however, refrigeration with condensation may remove a small percentage of the siloxanes. Higher removal efficiencies may be achieved using subzero refrigeration which involves reducing the temperature to -20 °F, but concerns over icing and cost-effectiveness have limited applications.

**Conclusion**

The economic impacts from siloxanes present in LFG can be significant for landfill owners, LFGTE facility owners, and their operators if those siloxanes are allowed to reduce the operating efficiency of the LFGTE equipment. Such loss of operating efficiency can increase the emissions of key pollutants such as CO, PM, and formaldehyde, and hence, cause exceedances of permitted emission limits or air quality standards that result in expensive violations. The reduced operating efficiency also increases operating and maintenance costs, and increases downtime of the power generation equipment.

Facilities with elevated siloxanes levels in the LFG can likely realize cost savings through installation of an SRS to remove much of the siloxane from the LFG ahead of the LFGTE equipment.
equipment. There are many variables to consider when performing a cost-benefit analysis for siloxane treatment; however, increased regulatory scrutiny of formaldehyde and PM emissions from LFGTE projects may necessitate installation of SRS equipment. This is particularly so if SRS technology is shown to not only remove siloxanes enough upstream to preserve the operating efficiency of LFGTE equipment, but to also reliably remove those siloxanes with the very high efficiency required to enable use of a downstream oxidative catalyst to achieve further control of formaldehyde emissions.

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References
A brief discussion of the associated health risks from long- and short-term exposure to formaldehyde emissions from landfill gas-to-energy.
Landfill gas (LFG) can be used beneficially to fuel landfill gas-to-energy (LFGTE) engines that produce electricity, which offsets greenhouse gas (GHG) emissions from fossil-fuel electric generation. However, increasingly stringent air quality standards are making it difficult to permit and operate LFGTE engines. The combustion of LFG creates byproducts such as carbon monoxide, nitrous oxides, sulfur dioxide, particulate matter, and other hazardous air pollutants such as formaldehyde. Probably best known as an indoor air toxin that off-gases from new building materials and wood products, formaldehyde is also ubiquitous at trace levels in outdoor air due to its emission from the combustion of hydrocarbon-based fuels, natural emissions from vegetation, and formation in atmospheric chemistry.¹

While there is a small amount of formaldehyde present in LFG, it is the combustion byproducts from LFGTE engines that generally represent the larger source of formaldehyde emissions, particularly if the LFG is not “cleaned” prior to combustion (i.e., reduction of siloxane concentrations) and/or the engine is not properly maintained. As these formaldehyde emissions are exhausted to the atmosphere, the incremental concentrations of formaldehyde that result in ambient air depend on a variety of factors that influence dispersion and dilution, including stack height, exhaust temperature and velocity, and meteorological conditions. Available post-combustion controls for formaldehyde such as catalytic oxidation are costly and not yet well proven.

LFGTE engine emissions of formaldehyde can be of regulatory significance. A 1.6-MWe engine has potential formaldehyde emissions of 8.7 tons/year at a typical engine emission guarantee of 0.42 g/bhp-hr, and hence multi-engine installations, or even a single engine that is poorly maintained, can easily exceed the major-source emissions threshold of 10 tons/year for a regulated hazardous air pollutant (HAP).

Moreover, combined with low stack heights, potential emissions of a typical LFGTE installation can lead to exceedances of stringent air toxics standards. As illustrated in Table 1, many state-specific standards/guidelines are below typical background concentrations in ambient air, which are on the order of a few µg/m³.² An EM article published in 2017 described the inability of a LFGTE engine to demonstrate compliance with formaldehyde ambient air standards.³ In this article, we demonstrate how a site-specific health risk assessment can be used as an alternate method of compliance demonstration. First, an overview is provided of acceptable techniques for conservatively assessing health risks associated with formaldehyde emissions from LFGTE facilities. Then, a case study is presented that illustrates how these risk assessment techniques can be successfully applied as an alternate means of compliance demonstration. The alternative approach entails back-calculating the maximum permissible emission rate of formaldehyde from a LFGTE facility that results in acceptably-low health risks.

One of the challenges associated with formaldehyde is the need to address both long-term and short-term exposures, for which potential health concerns differ. We provide a brief discussion of risk assessment equations, then follow with a case-specific example of using risk assessment and air dispersion modeling in a “backwards mode” to derive facility-specific allowable emissions of formaldehyde.

### Long-Term Exposures

The additional chance of getting cancer is one type of risk relevant to formaldehyde emissions from LFGTE engines. Formaldehyde is recognized by the U.S. Environmental Protection Agency (EPA) as a probable human carcinogen after long-term exposure to it. Potential health risks due to long-term formaldehyde exposure are estimated according to standard EPA methods adapted from the National Air Toxics Assessment⁴ and regional screening level spreadsheets for air/inhalation exposure.⁵

Long-term estimates of the formaldehyde concentration in the ambient air, $C_{\text{Long}}$, are typically based on use of the maximum, projected annual (1-year) impact as a conservative representation of the chronic, cumulative exposure over an extended period of time. For assessing long-term health impacts, the incremental (increased) risk of contracting cancer is used as the critical health “endpoint” (health effect). Incremental cancer risk due to potential exposure to LFGTE engine emissions can be calculated as:

$$ILC R = C_{\text{Long}} \times f_{\text{Life}} \times IUR$$

where the terms are:

- $ILC R$ Incremental lifetime cancer risk (unit less probability);
- $C_{\text{Long}}$ Highest annual-average concentration of formaldehyde in air ($\mu g/m^3$) due to engine emissions based on air dispersion modeling;
- $f_{\text{Life}}$ Fraction of a human lifetime over which exposure occurs; and
- $IUR$ Inhalation unit risk factor ($m^3/\mu g$).

By assigning values to the target maximum $ILC R$, $f_{\text{Life}}$, and $IUR$, we can solve the above equation for $C_{\text{Long}}$ and target that value as the maximum allowable concentration during air dispersion modeling. EPAs current $IUR$ is $1.3 \times 10^{-5}$ $m^3/\mu g$.⁶ A representative site-specific value for $f_{\text{Life}}$, is 0.429, based on an average lifetime of 70 years and an assumed exposure period of 30 years (both an upper-end estimate of the length of time an individual remains at a single residence and a reasonable high-end estimate of the period that LFGTE engines might operate).⁴ The choice of the $ILC R$ reflects the degree of
desired protection. Many state air toxics standards are based on an allowable incremental risk of 1 in a million, but in site-specific applications, higher permissible risks of 10 to 100 per million may be acceptable. For perspective, these risks add to a person's overall chance of death from cancer, which is currently about 1 in 4, or 250,000 per million.

### Short-Term Exposures

Short-term exposures to formaldehyde may cause irritation to the eyes, nose, throat, and skin in addition to exacerbating health issues for people with underlying conditions such as asthma. Problematically, there is no uniform agreement on the appropriate exposure period to consider. Therefore, short-term impacts over 1-hour and 24-hours (typical of a number of state-specific air toxic standards) are examined for evaluating non-cancer respiratory irritation effects. In correspondence with dispersion modeling, short-term concentration estimates $C_{Short}$ are based on the maximum predicted 1-hr daily and 24-hr impact concentrations.

The potential for adverse non-cancer health effects is characterized through the calculation of a hazard quotient. Because respiratory irritation (the key health endpoint for formaldehyde) can occur over short periods, risk is evaluated on a short-term (sub-chronic) basis assuming continuous exposure.

The hazard quotient is calculated as:

$$HQ_{Short} = \frac{C_{Short}}{C_{Ref}}$$

where the terms are:

- $HQ_{Short}$: Non-cancer hazard quotient (dimensionless);
- $C_{Short}$: Maximum short-term 1-hr or 24-hr average concentration of formaldehyde in air ($\mu g/m^3$) due to engine emissions based on air dispersion modeling; and
- $C_{Ref}$: Concentration of formaldehyde that can be safely breathed ($\mu g/m^3$) for periods of either 1 hr or 24 hr.

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**Table 1. Formaldehyde Toxicity: Concentrations of Concern.**

<table>
<thead>
<tr>
<th>Regulatory Authority</th>
<th>Risk-Based Concentration of Concern ($\mu g/m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acute ($\leq 1$-hr)</td>
</tr>
<tr>
<td>EPA Acute Exposure Guideline (AEGL-1)(^1) and Regional Screening Levels (RSLs)(^2)</td>
<td>1,100</td>
</tr>
<tr>
<td>California Reference Exposure Levels (RELs)(^3)</td>
<td>55</td>
</tr>
<tr>
<td>ATSDR Minimum Risk Levels (MRLs)(^4)</td>
<td>49</td>
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<tr>
<td>OSHA Short-Term Exposure Limit (STEL) and Permissible Exposure Limit (PEL)(^5)</td>
<td>2,460</td>
</tr>
<tr>
<td>New Hampshire Ambient Air Limit (AALs)(^6)</td>
<td>n/a</td>
</tr>
<tr>
<td>Louisiana Toxic Air Pollutant Ambient Air Standard(^7)</td>
<td>n/a</td>
</tr>
<tr>
<td>Massachusetts Allowable Ambient Limit and Threshold Effects Exposure Level(^8)</td>
<td>n/a</td>
</tr>
</tbody>
</table>

**Sources**

2. EPA's Regional Screening Level (RSL) Resident Ambient Air Table, May 2018.
4. Agency for Toxic Substances and Disease Registry (ATSDR); https://www.atsdr.cdc.gov/mrls/mrllist.asp. Note: ATSDR defines acute exposure as 1-14 days, short-term (intermediate) exposure as 15-364 days, and chronic exposure as $\geq 1$ year.
7. Louisiana Environmental Regulatory Code, April 2014, Title 33, Part III, Section 5112, Table 51.2.
The short-term reference concentration ($C_{\text{Ref}}$) is intended to connote a “safe” exposure level, and often embodies a margin of safety placed there by a regulatory agency. This provides a greater level of confidence that a target hazard quotient ($HQ_{\text{Short}}$) of 1 will not result in adverse health effects.

The value to choose for $C_{\text{Ref}}$ in the framework of risk assessment is challenging because there is no shared threshold value accepted by all regulatory agencies. The following are examples of candidates for formaldehyde $C_{\text{Ref}}$:

- For the 1-hr averaging period, the California Office of Environmental Health Hazard Assessment’s (CA OEHHA’s) Reference Exposure Level (REL) is 55 µg/m$^3$;
- CA OEHHA’s REL of 9 µg/m$^3$ applies to both 8-hr and annual periods, and hence is an appropriate value ($C_{\text{Ref}}$) for the 24-hr averaging period; and

Interestingly, CA OEHHA’s REL of 9 µg/m$^3$ is similar to the chronic Minimum Risk Level (MRL) of 9.8 µg/m$^3$ derived by the Agency for Toxic Substances and Disease Registry$^6$ for evaluating long-term exposure of a year or longer. The ATSDR MRL for acute exposure from 1 to 14 days duration is 49 µg/m$^3$, and the MRL for intermediate exposure from 15 days to 364 days is 37 µg/m$^3$. These values are similar in magnitude to CA OEHHA’s acute 1-hr REL, emphasizing the conservative/protective bias inherent to deriving CRef values.

Both the 24-hr REL of 9 µg/m$^3$ and the chronic MRL of 9.8 µg/m$^3$ were derived from a study of furniture workers exposed to characteristically high levels of formaldehyde.$^8$ That study showed that an exposure of 294 µg/m$^3$ of formaldehyde in factory air over a period of about 10 years was sufficient to cause clinical symptoms of mild irritation of the eyes and upper respiratory tract and mild damage to certain nasal tissue. Hence, the margin of safety between the concentrations that was found to cause mild respiratory effects (294 µg/m$^3$) and the REL or MRL (9 or 9.8 µg/m$^3$) is about 30. The lowest concentration of 294 µg/m$^3$ found in the factory study to cause observable adverse effects is considerably greater than the concentrations of formaldehyde typically found in ambient air, inclusive of local increases due to emissions from LFGTE engines.

**Case Study Example**

Given worst-case maximum concentrations from air dispersion modeling, the long- and short-term framework equations will provide quantitative estimates of risk. However, the equations can be recast to solve for the maximum concentrations of formaldehyde allowable to meet given target, maximum risk levels. Then, working backward, air dispersion modeling is used to calculate the maximum allowable emission rates of formaldehyde that correspond to the allowable, risk-based concentrations.

As a case study example, a two-engine LFGTE facility was required by the state regulatory air agency to demonstrate compliance with state ambient air limits for formaldehyde as part of an air permit renewal application. Similar to the previous case study cited above,$^3$ this air dispersion modeling study demonstrated that at the formaldehyde emission rate guaranteed by the engine manufacturer, the stringent 1-hr, 24-hr, and annual ambient air limits could not be met. Therefore, the risk assessment approach equations described above, linked to the facility-specific air dispersion modeling study, were implemented to back-calculate the allowable, case-specific, risk-based emission factors:

- **Long-Term Cancer Risk**: Based on a target maximum $ILC_{\text{R}}$ of $10^{-5}$ (incremental lifetime cancer risk of 10 per million) and parameters described above, the equation for $ILC_{\text{R}}$ was solved to yield the concentration $C_{\text{Long}}$ of 1.79 µg/m$^3$, which from the dispersion modeling, corresponded to a formaldehyde emission factor of 1.34 g/bhp-hr. Hence, limiting emissions to this value would keep the incremental cancer risk below the regulatory “acceptable” level of 10 chances per million.

- **Short-Term Irritation Risk**: Based on a target maxi-
mum short-term hazard quotient $H_{Q_{short}}$ of 1, the short-term reference concentrations $C_{Ref}$ of 55 µg/m³ (1-hr) and 9.8 µg/m³ (24-hr), when used as the critical values of $C_{short}$ in the dispersion modeling analysis, corresponded to formaldehyde emission factors of 0.60 g/bhp-hr and 0.42 g/bh-hr, respectively. Limiting emissions to these 1-hr and 24-hr values would result in acceptably-low risks of irritation health effects from short-term exposure.

The lowest of the emission rates that meet all of the three risk scenarios addressed above is 0.42 g/bhp-hr. Therefore, this value is the limiting formaldehyde risk-based emission factor. Facility-specific stack testing, as well as test results from similar engines, indicate formaldehyde emissions of the order of 0.3 g/bhp-hr. Hence, based on typical engine performance, the site-specific evaluation indicates no significant risks to health for residents living around the landfill and LFGTE facility, and no additional permit requirements for formaldehyde were deemed necessary. The site-specific risk assessment approach as an alternate compliance method allowed for the use of less conservative, though still highly protective, assumptions. Meeting the state-specific air standards would have demanded a formaldehyde emission factor limit of 0.03 g/bhp-hr, which would have required costly post-combustion emission controls that may not have been operationally sustainable.

**Conclusion**

Formaldehyde is a regulated HAP that is ubiquitous in trace levels in outdoor air. Formaldehyde is of concern because it is a probable human carcinogen and is also known to cause irritation-related health effects with sufficient short-term exposure. Formaldehyde emitted by LFGTE engines can be significant and lead to exceedances of stringent state air toxics standards set for this pollutant. In fact, ambient background levels alone sometimes exceed those state standards. At LFGTE facilities where the formaldehyde emissions impacts would exceed the allowable state standards, a site-specific health risk assessment may be useful as an alternate method for compliance demonstration.

**References**

5. Integrated Risk Information System (IRIS); U.S. Environmental Protection Agency, 2017; [http://www.epa.gov/iris (accessed September 2017)].

**In Next Month’s Issue...**

**Short-Lived Climate Pollutants**

Some short-lived climate pollutants (SLCPs), such as methane, are more-or-less covered by agreements that aim to reduce greenhouse gases (e.g., the Paris Accord); others, like black carbon, are left out because they are particles and not gases. SLCPs stay in the atmosphere for much shorter periods than long-lived climate pollutants like carbon dioxide (CO2), but pound-for-pound, they warm the atmosphere much more than CO2. The upside is that reducing SLCP emissions has a more immediate climate benefit than reducing CO2 emissions alone. This issue will identify sources of SLCPs and discuss how they are controlled and what can be done to better address their impacts.
Landfills
Be Aware of Emerging Contaminants!

Landfill operations have long been regulated for contaminants such as heavy metals and toxic organic compounds. However, environmental professionals must now become aware of certain additional contaminants of emerging concern that are associated with landfills and are receiving new scrutiny for posing potential environmental risks.
Emerging contaminants generally arise from the Unregulated Contaminant Monitoring Rule (UCMR), a portion of the U.S. Safe Drinking Water Act used by the U.S. Environmental Protection Agency (EPA) to identify additional contaminants that may present a public health risk. Every five years, EPA develops a list of suspected contaminants that could be present in drinking water and requires sampling for them by large public drinking water systems. EPA examines the sampling results on a national basis to characterize the frequency with which each contaminant is detected and the percentage of samples greater than risk-based target levels. If EPA determines a significant public risk, it can engage in rulemaking to develop a federally enforceable Maximum Contaminant Level (MCL) for the nation’s drinking water supply.

EPA is presently implementing its fourth UCMR sampling round. Although no new MCLs have resulted from the first three rounds, previous sampling has drawn attention to a number of contaminants, and in some cases have prompted state-specific regulatory actions that are presently affecting the solid waste industry.

In particular, a growing number of states are focusing on 1,4-dioxane and per- and polyfluoroalkyl substances (PFAS), which were included as part of the third UCMR sampling round (UCMR3). Both 1,4-dioxane and PFAS are of concern because people exposed to them may potentially be at elevated risk for cancer and other health effects, although such a link has yet to be clearly demonstrated. A summary of the UCMR3 sampling results for the nation’s water supplies is provided in Table 1.

About 37,000 samples were analyzed for 1,4-dioxane and PFAS. The results indicate that 1,4-dioxane was found above the reporting limit of 0.07 micrograms per liter (µg/l) in 11% of samples nationally, and 2.9% of samples were above the 0.35 µg/l risk-based screening concentration (RSC). PFAS sampling included 6 different compounds, and these compounds were detected less frequently, ranging among compounds between 0.05% and 1% of samples. PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulfonic acid) exceeded their 0.07 µg/l RSC in only 0.3% and 0.09% of samples, respectively. Since multiple samples were collected from each of the approximately 4,900 public water supplies, the percentages of water supplies that detected 1,4-dioxane and PFAS in at least one sample are higher. For example, 1,4-dioxane was detected in 22% of the public water supplies tested.

### Evolving Toxicity of Emerging Contaminants

Though detected relatively infrequently in the UCMR, 1,4-dioxane and PFAS have garnered considerable attention. The term “emerging” implies a dynamic and incomplete process, and this description befits contaminants such as 1,4-dioxane and PFAS. In each case, there are indications of health concerns that originated many years ago, but data uncertainties and limitations prevent robust characterization. While studies continue, citizens and politicians are pressuring (and in some cases requiring) state environmental agencies to develop standards in the absence of federal MCLs.

In 1987, EPA issued a Lifetime Health Advisory (LHA) of 200 µg/l for 1,4-dioxane in drinking water, which in time prompted some states to add it to contaminant sampling lists. For example, groundwater near landfills is monitored for landfill-related contaminants including 1,4-dioxane, because groundwater contaminated by landfill leachate can degrade the local water supply. As one consequence, such monitoring near landfills has indicated 1,4-dioxane to be a useful marker for groundwater impact delineation as its complete miscibility places it at the leading edge physically of contaminant plumes from landfill leachate releases.

Concerns over lower concentrations of 1,4-dioxane ensued with

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Number of samples</th>
<th>Number of public water supplies</th>
<th>Minimum Reporting Limit (MRL) (µg/l)</th>
<th>Percentage (%) of samples &gt; MRL</th>
<th>Percentage (%) of public water supplies with a detect &gt; MRL</th>
<th>Risk-Based Screening Concentration (RSC) (µg/l)</th>
<th>Percentage (%) of samples &gt; RSC</th>
<th>Percentage (%) of public water supplies with a detect &gt; RSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,4-dioxane</td>
<td>36,810</td>
<td>4,915</td>
<td>0.07</td>
<td>11</td>
<td>22</td>
<td>0.35</td>
<td>2.9</td>
<td>6.9</td>
</tr>
<tr>
<td>PFBS (perfluorobutanesulfonic acid)</td>
<td>36,972</td>
<td>4,920</td>
<td>0.09</td>
<td>0.05</td>
<td>0.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PFHxS (perfluorohexanesulfonic acid)</td>
<td>0.03</td>
<td>0.6</td>
<td>1.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PFHpA (perfluorheptanoic acid)</td>
<td>0.01</td>
<td>0.6</td>
<td>1.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PFOA (perfluorooctanoic acid)</td>
<td>0.02</td>
<td>1.0</td>
<td>2.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PFOS (perfluorooctanesulfonic acid)</td>
<td>0.04</td>
<td>0.8</td>
<td>1.9</td>
<td>0.07</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PFNA (perfluorononanoic acid)</td>
<td>0.02</td>
<td>0.05</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
time, and use of more sensitive analytical methods has led to more widespread detections of 1,4-dioxane in groundwater. In September 2013, EPA categorized 1,4-dioxane as a likely human carcinogen and established, using its standard guidance, a risk factor based on an assumed lifetime exposure via the ingestion exposure pathway. Application of EPAs standard risk-assessment model (a “zero threshold” model) results in a drinking water Risk Screening Level (RSL) of 0.35 µg/l, and similar values have recently been adopted in state regulations by agencies such as the New Hampshire Department of Environmental Services (0.32 µg/l) and the Massachusetts Department of Environmental Protection (0.3 µg/l). While such RSLs are not contaminant limits as such, they are intended to flag contaminant levels indicating the need for further case-specific risk assessment.

A similar evolution is in progress with PFAS. In 2009, EPA issued provisional health advisories of 0.4 µg/l for PFOA and 0.2 µg/l for PFOS, then in 2016 issued a LHA for drinking water of 0.07 µg/l for the combination of the two compounds. Numerous states have adopted EPAs drinking-water LHA to also prescribe requirements for groundwater cleanup levels, and some states have issued lower standards and/or have expanded coverage to include additional PFAS. As an example, Vermonts 0.02 µg/l health advisory covers the sum of PFOA, PFOS, PFHxS (perfluorohexane sulfonic acid), PFHpA (perfluoroheptanoic acid), and PFNA (perfluorononanoic acid). Although the tendency has been toward lower and lower risk-based criteria, not everyone is convinced that 1,4-dioxane and PFAS require part-per-trillion standards to protect public health. Evidence from laboratory animal studies suggests that 1,4-dioxane requires a threshold level of exposure before that exposure promotes cancer (rather than a zero-exposure threshold), and that a level 1,000-fold higher than the 0.35 µg/l LHA is health protective. Similar doubts over toxicity have been noted for PFAS. A recent review commissioned by the Australian Government Department of Health concluded that “there is mostly limited, or in some cases no evidence, that human exposure to PFAS is linked with human disease,” and “there is no current evidence that suggests an increase in overall cancer risk.” But at the same time, the Australian panel was unwilling to declare PFAS exposure safe, noting that “even though the evidence for PFAS exposure and links to health effects is very weak and inconsistent, important health effects for individuals exposed to PFAS cannot be ruled out based on the current evidence.”

The trend toward more stringent health advisories reflects the need for regulatory agencies to act in the face of uncertainty and the application of the precautionary principle. However, the price of protection may be steep, as the costs associated with compliance and treatment to meet standards for 1,4-dioxane, PFAS, and other future emerging contaminants could be substantial, and overly protective standards may yield little in the way of health benefits.

**Concerns for Landfills**

Both 1,4-dioxane and PFAS have been widely used in commerce and consumer products, and hence, have numerous sources in the municipal solid waste stream. Both 1,4-dioxane and PFAS have been detected in landfill leachate, in some cases at levels considerably higher than EPAs LHAs. Environmental monitoring programs around unlined landfills have also identified PFAS in groundwater and surface water, also in some cases at concentrations well in excess of EPAs LHAs.

Published concentrations of 1,4-dioxane in groundwater have been reported in the 10–100 µg/l range, though data are scarce. 1,4-Dioxane is increasingly being required as an analyte in groundwater monitoring programs as states react to its designation as a carcinogen by EPA, and because it is not unusual to detect it above EPAs 0.35 µg/l screening level.

Table 2 provides a summary of the concentrations of the six UCMR3 PFAS detected in landfill leachate sampling in two

<table>
<thead>
<tr>
<th>Table 2. PFAS Sampling of Landfill Leachate.</th>
<th>18 Landfills in the United States(^8)</th>
<th>6 Vermont Landfills(^9)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PFAS Compound</strong></td>
<td>Frequency of Detection</td>
<td>Average (µg/l)</td>
</tr>
<tr>
<td>PFBS</td>
<td>87 of 87</td>
<td>0.23</td>
</tr>
<tr>
<td>PFHxS</td>
<td>86 of 87</td>
<td>0.36</td>
</tr>
<tr>
<td>PFHpA</td>
<td>87 of 87</td>
<td>0.59</td>
</tr>
<tr>
<td>PFOA</td>
<td>87 of 87</td>
<td>0.89</td>
</tr>
<tr>
<td>PFOS</td>
<td>84 of 87</td>
<td>0.13</td>
</tr>
<tr>
<td>PFNA</td>
<td>86 of 87</td>
<td>0.05</td>
</tr>
<tr>
<td>Total PFAS</td>
<td>87 of 87 (69 PFAS compounds)</td>
<td>11.9</td>
</tr>
</tbody>
</table>
recent studies. Levels are typically detected at concentrations above EPA’s 0.07 µg/l LHA (which applies specifically to the sum of PFOA and PFOS). Also, the six UCMR PFAS account for only a small fraction of total detected PFAS concentrations. Though the studies examined different lists of PFAS (a “standard” analyte list has not yet been developed), two compounds found at levels higher than the UCMR3-specific compounds were PFBA (perfluorobutanoic acid) and PFPeA (perfluoropentanoic acid). Recalling a bit of chemistry, this might reflect the advent of shorter-chain PFAS that have replaced the C8 compounds PFOA and PFOS, which have been phased out of use in the United States. Hence, landfill leachate typically contains PFAS at levels that, if released to groundwater, could lead to exceedance of drinking water standards for PFAS in states that currently regulate PFAS. This is significant, as the number of states regulating PFAS, as well as the number of PFAS subject to regulation, are likely to grow.

Developing regulation of 1,4-dioxane and PFAS at landfills could lead to costly treatment of leachate, enhanced environmental monitoring, and potential remediation/mitigation costs that may vary across states. Many landfills currently discharge leachate to wastewater treatment plants (WWTPs). Regulatory pressures on WWTPs to reduce effluent concentrations of contaminants of emerging concern may in turn be shifted upstream to the leachate generators, through WWTP demands for leachate pre-treatment and reduced contaminant loadings as a condition of continued acceptance of leachate. Similarly, landfills that accept sewage sludge may need to consider the acceptability criteria based on concentrations of these compounds in the sludge.

The potential importance of groundwater contamination resulting from landfill leachate releases depends on neighboring land use. Drinking water ingestion is typically the most important exposure pathway to 1,4-dioxane and PFAS, and under most circumstances, the potential risks associated with off-property contamination depend on the existence or absence of affected drinking water wells. An example of the potential implications of PFAS regulations can be found in New Hampshire and Vermont, where landfills have been required to sample for PFAS in conjunction with groundwater monitoring programs. PFOA and PFOS were detected above the 0.07 µg/l LHA in groundwater monitoring samples collected at approximately 30% of active and closed landfills in New Hampshire whereas PFOA and PFOS were detected above detection limits in groundwater at 67% of landfill sites sampled. In Vermont, PFOA and PFOS were sampled in groundwater near eight closed landfills (see Table 3). PFOA was detected at all landfills, and PFOS at most of them, in two cases at levels above the EPA LHA of 0.07 µg/l.

Treatment and remediation options differ for 1,4-dioxane and PFAS. Because leachate typically contains many other contaminants at higher concentrations, primary treatment may be required before treatment to remove 1,4-dioxane and PFAS. Reverse osmosis (RO) is a potential option to remove both 1,4-dioxane and PFAS, and PFAS can also be removed through use of activated carbon and resins. Concentrated RO waste streams and spent carbon/resin media must be discarded or regenerated. These same methods are applicable to ex-situ treatment of groundwater used for drinking water. In-situ groundwater remediation is more challenging and less studied, though techniques such as aggressive chemical oxidation show promise. In cases of contaminated wells, providing alternate supplies of drinking water is another potential mitigation option. Any and all of these efforts may be costly additions to operating and post-closure expenses at landfills.

### Regulatory and Legal Implications

EPA is evaluating the possibility of establishing a federal MCL to limit the amount of PFAS allowable in drinking water, which could help to establish a more uniform direction among states. Establishing a federal MCL will require time, however, and states are likely to continue to move forward with individual and varying regulations. Actions regarding 1,4-dioxane and PFAS will not likely be limited to the regulatory arena. As potential environmental sources of 1,4-dioxane and PFAS, landfills may be parties to future litigation, for example, for remediation cost recovery at Superfund sites and arising from private party tort—and such litigation is already underway at locations in Michigan and other states. Drinking water contamination and property damages are at this point the primary concerns, as the uncertainties regarding toxicity make it difficult to meet the legal standard for causality between exposure and adverse health effects.

### Table 3. Groundwater Sampling Results for PFAS (in µg/l) at Vermont Landfills.10

<table>
<thead>
<tr>
<th>PFAS Compound</th>
<th>MSW 1</th>
<th>MSW 2</th>
<th>MSW 3</th>
<th>MSW 4</th>
<th>MSW 5</th>
<th>MSW 6</th>
<th>Paper Sludge</th>
<th>C&amp;D*</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFOA</td>
<td>0.011</td>
<td>0.045</td>
<td>0.008</td>
<td>0.014</td>
<td>0.002</td>
<td>0.009</td>
<td>0.018</td>
<td>0.9</td>
</tr>
<tr>
<td>PFOS</td>
<td>ND</td>
<td>0.037</td>
<td>0.005</td>
<td>0.005</td>
<td>ND</td>
<td>ND</td>
<td>0.011</td>
<td>0.14</td>
</tr>
<tr>
<td>Total</td>
<td>0.011</td>
<td>0.082</td>
<td>0.013</td>
<td>0.019</td>
<td>0.002</td>
<td>0.009</td>
<td>0.029</td>
<td>1.04</td>
</tr>
</tbody>
</table>

*C&D = Construction and demolition waste.
Conclusions
Emerging contaminants such as 1,4-dioxane and PFAS will increasingly demand the attention of the solid waste management industry by raising the costs of compliance, environmental protection, and remediation at landfills. An EPA rule (i.e., the UCMR) provides the ability to identify new contaminants of concern for drinking water, based on national sampling results. But, by drawing attention to emerging contaminants and not developing maximum permissible levels (MCLs) to limit them uniformly nationwide, EPA is in effect prompting individual states to act in response to public pressure, resulting thus far in very protective and potentially very costly regulations that vary among jurisdictions. And just around the corner, it will be interesting to see if the upcoming new round of UCMR sampling draws a focus upon some other new emerging contaminant such as manganese (commonly detected in groundwater near landfills).

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References
Many A&WMA members are employed by consulting firms; others are employed by industry or regulatory agencies and may hire consultants or transition into careers in consulting. Given the importance of consulting in the environment, health, and safety (EH&S) project management field, it is appropriate to address issues that are unique to project managers in the consulting field. The goal of my next several columns is to help members of the EH&S community better understand the financial aspects of consulting firm operations and management. We reviewed direct and indirect labor and expenses in my last column and discussed their importance relative to the management of an EH&S consulting firm. We’ll build on that information here and examine how EH&S consulting firms develop billing rates for project staff using direct and indirect costs. Specifically, we’ll examine the Breakeven Multiplier, the Net Fee Multiplier, and the Billing Rate.
The “Breakeven Multiplier” is defined as the sum of indirect expenses and direct labor costs divided by direct labor costs. The “Net Fee Multiplier” is defined as the sum of indirect expenses, direct labor costs, and profit divided by direct labor costs. The “Billing Rate” for an individual is determined by multiplying the Net Fee Multiplier by the individual’s base hourly compensation rate.

Table 1 provides financial information about a hypothetical EH&S consulting firm. In the previous column, we discussed utilization/chargeability/billability in terms of hours. Table 1 data yield a calculated average utilization of 56 percent for the overall firm based on total direct and indirect labor costs. Using the formula provided above, Table 1 data yield a calculated Breakeven Multiplier of 2.54. Based on a profit margin of 10 percent, the calculated Net Fee Multiplier is 2.79, which translates into a billing rate of US$69.75/hour for an individual who is paid US$25 per hour (2.79 x US$25/hour).

Table 2 adjusts the information in Table 1 by increasing Direct Labor costs by 5 percent (US$22,500), reducing Indirect Labor costs by the same amount, and holding all other values the same. This redistribution of labor costs results in a 5-percent increase in the overall utilization rate (a three-percentage point improvement from 56 to 59) with a corresponding approximate 5-percent decrease in the Breakeven and Net Fee multipliers. As the result, the firm is now able to bill the individual earning US$25 per hour at US$66.50 per hour and still maintain its profit target. For a highly competitive project, this slight difference in project labor cost could mean the difference in winning and losing the job.

### Table 1. Financial Statement for Example Environmental, Inc., Baseline

<table>
<thead>
<tr>
<th><strong>Total Direct Labor Expense</strong></th>
<th>$450,000</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indirect Expenses</strong></td>
<td></td>
</tr>
<tr>
<td>Payroll Taxes</td>
<td>$75,000</td>
</tr>
<tr>
<td>Personal Time Off, Holiday</td>
<td>$30,000</td>
</tr>
<tr>
<td>Health, Life Insurance</td>
<td>$40,000</td>
</tr>
<tr>
<td><strong>Total Payroll Expenses</strong></td>
<td>$145,000</td>
</tr>
<tr>
<td><strong>General &amp; Administrative Expenses</strong></td>
<td></td>
</tr>
<tr>
<td>Indirect Labor</td>
<td>$350,000</td>
</tr>
<tr>
<td>Accounting and Legal Services</td>
<td>$10,000</td>
</tr>
<tr>
<td>Charitable Contributions</td>
<td>$1,000</td>
</tr>
<tr>
<td>Communications</td>
<td>$10,000</td>
</tr>
<tr>
<td>Insurance (Liability, Errors &amp; Omissions)</td>
<td>$30,000</td>
</tr>
<tr>
<td>Information Technology</td>
<td>$25,000</td>
</tr>
<tr>
<td>Marketing &amp; Advertising</td>
<td>$25,000</td>
</tr>
<tr>
<td>Professional Development</td>
<td>$10,000</td>
</tr>
<tr>
<td>Travel (indirect)</td>
<td>$25,000</td>
</tr>
<tr>
<td>Rent</td>
<td>$50,000</td>
</tr>
<tr>
<td>Utilities</td>
<td>$10,000</td>
</tr>
<tr>
<td><strong>Total General &amp; Administrative Expenses</strong></td>
<td>$546,000</td>
</tr>
<tr>
<td><strong>Total Indirect Expenses</strong></td>
<td>$691,000</td>
</tr>
<tr>
<td><strong>Average Utilization</strong> ($450,000/($450,000+$350,000))</td>
<td>56%</td>
</tr>
<tr>
<td><strong>Breakeven Multiplier</strong> (($450,000+$691,000)/$450,000)</td>
<td>2.54</td>
</tr>
<tr>
<td><strong>Target Profit</strong> (10% of ($450,000+$691,000))</td>
<td>$114,100</td>
</tr>
<tr>
<td><strong>Net Fee Multiplier</strong> ($450,000+$691,000+$114,100)/$450,000)</td>
<td>2.79</td>
</tr>
</tbody>
</table>

1The information presented in this table is a hypothetical example and does not reflect the financial data for any particular firm.
Alternatively, the firm may maintain the billing rate established in Table 1 and achieve an additional US$1,125 in profit (or 5 percent of the US$22,500 increase in Direct Labor) for a total profit of US$115,225, or about a 1-percent increase in profit above the planned US$114,100.

In practice, most EH&S firms do not bill based on an individual employee’s compensation rate. Instead, the firm will develop a billing rate for a labor category (e.g., Project Scientist, Project Engineer, Project Manager, Senior Project Manager) that represents a weighted average of salary costs for the overall labor category. Accordingly, the firm realizes more profit when individuals on the lower end of the compensation range for the labor category are assigned to projects.

It should also be noted that utilization rates are typically higher for junior staff and lower for senior staff. As a result, slight increases in utilization for senior staff can translate into billing rate reductions or profit improvements that exceed those associated with the across-the-board increase in utilization rate presented in this example.

Similar results can be achieved by managing other indirect costs; however, the most significant indirect costs are often associated with fixed costs (like rent and insurance). As a result, the most significant action a successful EH&S consulting firm can take to improve competitiveness and profitability is to manage labor costs by achieving a healthy balance between direct and indirect costs. The operative words are “healthy balance.” While direct labor provides the revenue for the firm, properly invested indirect labor determines the future of the firm.

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**Table 2. Financial Statement for Example Environmental, Inc., Improved Utilization**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Direct Labor Expense</td>
<td>$472,500</td>
</tr>
<tr>
<td>Indirect Expenses</td>
<td></td>
</tr>
<tr>
<td>Payroll Expenses</td>
<td></td>
</tr>
<tr>
<td>Payroll Taxes</td>
<td>$75,000</td>
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<tr>
<td>Personal Time Off, Holiday</td>
<td>$30,000</td>
</tr>
<tr>
<td>Health, Life Insurance</td>
<td>$40,000</td>
</tr>
<tr>
<td>Total Payroll Expenses</td>
<td>$145,000</td>
</tr>
<tr>
<td>General &amp; Administrative Expenses</td>
<td></td>
</tr>
<tr>
<td>Indirect Labor</td>
<td>$327,500</td>
</tr>
<tr>
<td>Accounting and Legal Services</td>
<td>$10,000</td>
</tr>
<tr>
<td>Charitable Contributions</td>
<td>$1,000</td>
</tr>
<tr>
<td>Communications</td>
<td>$10,000</td>
</tr>
<tr>
<td>Insurance (Liability, Errors &amp; Omissions)</td>
<td>$30,000</td>
</tr>
<tr>
<td>Information Technology</td>
<td>$25,000</td>
</tr>
<tr>
<td>Marketing &amp; Advertising</td>
<td>$25,000</td>
</tr>
<tr>
<td>Professional Development</td>
<td>$10,000</td>
</tr>
<tr>
<td>Travel (indirect)</td>
<td>$25,000</td>
</tr>
<tr>
<td>Rent</td>
<td>$50,000</td>
</tr>
<tr>
<td>Utilities</td>
<td>$10,000</td>
</tr>
<tr>
<td>Total General &amp; Administrative Expenses</td>
<td>$523,500</td>
</tr>
<tr>
<td>Total Indirect Expenses</td>
<td>$668,500</td>
</tr>
<tr>
<td>Average Utilization ($472,500/($472,500+$327,500))</td>
<td>59%</td>
</tr>
<tr>
<td>Breakeven Multiplier (($472,500+$668,500)/$472,500)</td>
<td>2.41</td>
</tr>
<tr>
<td>Target Profit (10% of ($472,500+$668,500))</td>
<td>$114,100</td>
</tr>
<tr>
<td>Net Fee Multiplier ($472,500+$668,500+$114,000)/$472,500)</td>
<td>2.66</td>
</tr>
</tbody>
</table>

1The information presented in this table is a hypothetical example and does not reflect the financial data for any particular firm.
2Table 1 calculation input values that have been changed in Table 2 are italicized.

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Late 2018 saw the U.S. Environmental Protection Agency (EPA) announce several regulatory and policy changes with potentially far-reaching impacts on the way the agency regulates the emissions of both criteria pollutants and hazardous air pollutants under the U.S. Clean Air Act. Each of these changes, their projected impact on both the regulated community and the environment, and the likelihood of legal challenges are discussed here in more detail.

**EPA Revises Cost Finding for MATS Rule to De-Emphasize ‘Co-Benefits’**

On December 27, 2018, EPA announced a proposal to revise the cost–benefit analysis for the Mercury and Air Toxic Standards (MATS) Rule. MATS is an Obama-era regulation aimed at reducing emissions of mercury and air toxics, including arsenic, chromium, and nickel, from coal-fired power plants. A 2015 U.S. Supreme Court decision (*Michigan v. USEPA*) had left MATS in place, but tasked EPA with reconsidering the rule with respect to the costs of compliance for impacted electric generating utilities.

It was unclear how the agency would go about its reconsideration of MATS in light of the court’s decision. Options included amending the rule, replacing the rule in its entirety, or rescinding the rule. Each of these options carried differing
risks of legal challenges from some combination of environmental groups, electric-generating utilities, and the coal industry. Confounding EPA’s calculus was the fact that the majority of coal-fired electric plants had already completed the capital investments necessary to comply with MATS. As a result, any undoing or relaxation of the rule offered no opportunity for these plants to recover these “sunk” costs—turning possible supporters of rule overhaul into bystanders at best.

EPA’s approach to revising its cost–benefit analysis involved retaining the Obama Administration’s US$10-billion per year compliance cost estimate, while dramatically altering the projected health benefits of the rule (which were calculated to outweigh compliance costs by a ratio of 9 to 1). The Obama-era EPA had originally calculated in 2011 that the MATS rule would result in non-hazardous air pollutants (HAPs) co-benefits ranging from US$33 billion and US$90 billion. Conversely, target HAP benefits related directly to mercury emission reductions were estimated to range from only US$500,000 to US$6 million annually. The agency’s revised accounting of health benefits retained those benefits tied directly to reductions in HAPs, but omitted all previously calculated “co-benefits” tied to indirect reductions in non-HAP air pollutants.

Given that the rule’s costs now exceed its benefits, MATS is no longer “appropriate and necessary”—likely rendering the 2012 rule retroactively “unreasonable”. This paves the way for opponents of MATS to seek repeal of the rule in court.

New EPA Policy Revises Historic Approach to Defining ‘Ambient Air’

In November 2018, EPA released draft guidance that promises to alter the agency’s longstanding interpretation of its own 48-year-old regulatory definition of “ambient air”. Ambient air is defined at 40 CFR 50.1(e) to mean “that portion of the atmosphere, external to buildings, to which the general public has access.” Historically (going back to at least 1980), EPA has interpreted ambient air to include all areas outside of buildings with the exception of land owned or controlled by a stationary source where public access is precluded by a fence or other physical barrier. The agency’s rationale was that air which the public could readily access (and breathe) was air warranting protection under the Clean Air Act.

The agency’s November 2018 draft guidance proposes to eliminate the requirement that a fence or physical barrier be present in order to better reflect the options available to a stationary source today to effectively deter and control public access. As such, the revised ambient air policy will look to “measures, which may include physical barriers that are effective in deterring or precluding access to the land by the general public.” EPA suggests that appropriate measures could consist of video surveillance and monitoring, security patrols, drones, and other “future technologies”.

The practical impacts of the new interpretation of what constitutes “ambient air” will be seen most readily in the context of air quality modeling conducted to determine “fenceline” impacts associated with permitting new and modified sources of air contaminants. As regulated entities may now have a path to moving hypothetical “offsite receptors” further away from sources, it will undoubtedly be easier for sources to pass modeling without reducing emissions, raising stacks, or investing in potentially costly physical barriers. All of this, of course, could result in legal challenges from environmental groups and impacted citizens.

EPA to Propose Regulation Formally Ending MACT ‘Once In, Always In’

EPA’s regulatory agenda for 2019 indicates that the agency intends to issue a Second Notice of Proposed Rulemaking (NPRM) in February 2019 in connection with its efforts to reverse its highly contentious “Once In, Always In” policy pertaining to major source Maximum Achievable Control Technology (MACT) applicability. In January 2018, EPA issued a memorandum announcing its intent to reverse the policy. The agency had maintained since 1995 that a facility subject to a major source MACT standard on that standard’s initial compliance date was forever bound to comply with the MACT regardless of subsequent HAP potential to emit reductions that may have rendered the facility “non-major” for MACT purposes.

The Second NPRM indicates an intent on behalf of EPA to formalize its January 2018 memorandum through administrative rulemaking. According to its regulatory docket, a Second NPRM in early 2019 would revive an initial NPRM originally issued by the George W. Bush EPA in January 2007. At that time, the agency had proposed a regulatory reversal of its 1995 “Once In, Always In” guidance memorandum. The effort lost momentum, however.

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The economy was the focus of the March 2009 issue of *EM*. As we entered 2009, a global economic crisis was at the forefront of everyone’s mind. For A&WMA members, how the environmental industry might be impacted by the recession was of particular concern. In this issue, we asked members and other experts for their feedback on where the industry stood at the beginning of 2009 as a result of the economic uncertainty, what challenges they thought lay ahead, and what environmental professionals might do to ensure their survival during the global recession.

In the article, *Working Smarter in the New Economy: A New Chapter in America’s Leadership on the Environment*, by Richard Crume, Stephanie Luster-Teasley, and Chatten Cowherd, the authors reflected on how the U.S. economy was evolving into something new—an economy with greater oversight and accountability, renewed transparency in procurements, and a newfound emphasis on sound fiscal management—and how the environmental industry might fare in these uncharted waters.

*Quoting from the article:* “How can we continue making progress on the nation’s environmental priorities in these tough economic times? One way is to be smarter about how we perform project assignments and research studies.”

In another article, *Looking for Opportunity in the Midst of Recession*, A&WMA Past-President Anthony Buonicore reminded us that in a bad recession environmental consultants just have to work a little harder and look a little deeper to find opportunities.

*Quoting from the article:* “Environmental consultants have a choice. They can complain about how terrible the market is, or they can work hard to seek out the opportunities that are always there. Yes, it may require a retuning of services and marketing efforts to target the ‘right’ clients with the ‘right’ services, but this should be viewed as a cost of doing business.”

Lastly, in *Avoiding a Compliance Downturn in a Rough Economy*, by Paul Gerbec and Mark Manninen, the authors considered how when faced with difficult economic conditions, successful and innovative companies seek out opportunities that will provide not just a way through the troubles, but a way to come out on top.

*Quoting from the article:* “One obvious impact will be that many, or even most, companies will focus their environmental programs on necessary compliance activities, while beyond-compliance initiatives will take a back seat.”

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