ACS central science

Ingredients for a Positive Safety Culture

With Thanksgiving on the horizon, many of us are planning ahead for our favorite and most elaborate meal of the year. We make shopping lists, line up our kitchen hardware, choreograph our stoves and microwaves, and delegate dessert to the people we trust. It works best when managed from the top down (by my UC Berkeley friend Matt Francis, for example), with attention to detail, careful risk assessment (are you sure you want to beta test that new recipe on this day?), and contingency plans (i.e., find out in advance which pizza places are open). It's a good thing the stakes are not all that high should things take a wrong turn.

Unfortunately, this is not the case in the laboratory setting. A lack of careful planning that includes hazard assessments and integrated safety precautions leads, at best, to a bad experiment and, at worst, to a tragedy. Indeed, a review of the last 12 months would lead to the disappointing conclusion that academic chemistry still has a major safety problem, despite heightened attention to the issue in the wake of fatal laboratory accidents such as the flash fire at UCLA in 2008. So many lessons were learned from that disaster—broad lessons regarding the responsibility and accountability of lab heads, the importance of collaborative relationships between EH&S specialists and the researchers they serve, and the imperative that everyone from top to bottom embrace a culture that prioritizes safety above all else. And specific lessons were learned as well—best practices such as reading the MSD sheet and understanding the potential hazards of chemicals *before* setting up an experiment, discussing potential hazards with colleagues, assessing risks that amplify with scale, consulting EH&S experts when in doubt, wearing appropriate personal protective equipment, never working alone in a lab, and knowing what to do and whom to call in the rare case when things go south. Then later, acknowledging error and accepting responsibility, identifying root cause, and improving processes so we can teach new lessons. UCLA's Craig Merlic even created the UC Center for Laboratory Safety.

Still, we read again and again about laboratory accidents. Over the past 12 months alone, there have been numerous accidents in both academia and industry, grave enough to draw international attention.

- In December 2015, postdoc Meng Xiangjian, 32, was killed following a hydrogen tank explosion in his lab at Tsinghua University in China. The accident called into question wider safety practices among Chinese chemists, particularly because Xiangjian was working alone on the day of his death.
- January 2016 brought two more major explosions—one an accident involving a dangerous mix of trimethylaluminum and water at Dow Chemical in Massachusetts and another at PeroxyChem in Texas when an "over-pressurized tank" exploded. These incidents resulted in multiple serious injuries and one death at the scene in Texas.
- In March 2016, an undergrad at Texas Tech was injured in a minor explosion when he omitted an experimental step while collecting a dry precipitate powder with a metal spatula, and of course, there was the deeply troubling incident at the University of Hawaii when postdoc Thea Ekins-Coward lost an arm due to a static electricity charge that ignited a highly flammable, pressurized tank of hydrogen, oxygen, and carbon dioxide.
- April was the deadliest month for chemical accidents in 2016. On April 16, a massive fire at Jubail United Petrochemical in Saudia Arabia killed 12 and injured 11 more. According to *Nature World News*, the fire started when "maintenance contractors and technicians were replacing catalysts", which led to a suffocating thick black smoke that trapped employees inside the plant. Just four days later, on April 20, 2016, an explosion at a Pemex vinyl chloride plant in Mexico killed 32 workers and injured another 136, believed to be due to a gas leak somewhere in the petrochemical plant.
- October 2016 brought the most recent round of chemical accidents. At Dickinson State University in North Dakota, Professor Ken Pierce sustained non-life-threatening injuries after the flash powder demonstration he was performing exploded. Lastly, on October 17, an explosion at the German chemical plant BASF killed four and injured at least 29 more.

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BASF speculated that the explosion was caused when a contractor cut the wrong pipeline.

There is certainly no shortage of resources the chemist can draw upon to learn about and execute safe laboratory practices. In an ACS Comment published last June in *C&EN*, ACS CEO Tom Connelly summarized the impressive documents and videos produced by universities, chemical companies, and professional organizations that he found online. And all universities have EH&S professionals who are there, in principle, to assist in person. Yet, as Connelly stated, "incidents continue to happen. What are we missing?"

Some insight in this regard can be gleaned by reading the comments section following Jyllian Kemsley's April 19 *C&EN* report on the cause of University of Hawaii explosion. Many opinions are voiced in the comments therein, but I found a comment by George Whitmyre, a retired lab safety specialist and author who worked in the Chemical and Biomolecular Engineering Department at University of Delaware, to be particularly compelling. He noted that "laboratory safety programs only work when they are top-down, with serious commitments from Regents, Presidents, CEOs, upper management, and even PIs." Especially PIs. When laboratory accidents occur, it is incumbent upon leadership at all levels to accept responsibility. Too often we read about efforts to assign blame instead. PIs are directly responsible for ensuring their trainees learn safe practices and work in a safe environment. And it is true that they are to blame if safety concerns are neglected, or worse, unsafe practices condoned. But PIs operate in an ecosystem whose values must be articulated from the top down, by a unified voice of chancellors, presidents and provosts, vice chancellors, deans, and department chairs. Without their aligned commitment to prioritizing safety as a campus mission, and their willingness to accept responsibility for systemic failures, there is little hope that students and PIs will embrace safety as their first educational or research goal.

From this perspective, I was encouraged by a recent guide to implementing a Safety Culture in our universities generated by the Task Force on Laboratory Safety formed by the Association of Public and Land-grant Universities (APLU) in coordination with the Association of American Universities (AAU), the ACS, and the Council on Governmental Relations (COGR). Comprising a group of senior research officers (including UCLA's Chancellor), environmental health and safety officers, faculty, and industry and national laboratory representatives, the Task Force's mission was "to provide research universities with recommendations and guidance on the most appropriate strategies to enhance a culture of laboratory safety." Their report is specifically intended for university chancellors and presidents and nicely articulates the core institutional value that "safety is everyone's responsibility."

Another recommendation in the Task Force's report is that academic institutions learn best practices through partnerships with industrial and government laboratories, environments that, despite the accidents mentioned above, generally have better-developed safety cultures. My own view of laboratory safety was widened considerably during a term as Director of the Molecular Foundry, a DOE nanoscience user facility at the Lawrence Berkeley National Laboratory (LBNL). We served a broad community of scientists with diverse backgrounds and interests, many of whom came to the Foundry to learn unfamiliar techniques and access specialized instrumentation for short periods of time. Guaranteeing a safe working environment was the first priority. This message originated from the LBNL Directorate, several levels above me. Such top-down support made my efforts to ensure a safe laboratory environment far more effective. We started every meeting—on any subject—with a "safety minute" recounting an incident or near miss that occurred in house or that we heard about elsewhere. We also learned how to implement Integrated Safety Management (ISM) when planning experiments. I now implement these tools in my academic research lab, and I try to reinforce the importance of positive safety culture in a group meeting presentation I deliver annually.

An important lesson I learned at the Molecular Foundry is that having daily access to highly skilled, interactive EH&S personnel can make a huge difference. We had the benefit of full-time, on-site professionals who were on a first name basis with our staff, postdocs, and students, and regularly circulated through the laboratories answering questions and offering advice. The relationship between lab researchers and EH&S staff created a very different tone than what I sense exists in many academic settings—one of collaboration rather than compliance. Academic research laboratories rarely have this level of EH&S support and integration embedded within their operation. This is something for university leaders to consider striving toward.

I continue to pick up new ideas from colleagues at Stanford and UC Berkeley, where discussions of how to best educate our trainees in laboratory safety are common in faculty meetings. Matt Francis, orchestrator of those brilliant turkey banquets from my intro, both talks the talk and walks the walk. Every year, he held a legendary hands-on training session for new students showing them proper Schlenk line

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technique. This is the kind of activity that most of us delegate to postdocs or senior students but perhaps shouldn't in light of what happened at UCLA. Matt's effort to ensure that students know how to safely manipulate air- and/or moisture-sensitive, often flammable reagents under vacuum may have spared them from countless accidents and injuries.

ACS also hopes to contribute to safety awareness beyond our campus walls through its publishing activities. Starting at the beginning of 2017, all ACS publications will require experimental details to address and emphasize any unexpected, new, and/or significant hazards or risks associated with the reported work. There are two different important aims in asking for this additional information. First, as the primary source of chemical information, it is crucial that we use the literature to educate researchers about the risks inherent in the experiments we publish. Second, we hope that making this information required and widely available will change how this and future generations of scientists think about safety as integral to their role in the chemical enterprise. It is a professional requirement and a chemist's responsibility in this world. Just as experimental details are turned into lab notebook entries for future findings, the community will then implement these better habits in their own papers and continue to catalyze the responsibility for safety throughout our industry. Finally, we do not want the most crucial of these safety notes to be sequestered only in the experimental sections. Particularly when unanticipated hazards or risks become apparent in the process of scientific inquiry, either in data acquisition or analysis, we want authors to highlight that information in results and discussion sections, perhaps even in the abstract.

I like to end on a positive note and I think there is one here. Chemists are leading the drive for change and the ship is pointing in the right direction. The positive impact we have on academic safety culture will have widespread benefits outside the chemical sciences. We all hope that, sometime in the future, people will look back on these years and say chemistry was central to safety.

Carolyn R. Bertozzi, Editor-in-Chief
Department of Chemistry, Stanford University

Author Information

E-mail: eic@centralscience.acs.org.

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